Using Computer-aided Design to Enhance Student Teachers' ICT Capacity: A Critical Participatory Action Research Project in a Private Higher Education Institution in KwaZulu-Natal

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A thesis submitted in fulfilment of the requirements for the degree of Doctor of Philosophy in Education in the Faculty of Education at the University of KwaZulu-Natal

School of Education

College of Humanities

Declaration

Submitted in fulfilment of the requirement for the degree of Doctor of Philosophy in Education in the Faculty of Education at the University of KwaZulu-Natal, Durban, KwaZulu-Natal.

I, Rowan Mark Thompson, declare that:

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Rowan Thompson

Abstract

This thesis analyses findings from a critical participatory action-research study documenting the integration of computer-aided design into an intermediate-phase ICT course in a private higher-education institution in KwaZulu-Natal. The research question was: *How might the use of computer-aided design in a teacher education programme enhance intermediate-phase student-teachers' learning and their capacity to use ICT in developing teaching and learning support materials for their classrooms?* The critical participatory action-research methodology involved intermediate-phase student teachers and a sample of lecturers to address the question. Data generation involved workshops, online assessments, interviews, and *WhatsApp* group discussions. Socio-technical systems theory formed the framework for analysis. The findings suggest that the use of computer-aided design increased the capacity of student teachers to use ICT in teaching technological subjects in their classrooms. For example, most student teachers created a clock example for teaching time while some produced extra resources to augment teaching of mathematics and natural sciences. The findings indicate differences in students' preferred modes of learning and application of computer-aided design in their teaching practice. Student teachers valued the flexibility of online and offline course material in multimodal blended online ICT courses, submitting online portfolio examples for assessment. Furthermore, the project enabled student teachers to collaboratively reflect on best practice and strategies for integrating computer-aided design into their teaching. However, not all students applied their knowledge to their teaching practice. Some of the factors that student teachers

identified as hampering their use of computer-aided design included limited time for supported practice in using available software on campus, inadequate campus provision for ICT, and lack of ICT infrastructure and mentorship in their teaching practice schools. The findings have implications for institutional policy and practice. This includes curriculum development which integrates computer-aided design in an extended ICT course across the primary education programme. Such a course must enhance the students' learning; and enable effective integration and teaching of computer-aided design in teaching practice to improve technology education and visual literacy. Finally, the institution must find and support creative and sustainable strategies to address unequal access to technology and related resources for student teachers and teaching practice host schools.

Dedication

I would like to dedicate this thesis to my late dear mother, Alison Thompson. My beloved mother passed away during the Covid-19 pandemic of 2020. She lived life with tireless hope in her heart and a friendly smile and greeting for anyone she met. She had music in her soul; and entertained us all with her virtuoso piano performances until the angels took her to a better place.

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List of Acronyms

The following acronyms are used in this thesis:

CAD	Computer-aided Design
CAM	Computer-aided Manufacture
CNC	Computer Numeric Control
CHE	Council for Higher Education
DBE	Department of Basic Education
DHET	Department of Higher Education and Training
DoE	Department of Education
ECI	Institutional Learning Management System (*Moodle*)
ICT	Information Communication Technology
ICTE	Information Communication Technology for Educators
KZN	KwaZulu-Natal
LMS	Learning Management System
MRTEQ	Minimum Requirements for Teacher Education Qualifications
NQF	National Qualifications Framework
PDF	Portable Document Format
SACE	South African Council of Educators

UN	United Nations
UNESCO	United Nations Educational, Scientific, and Cultural Organization
2D	Two-dimensional (drawing)
3D	Three-dimensional (drawing or printing)
Wi-Fi	Wireless Fidelity (relating to wireless connection to the internet)

Chapter 1. Introduction to the Study

1.1 Introduction

This study used a critical participatory action-research (CPAR) approach to introduce computer-aided design (CAD) to an end-user information and communications technology (ICT) course for second year intermediate-phase (IP) student teachers. The study presents findings in a novel manner, combining qualitative data, supported by quantitative results, with illustrations to support descriptions of changing socio-technical systems. The purpose of the study was to use the CPAR approach as an instrument for bringing together student teachers and ICT lecturers to explore pedagogies for the teaching of computer-aided design (CAD); and students' application of CAD for producing resources for teaching practice. Action research (AR) is used in this study within a pragmatic paradigm: the study sought to implement CAD in a new way in response to a perceived need in primary-school teachers' ICT education. Pursuing two AR cycles allowed inclusion of data from multiple sources, and stimulated constructive critique from students and lecturers. Although the study followed a critical foundation, a pragmatic approach to AR enabled the researcher and co-researchers to respond to unpredictable change, in our case, the Covid-19 shutdown of institutions, which influenced the second cycle of action.

Computer-aided design is a vital tool in modern design and technology. CAD enables designs to be technically formalised as accurate reproducible drawings in two-dimensional and

three-dimensional formats. These drawings can be used to promote ideas, collaborate with others in development of products, and to manufacture products more efficiently and accurately using computer-aided manufacturing technologies. CAD software has been refined and simplified over the last thirty years so that school learners can experience its power and versatility in learning to design products early in their education.

South African primary schools do not teach CAD routinely because this subject is not listed explicitly in curriculum assessment policy statements (CAPS) for primary teaching programmes. Teacher-training institutions, likewise, do not routinely teach CAD in their ICT literacy courses for teachers. This is evident in their published module statements. To inspire student teachers to use 21st century skills, such as CAD, this study sought to implement the teaching of CAD in such an ICT course. Because this had not been done before, a critical participatory action research (CPAR) approach was used to engage with student teachers learning CAD for the first time, and ICT lecturers teaching CAD for the first time. The CPAR approach also sought to promote the use of CAD for development of teaching resources and to monitor students' feedback on the use of CAD resources in teaching practice, as evidence of their application of CAD skills.

This chapter describes the socio-technical contexts that inspired the study and justified the action-research intervention. The research questions, aims, and objectives are presented within a CPAR structure that encourages collaboration between lecturers and students in implementing the study. This is followed by the rationale and motivation which are presented to indicate why the study was attempted, during a period of institutional upheaval, to benefit

student teachers and the lecturing community. Next, the various modes of learning and physical location are explained and justified; the study developed alongside a larger institutional venture, creating a flexible hybrid learning environment as a convergence of contact learning and distance learning.

The chapter then summarises the key stages of the research study. The summaries explain how the study grew from lecturers' motivation to augmenting and updating existing Microsoft-biased ICT module content; institutional pressures to change existing contact-learning courses; and a need to improve student-teachers' skills in designing their own resources for teaching practice. The significance of the study is summarised alongside predicted outcomes enabling a comparison with the actual outcomes of the intervention later in the thesis. The study is guided by human practices and practice architectures, which provide structure and context to the activity. Activity is influenced by wider socio-technical systems. These impact at different stages, influenced by the organisation's commercial growth, changes to institutional policy and wider macro political issues relating to higher education in South Africa.

1.2 Contextualizing the Study

In South Africa, the *National Development Plan 2030* proposes that: "ICT will underpin the development of a dynamic and connected information society and a vibrant knowledge economy that is more inclusive and prosperous." (The National Planning Commission, 2011, p. 190). To respond to this challenge globally, teacher-training institutions, both in state and

private sectors, must play an important role in the development of student teachers (OECD, 2019, p. 152). These institutions must enable student teachers to deliver relevant contextualised training, cultivating an attitude of life-long ICT learning and practical vocational skills acquisition. In schools, various pedagogical approaches and resources will be required. These approaches are often referred to as "new learning ecologies" (Gerber *et al.*, 2016, p. 163). Such approaches are required to respond to changes in educational technology and the diversity of students in these institutions. These ecologies locate the student, or learner, at the centre of the learning process Here they share power as active participants, in a democratized path to meaning- making which has been described as "critical dialectical pluralism" (Onwuegbuzie & Frels, 2013, p. 9).

In South Africa, student teachers receive information and communications technology (ICT) training as part of recognised Council for Higher Education (CHE) accredited degrees. The training in higher-education institutions is generally end-user Microsoft Office training which develops their ICT administrative skills but does not teach ICT pedagogy (Appendix 42). Students' capacity to apply this training purposefully in practice can be influenced by many factors: prior knowledge; quality of ICT training in HEIs; facilities for teaching ICT; and teachers' perceived value of ICT to learners. Furthermore, the World Bank Report (World Bank, 2016), insists that ICT skills are vital for students entering the teaching profession.

Primary-school teachers need these skills to manage their professional work, while also being expected to pass on digital skills to learners. ICT skills are considered a necessary part of the modern teachers' toolkit, internationally. However, teachers' integration of ICT skills

into teaching and learning can be influenced by many factors (Lawrence & Tar, 2018). Pedagogies for teaching student teachers ICT skills have to impart knowledge and practical skills, while simultaneously developing the pedagogical contextual understanding of ICT needed to inspire diverse groups of school learners (African Union Commission, 2015; OECD, 2019). This integrated strategy is necessary for remedying youth unemployment due to poor schooling and educational outcomes. The South African government's white paper (Department of Telecommunications and Postal Services, 2016) points to e-learning and innovative use of ICTs in the education sector as strategies for improving of educator skills, addressing educational inequality, boosting digital literacy, and increasing employability of matriculants. Studying student-teachers' transfer of ICT skills from higher-education training to application in the primary-school classroom is a necessary process for understanding what needs to be prioritised. Currently, basic end-user computing using Office tools is prioritised; however, this is only the tip of the iceberg when it comes to 21st century skills.

Studies in schools and universities in South Africa have shown that teachers and student teachers generally appreciate the importance of ICT skills in education and employment (Padayachee, 2017). However, many teachers lack the ICT skills training and requisite skills (Chisango *et al.*, 2020). When school leavers are taught in environments in which their teachers are not empowered to use ICT, this can lead to negative attitudes in students in higher-education institutions. Such negativity inhibits student development and application of these skills while studying, together with the ability to follow ICT-related professions (Kirlidog *et al.*, 2018).

Wider global studies of what influences teachers' decisions to apply their ICT learning in classroom teaching over the last two decades, point to access to a variety of socio-technical factors. Such includes access to quality ICT resources, schools, policymakers and the teachers themselves (Mumtaz, 2000; OECD, 2019). Understanding ICT skills required for teaching and administration of teaching, combined with the ICT needs of learners, requires engagement with ICT lecturers and student teachers. Implementing ICT to teach technological subjects requires additional ICT training in content, skills, and pedagogical approaches (European Commission, 2020, p. 4). This study sought to create a collaborative forum in which this was possible using the case of teaching, learning, and applying computer-aided design (CAD).

1.3 Problem Statement

Although the need for a variety of ICT skills is evident in the South African curriculum taught from primary through to tertiary level (Department of Basic Education, 2018, 2021), computer-aided design (CAD) is a neglected skill in ICT courses for primary-school student teachers in higher-education institutions. CAD is often only introduced in the high school teaching specialism "teaching engineering graphics and design". Subsequently, computer-based designing skills are identified in South Africa's Department for Basic Education's *Action Plan to 2019* (Department of Basic Education, 2015), *Teachers' Digital Learning Framework* as one of the priority digital learning competencies (DLC-5.6) that must be addressed.

For the purposes of this study: 'computer-aided design' can be defined as: "

A form of computerised vector based, or solid surface modelling system software which replaces traditional manual technical drawing. Various packages can produce either purely two-dimensional drawings or fully rendered 3D solid models (Merriam & Brockett, 1997, p. 8).

A desk study of existing end-user computer literacy courses provided by state and private higher-education institutions in BEd intermediate-phase primary teaching programmes revealed that none offered CAD as part of their courses (Appendix 42: South African Universities-ICT Course Provision for BEd Courses-2022). However, some higher-education institutions were offering more variety in terms of multi-media video editing, learning management systems and coding and robotics skills as part of their ICT courses.

The primary-school curriculum includes design and technology topics in natural sciences and technology; and, from 2021, coding and robotics, which require practical design projects. It is logical to expect that teachers should be able to use up-to-date technology to teach these topics. However, training teachers globally to use and teach alternative software to solve practical problems with ICT is not a priority when teachers often lack basic ICT skills to complete administrative work (OECD, 2019). When teachers lack this experience, they revert to using older technologies, teaching technology by rote, or completely avoiding teaching the topics (Mapotse, 2018).

Learning additional skills, such as CAD, can assist novice ICT students to better understand the common tools used in other office software applications (Thompson & Alant, 2021). Primary-school learners must also be taught a wider variety of ICT skills to meet the

needs of new subjects such as coding and robotics (Department of Basic Education, 2024). This subject ideally includes designing with CAD as part of improving learners' computational thinking and visualisation skills (Eryilmaz & Deniz, 2021). The institution's School of Education has recognised this over the last three years, making its compulsory ICT course content more diverse, by introducing additional software packages into module qualifications which previously taught only Microsoft Office applications.

Of recent years, the development of online versions of modules for contact learning and distance learning modes, has been prevalent in improving access for students from diverse backgrounds. Assessment of traditional hand-written assignments has been replaced by online marking of work produced on computers. Assessable CAD outcomes fit into this new model in that they can easily be shared and uploaded electronically. Concerns about the ease of plagiarism of electronically produced work using artificial intelligence (AI) have also raised new debates about the design of online assessment which are explored in this study (Grassini, 2023). Additionally, developments in AI-generated imagery are changing the way educators think about image creation and what needs to be taught as fundamental design skills (Bartlett & Camba, 2024).

Existing ICT modules in HEIs offering teacher training tend to follow a rigidly assessed behaviourist structure. These modules leave little opportunity for students to construct their own knowledge, explore various learning pathways, or use different software tools to achieve practical outcomes. This study explores ways in which CAD can be taught and assessed in a more creative manner to make learning more experiential for student teachers.

1.4 Research Problem

The research problem, or perceived need guiding this study is an imperative to train primary-school student teachers in a wider variety of ICT skills, such as CAD, to meet the needs of the 21st century primary-school classroom. ICT skills are not only required to augment teaching: learners must also be taught ICT skills as part of their prescribed digital skills programme. CAD is not currently prescribed as part of the formal ICT programme. The challenges are how best to teach and integrate CAD skills alongside other ICT applications, and how to ensure that student teachers apply these skills in their teaching practice.

1.5 Motivation for the Study

Motivation for researching the integration of CAD, as part of an end-user CAD course in the primary-school teacher-training context, is both professional and personal.

Firstly, motivation comes first from the identified need in government research and policy. For example, the *Professional Development Framework for Digital Learning* for teacher-training institutes, district & school managers and educators themselves (Department of Basic Education, 2018) was developed from South Africa's Department for Basic Education's *Action Plan to 2019* (Department of Basic Education, 2015). This document identified five priority goals (highlighted with three stars) that include:

Goal 16 : Improve the professionalism, teaching skills, subject knowledge, and computer literacy of teachers throughout their entire careers (Department of Basic Education, 2015, pp. 34-36).

In response to this goal, the digital learning framework aims to:

"Define professional development for digital learning in an education system that seeks to improve access, quality, equity, redress, and efficiency." (Department of Basic Education, 2018, p. 9)

The digital learning framework assembles theoretical and methodological frameworks for improving the "digital learning competencies*"* (DLCs) of educators (p15 – 19) and targeting these skills at improving educational outcomes. This includes selecting appropriate tools for the development of skills for "creating, publishing and sharing content*" (DLC-5.5),* "designing graphics*" (DLC-5.6),* and *"*designing interactive learning activities*" (DLC-7).* Creative application of computer skills is explicit in the framework; this is exciting, in that some might view ICT skills as simply integrating learners into the world of computerised work using traditional office software (e.g., Microsoft Office).

'Digital skills', for the sake of this study, are defined as:

"Practical skills which enable students to demonstrate 'digital literacy' or 'the ability to appreciate the potential of digital tools and resources to support living in a digital society' as defined in the Digital Learning Framework" (Department of Basic Education, 2018, p. 6).

The DBE framework does not define 'digital skills' directly: it only defines digital literacy. The implication of this is that learners may not have to demonstrate their computer skills: they

would only have to understand their necessary skills theoretically. This may be a deliberate omission to make allowances for schools that do not have access to computer resources. This policy framework empowers decision-makers, including educators themselves, to select appropriate digital tools, and not necessarily use the same as other established schools. This means that educators should be able to introduce new types of contemporary and appropriate software to local learners, without being driven by monopolising software companies pushing commercial software designed for adults, into school curricula. Where the policy may be weak, is that it is overly ambitious. The policy is perhaps modelled too heavily on Westernised education policies which have more established physical infrastructure, or 'practice architectures', for teaching ICT, technology subjects, and CAD. A sustainable South African model must acknowledge the inequity of school facilities, teacher training and students' access to technology, supplying more realistic and achievable goals. In South Africa historic inequity due to Apartheid has left divisions in quality of education in the various provinces and schools. However, the same model could be applied to any country with a history of unequal access to resources and education.

Secondly, personal motivation is derived from extensive experience of teaching technology and of integrating the teaching of CAD in school curricula in various countries. In this regard, my first profession was industrial design. Following a PGCE from the University of Edinburgh, I taught design and technology [D&T] from Grade 7 to Grade 12 in Scotland, Botswana, and England, between 1995 and 2014. Over the past 25 years, I have used computer-aided design (CAD) to teach D&T as a subject, also to develop teaching resources and to

illustrate publications, slideshows, and reports. As a high school teacher, I trained learners to develop CAD proficiency, and to graduate with vocational CAD skills before entering engineering, architecture, and design professions. Using CAD, learners discover that it is not essential to be good at drawing to be a good designer: students can become proficient in the rapid development and management of design ideas (Downey, 1992a). Traditional drawing takes practice, manual skill, and learner dexterity. A CAD design can be produced and modified in seconds by learners with limited drawing ability (Chao, Chen, & Chuang, 2015). However, CAD does not draw for you. Just as one must acquire skills using manual tools to execute manual technical drawings, logical application of computerised drawing tools must be applied to create graphic outputs using CAD software. It follows that early exposure to simplified forms of CAD in primary-school technology lessons will assist learners to apply CAD more effectively in formal subjects high up the school system.

Since 2016, I have been Head of Department and Discipline Leader for mathematics, natural science, and technology studies in a private higher-education institution focusing solely on teacher education. My position involves lecturing PGCE modules in engineering graphics and design (EGD); and managing more than 20 lecturers in my discipline and training staff in ICT and institutional systems across four campuses in Cape Town, Durban, Johannesburg, and Pretoria. It markets itself as an institution that trains resourceful teachers for the workplace. From my perspective, this should include training teachers to create their own two- and three-dimensional resource materials (manipulatives, posters, worksheets, and models) for teaching. This should include the use of CAD. When I entered the institution in 2016, I found that none

of our ICT modules included CAD training. Furthermore, assessment of teaching practice lessons revealed that students did not use CAD, and relied heavily on hand-drawn images, or images downloaded from the internet.

As an HOD, I lobbied for CAD to be included in ICT modules to extend students' learning beyond MSOffice tools. CAD was introduced in compulsory first- and second-year ICT modules for higher certificate, diploma and degree student-teacher programmes as a result of this research study. Teaching of CAD has been justified to students and lecturers on three levels. *Firstly,* it develops design skills for students wishing to specialise in robotics in third-year degree programmes. *Secondly,* CAD is provided for all students as a software tool for developing visual resources to enhance TPR. *Thirdly,* students are expected to demonstrate ICT skills in their personal professional portfolio (PPP); CAD is an ideal tool for enhancing teachers' resource design skills.

In addition, my recent work in rural and marginalised schools, as a teacher trainer with CASME[i], and as HOD and teaching assessor, has impressed on me the need for student teachers to be better prepared to apply ICT drawing skills productively alongside traditional office applications. By integrating ICT skills, including design tools, with traditional teaching, teachers are expected to develop pedagogies to teach more effectively and efficiently so as to meet the needs of 21st century learners (Fraillon *et al*., 2019). For example, recent experience in working with young mothers in an ICT skills and basic nutrition training implementation revealed that learning of basic ICT skills was more effective using drawing tools and activities linked to real-life contexts (Thompson & Alant, 2021).

1.6 Influential Academics during my CAD Education as an Industrial Designer and Teacher

I learned CAD during my Industrial Design honours degree and PGCE in technology education as part of the high school subject specialism graphic communication. As CAD teaching in high schools was new to student teachers, in the late 1980s and early 1990s, we were encouraged to follow Donald Schon's model (Schon, 1983). We had to reflect on and redesign manual technical drawing lesson plans to incorporate alternative CAD drawing using computers. CAD lessons were treated as augmentation of manual drawing rather than as an efficient alternative. Resource creation was often conducted with CAD to form an accurate example for reference against an assessment.

Schön's *The reflective practitioner: How professionals think in action* (Schon, 1983), was a prescribed reference in my technological teacher training in Scotland in the mid-1990s. This work posits that educators often know more than they can say. Educators display their knowledge through various verbal and non-verbal tools, which develop alongside their theoretical and pedagogical knowledge by means of experimentation, reflection, and re-invention. To learn to be reflective, collaborative models of master-peer self-critique of practice were proposed (Schon, 1983). This promotes an understanding of technological education as a social and socialising process requiring experts to work with novices to improve practice (Hartley, 1990).

Schön's work was built on his critique of "technical rationality", a theory that professional activity involves practitioners maintaining an illusion of competence through the selective application of scientific theory and technique, or a "mystique of practical competence" (Schon, 1983, p. vii). Schon's critical action research attempted to demystify design and technology teaching through observation and recording. He pointed to the positionality of the researcher practitioner, saying: "demystification is not showing of the falsity of the practitioner's claims to knowledge but a bid to undertake the, often arduous, task of opening it up to inquiry" (Schon, 1983, p. 289).

Schön's publication, *Educating the reflective practitioner* (Schön, 1987b), built on research in architectural and design education studios and workshops (Schön, 1984, 1985). These earlier studies defined an ideal reflective educational practitioner: a professional who develops, through coaching and encouragement, to reflect on what they do, as they do it, and thus to learn in a more profound way. As Schön pioneered teacher development in design and technology, his inclusive models of training informed the later work of Stephen Petrina (Petrina, 1998, 2003, 2008, 2017, 2018), who aligned reflective pedagogical practice with socio-technical systems critique.

My initial learning and teaching of CAD in Scotland involved replication of manual drawing tasks using desktop computers. Assisted by peer-teacher feedback, I realised that CAD allowed bypassing of time-consuming manual processes such as measuring and checking dimensions and drawing scaling grids and construction lines to project sizes to different views of an object. Critique by mentor teachers, observing my teaching, showed that CAD enabled

faster, more efficient methods of designing, as well as resourcing and assessing of design lessons. Mentors also highlighted the new socio-technical challenges CAD brought in design of classrooms for computerised lessons; assessment of learners' work; and in dealing with plagiarism in electronically produced drawings.

My latter years of teaching, in a well-resourced English private school, cemented integration of sketching, manual drawing, CAD, and CADCAM to efficiently design and manufacture learners' personalised projects for GCSE, GCE, and IB qualifications.

1.6.1 Summary

Focusing on one aspect of ICT competency – computer-aided design [CAD] skills, this study aims to explore how innovative pedagogical approaches to training may influence the adoption of CAD in primary-school student-teachers' ICT usage. Although CAD has appeared in the CAPS documentation for engineering graphics and design (EGD) for the FET phase since 2011, it is given no consideration as part of the primary-school curriculum; this despite that it can be taught in subject areas such as visual arts, technology, or ICT. Further, in under-resourced schools, in which computer facilities are lacking, students are unlikely to encounter CAD. This applies to South Africa and to all under-resourced schools internationally (Fraillon *et al*., 2028).

Learning such skills in a teacher-training environment may be the first opportunity students have of using CAD and experiencing it as a teaching resource. This study uses a critical participatory action-research approach (CPAR), encouraging student participation as

one way of developing CAD skills among student teachers. The action-research approach develops on social forms of learning, designed to grow collective knowledge, and enable connection of teaching with extra-curricular interests among the student teachers (Ito *et al*., 2013; Kalantzis & Cope, 2012; Reilly, Vartabedian, Felt, & Jenkins, 2012).

The use of CAD, as a presentation resource to illustrate the findings study, was implemented to promote CAD as a design resource and an adaptable diagramming tool (Thompson & Alant, 2021). Student-centred, constructivist approaches to technological teacher training commonly involve teaching by example, demonstrating skills which are practised by students. By demonstrating CAD skills in the study, the intention was to provide living examples of CAD's value in teachers' education and continuing professional development.

1.7 Aim of the Study

The aim of this study was to explore the ways in which the teaching of computer-aided design (CAD) in the intermediate-phase (Grades 4 – 7) teacher education programme might enhance the capacity of student teachers to effectively use ICT in developing teaching and learning material for their teaching practice. To address this aim, the study responded to the question: *To what extent, and in which ways, might the use of CAD in teacher education enhance student-teachers' capacity to use ICT in developing teaching and learning resources for their classrooms?* In responding to this question, two critical sub- questions were addressed: 1) Which pedagogical approaches can best provide

contextualized computer-aided design (CAD) education for enhancing intermediate-phase student-teachers' learning? 2) How might the use of CAD help intermediate-phase student teachers to effectively integrate ICT in developing teaching and learning support materials for their teaching practice?

By exploring the pedagogical approach to implementing or integrating CAD into an existing ICT course, it was intended that the methods used to teach student teachers may inform best practice for teaching learners this technology in an untested primary-school space. Furthermore, studying student-teachers' ability to convert CAD learning into practical teaching practice resourcing enables better understanding of their ability to action their teacher-training ICT experience in the field.

1.8 Overview of the Theoretical Framework

Analysis in the study was informed broadly by critical theory and follows a pragmatic approach to action research (Green, 2007). Critical theory, relating to technology, seeks to locate human rights, emancipation, and democratic participation at the centre of social activity; while pragmatism uses a structured research question to guide interpretation of the social activity (Kaushik & Walsh, 2019). Technological systems integration is considered part of a socio-political agenda (Callaghan, 2016; Feenberg, 1991). Critical theory is used to question the need for technology, arguing its value to society (Feenberg, 2005). The influence of technology as a tool for managing and standardising education systems, and control societies, is a significant and constant part of the wider critical debate (Freire, 1972; Illich, 1976).

South Africa is heavily influenced by global capitalist trends towards accepting technological change; in particular, computerization of the learning environment and workplace (Callaghan, 2016). Using a critical theoretical base enables consideration of the social and political benefit that technology has on participants, as well as observing how it affects them individually. Such a critical theoretical base also views CAD technology impartially in relation to human emancipation from forms of work which make them slaves to modern technology. South African action-research theorists stress the use of participatory methods to provide authentic evidence and generally, to inform critical debate regarding education (Wood, 2014), particularly, technology education (Mapotse, 2018).

Analysis was specifically informed by Petrina's (Petrina) socio-technical theory related to computer-aided design integration into the workplace. Analysis evolved as a pragmatic critical response to optimistic predictions of the impact of technology on society in the middle of the 20th century. Such analysis grew from research on integration of technology into the workplace (Cherns, 1976). Building on systems theory (Churchman, 1968), early socio-technical theory views technology integration into the workplace as a design process which integrates social and technical subsystems in organisations. The cornerstone of the theory is that efficient integration and use of technology is only possible if there is joint optimization of the social and technical elements of the system. Early theorists stressed the importance of humanistic principles (Cherns, 1976). As the theory developed and computer technology became a universal reality in most workplaces, managerial (Mumford, 1995), ergonomic (Clegg, 2000), and environmental (Mumford, 2003) principles were emphasised.

Figure 1.1

Socio-Technical Systems Incorporating Central Technical and Social Subsystems and Wider Organisational and Environmental Influences (Adapted from Bostrom & Heinen: The Application of Socio-Technical Theory (1977))

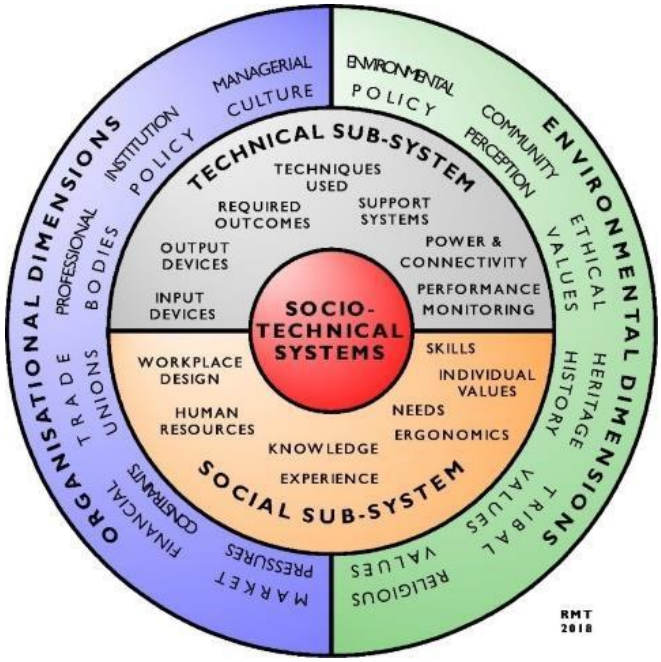


Figure 1.1 illustrates the technical and social systems operating within the constraints of wider organisational, and environmental systems (Bostrom & Heinen, 1977). Petrina's work focuses specifically on computer-aided design and technology education (Petrina, 2000, 2003, 2017); however, it draws on the early pioneers' work described above.

Socio-technical theory challenges deterministic views of technology. For example, judging pedagogical approaches purely by the technical proficiency of students in CAD is not enough (Downey, 1992b). The ideal pedagogical approaches must be judged on how they address the wider political, cultural, and environmental issues surrounding the chosen teaching context (Petrina, 2000a). In the case of student teachers, it is expected that use of CAD in development of resources for teaching specific lessons will provide an understanding of their practical interpretations of its value in various learning contexts. The assumption is that innovation in CAD technology education can be best understood when its role in wider socio-political dimensions are included. The theoretical viewpoint aligns with a critical participatory action-research approach (Kemmis, *et al.*, 2014) which draws on various participants' lived experiences to address research questions.

1.9 Location of Study

This study was undertaken at a South African higher-education institution dedicated to teacher training. The participatory action research was conducted primarily on location at the institution's Durban campus (Campus 1), KwaZulu-Natal province. The CAD course was developed initially with module coordinator and Lecturer-1 (ICT-1) who is based at the Durban campus. The same module was also delivered, in the same mode of study, by two lecturers (Lecturer-3 and Lecturer-4) at Gauteng campuses (Campus 2 and Campus 3). Lecturer-1 also managed and lectured a parallel distance-learning version of the module ICTE200-DL.

The institution moved to its current location at the beginning of 2018 as its teacher education business expanded. The location was important for the collaborative design of the course, meeting staff, administrators and students for workshops, face-to-face training, and interviews. An additional location is acknowledged. There was also a virtual online location on which students accessed resources, submitted work, and provided contributions to online discussions.

This "online location" was four locations, or "online field sites" (Gerber *et al*., 2016, pp. 29-33): the *Moodle*-based LMS on which the ICTE200 course was located and online activity observed; the Outlook email system used for day-to-day communications; Google Forms survey database; and two mobile phone *WhatsApp* social networking forums. These locations offered a choice of alternative pathways for participants to contribute to and reflect on practice instead of relying solely on a single researcher-dictated communication method.

1.10 Overview of the Research Design and Methodology

To address the research question, this study used the critical participatory action-research (CPAR) methodology (Kemmis *et al*., 2014). For the purposes of the study, 'critical participatory action research' is defined as: Practice changing research practice which "gives practitioners intellectual and moral control over their practice" so long as this is justified by "sustained critical individual and collective self-reflection." (Kemmis, McTaggart, *et al*., 2014, pp. 26-27). CPAR is a modern refinement of Kurt Lewin's action research (McNiff, 2005) which employs methods of enquiry designed to change social practice, and perhaps to change

the research itself. In short, CPAR involves participants collaborating to change practice, or the systems which influence their practice, to improve their lives, or to solve a collectively agreed problem. This means that CPAR is reflexive, requiring participants to examine and discuss their practice systematically, while still following an action-research cycle of planning, action, observing, and reflecting, as developed by Corey and Lewin (Corey, 1949). Action research assumes that educators work best to solve problems they have identified themselves, are more effective when assessing their own work; and when they work collaboratively to solve problems (Watts, 1985, p. 185). Action-research methodology is applied in both critical and pragmatic paradigms and therefore, does not restrict use of qualitative and quantitative data to find meaning in human behaviour (Kaushik and Walsh, 2019).

CPAR draws on socio-political, socio-technical, and environmental issues affecting research. CPAR employs the term "practice architectures*"* (Kemmis *et al*., 2014, p. 7) which involves critically interrogating people's actions and ways they operate in different spaces. This approach is valuable in an ICT education environment in which facilities are set up for 'bring your own device' (BYOD) learning; and ICT teaching is conducted in lecture theatres, tutorial classrooms, and in online spaces.

Specifically, the research covered two two-semester academic years. Semester 1 focused on intermediate-phase student teachers learning CAD as a new topic in an introductory end-user computing ICT module [ICTE200]. Students followed a week-in-week-out teaching

practice model, which meant that practical skills, taught in lectures, could be practised in subsequent weeks should they be motivated to integrate their learning into TPR.

1.10.1 Data generation

To generate data in the study, students and lecturers were recruited to participate in CPAR activities related to the research questions. Participants were invited to contribute to the development of the CAD course: actively participating in the construction of lesson plans; co-creating content to meet lesson objectives; critically appraising one another's work using online peer assessment tools; and providing feedback and suggesting improvements to the course design both via online surveys and face-to-face interviews. Following completion of their in-house training, the students were asked to report on their use of CAD resources on teaching practice, initially via *WhatsApp* dialogues, and later in interviews. The study used research tools located online in a common depository on a *Moodle* learning management system. In addition, participating students and staff were sent resources and prompts via email and *WhatsApp* group.

Data generation followed a CPAR collaborative learning process enabling understanding of what participants think and say, what they do and how they relate to others in the socio-technical landscape in which they are operating (Kemmis *et al*., 2014, p. 20). Kemmis *et al*. (2013, pp. 190-191) highlight the need for participants to engage fully in the process which requires careful management and involvement in member checking (Mertler, 2016, p. 131) of data to ensure quality. The action-research process involved planning and

"reconnaissance" (Kemmis, McTaggart, *et al*., 2014 2014, p. 92); recruiting and securing the commitment of participants; maintaining dialogue throughout the process; sharing results both in person and online; and meeting to reflect and discuss outcomes and improvements to the process at different stages in the cycle (Gerber *et al*., 2016; Pain *et al*., 2011). The key stages represent the participatory processes involved in co-constructing a CAD course for student teachers with students, lecturers, and programme managers (Cohen *et al*., 2007).

The stages of the research project 'complex' involved, firstly, preliminary desk-top research, in which I explored existing CAD training in South African HEIs, and a review of literature relating to CAD training and use in primary teacher education. Additional literature relating to CAD implementation in schools and HEIs, generally, was sought. A wider overview of the literary landscape influenced the history and teaching of CAD, globally. Furthermore, the review focused on various technological pedagogical approaches, including technological pedagogical content knowledge (TPACK) (Koehler, *et al.*, 2007; Koehler & Mishra, 2009; Mishra, 2019), substitution augmentation, modification and redefinition (SAMR) (Puentedura, 2014). The review also included teachers' pedagogical change framework models for understanding technological education, and their impact on the primary-school curriculum (Tarling & Ng'ambi, 2016).

First, the institution's published student course materials for existing and planned ICT and technological courses were reviewed, in discussion with lecturers. These courses were revised to include reference to new CAD unit content and assessment.

Second, the study involved reconnaissance and planning, which included: discussion of CAD course and resources with stakeholders; seeking of gatekeeper permissions and consents for ethical approval purposes; refinement of CAD course content; and preparation of initial training resources and *Moodle* page data-collection tools.

Third, the research moved to action involving three main stages: Stage 1) Briefings and workshops were used to recruit and secure informed consent from student and lecturer participants. Stage 2) Course design and refinement involved a collaborative process of sharing and revising lesson plans and resources with students and lecturers. Stage 3) CAD course teaching and assessment, involved interactive training using observed live lectures and *Moodle* virtual learning environment (VLE) as an online learning, sharing, and portfolio creation tool.

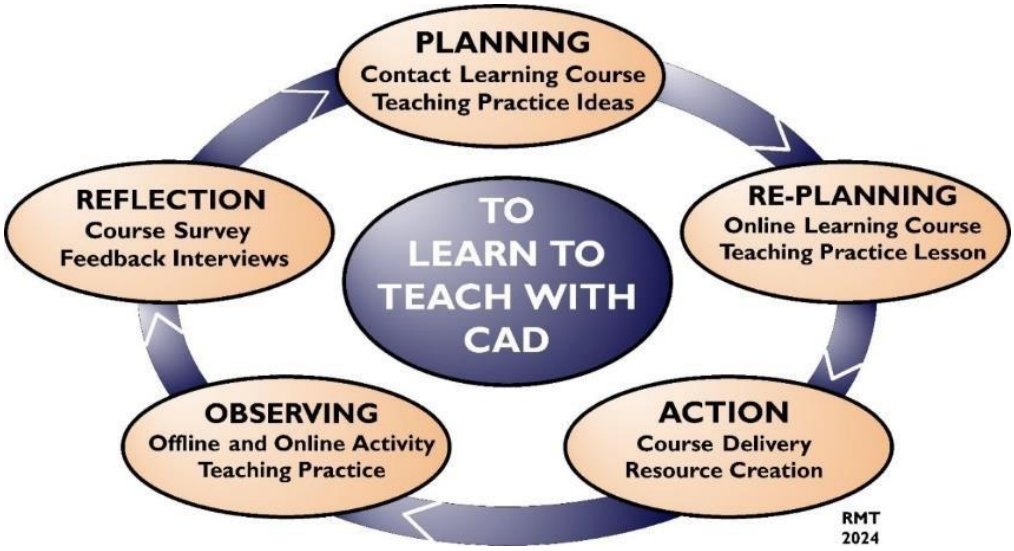
Fourth, the research involved three main stages of observation. Stage 1) Observation of CAD tutorials at campus. Stage 2) Online viewing of course outcomes and teaching practice implementation through peer assessment of CAD drawing outcomes, and feedback from lecturers and students in *WhatsApp* groups. Stage 3) Teaching and learning practice required observation of CAD drawing submissions, lecturer and student feedback from teaching practice visits, and review of students' CAD resource outcomes via their portfolio submissions.

Fifth, the study involved three main stages of reflection and evaluation. Stage 1) Initial reflection on CAD learning was conducted through an online survey completed at the end of the course. Stage 2) Reflection was conducted on CAD learning and outcomes by face-to-face interviews with lecturers and students. Stage 3) Discussion of results and evaluation of the CAD course were initially achieved in a nominal group workshop with lecturers and students.

The main action-research cycle of the process of learning CAD and application of CAD to produce resources for teaching practice: reconnaissance and planning, action, observation, and reflection, are summarised in Figure 1.2 below.

Figure 1.2

To Learn to Teach with CAD (Computer-Aided Design) Illustrated in an Action-Research Cycle with an additional Re-Planning Stage to Set Up Online Learning Mode on Moodle.



An additional stage, ‘re-planning’, is included to acknowledge the adjustment required for additional modes of online learning. All the institution’s contact learning modules are supplemented by learning management system course pages to stimulate blended online

learning. Additional planning work was required to enable all participants to engage with content meaningfully, sharing opinions online.

Specifically, the action covered two two-semester academic years. In both years, Semester 1 focused on IP student teachers learning CAD as a new topic in an introductory year-long ICT module (ICTE200); and Semester 2 involved production of a portfolio which included CAD drawings. SSoE students followed a week-in-week-out teaching practice model providing the opportunity for CAD skills, taught either on campus or online, to be tried out in the following week should students be motivated to integrate their learning into teaching practice at a school. The key stages of the process relating to research questions, participants' roles in the action, instruments employed to gather data, and justification of their use are presented in Appendix 3: Research Design Tables.

Students and lecturers were invited to contribute to the development of the CAD course and the co-construction of lesson plans. Students critically appraised peers' work using online tools provided on the learning management system (LMS). Both groups provided feedback on their experience by discussing the course via email and *WhatsApp* group, online surveys, and face-to-face interviews. Following initial data processing, a nominal group workshop was used to bring students and lecturers together at the end of the academic year to review initial findings, refine data themes, and discuss improvements to the course content, thereafter, planning its delivery in the second cycle.

Following completion of their campus training, students were asked via email and *WhatsApp* group during the following weeks to report on their use of CAD resources on teaching practice. This method was pursued again in face-to-face interviews with those students who consented to be interviewed. The second semester ICT portfolio submission provided additional opportunity for students to share CAD resources designed for their own use.

Post-implementation review of the course was facilitated through review of marks and portfolio submissions, with lectures followed by module coordinator meetings. Data that emerged from these meetings, relating to CAD, was shared and re-shared via email and *WhatsApp* group communication, to lecturers and students.

Student survey and staff report data, from the second cycle of teaching CAD during the Covid-pandemic lockdown, produced some comparative results. This second phase provided additional evidence of pedagogical changes driven by national pandemic rules and institutional decisions. Mapping of the changes of teaching mode and technical delivery were recorded diagrammatically (see Chapters 7, 8 and 9). The influence of wider socio-technical change, affecting delivery of planned module content, was tracked and discussed to interpret how students' practice may have been influenced by changes to practice architectures; and how these disrupted the teaching and application of CAD.

1.11 The Significance of the Study

A significant aspect of critical participatory action research (CPAR) is inherent in its name which locates action research in a realm of human endeavour considered emancipatory – or designed to set participants free from restrictive, or demeaning, work or learning practices. Use of CPAR does not imply that all change leads to improvement of participants' lives, or emancipation. CPAR use acknowledges that there is a "doubleness" in human activity (Kemmis, McTaggart, *et al*., 2014, p. 27), in other words, studying a situation does not necessarily bring better solutions to problems.

The active involvement of the learning community in a participative study should contribute to greater awareness of the creative opportunities available through learning and applying CAD skills. The study should also promote better understanding of the problems and opportunities that exist for participants learning and using software for the first time, in a multimodal setting. By bringing lecturers together with students, to critically reflect on their practices, the design of better "practice architectures", or systems in which practice is cultivated, should be possible (Kemmis, McTaggart, *et al*., 2014, p. 57).

In terms of wider significance, the collaborative study of implementation, teaching, and learning CAD, including multiple perspectives, has value institutionally if there is a culture of continuous improvement. In a wider sense, a collaborative study aims to explore sustainable pedagogies which work across different socio-technological modes of operation. The study also has potential to provide guidance on design and delivery of better multimodal (Kress, 2010) online and offline pedagogies (Blewett, 2016) for teaching of creative subjects.

Integrating design processes and computer software has potential to provide student teachers with better practical skills to apply in classrooms.

The process having been envisaged as a participative study, developing with participants over time, final outcomes were expected to vary from previously recorded interventions. Both the learning environments for the study, and the training of primary-school teachers on the use of CAD, were new. A range of variables could influence the outcomes. These are discussed further in the theoretical framework and methodology.

Certain significant outcomes were considered in advance. It was hypothesised that student teachers should emerge from the course with more CAD skills, enabling them to produce creative resources for teaching in primary schools. Therefore, increased participation of student teachers in co-creation and re-creation of courses should empower student teachers to develop their own teaching plans. It was predicted that some individuals would emerge as 'champions', while others may emerge as 'detractors', human nature tending to expose both positive and negative responses to change. In a private learning environment, this can be heightened by the 'customer's expectations' compared with the actual delivered product.

Furthermore, participants should emerge with a greater practical understanding of what is involved in implementing a new CAD course using both online and offline methods. Involvement should stimulate greater awareness of one another's practice and pedagogical approaches when learning CAD. Collaboration should stimulate greater empathy for the collective group and for the ICT needs of the teaching and learning community. Finally, a greater appreciation of using CAD as a tool for creating customized resources should be

inculcated into the group. The hypothetical outcomes, above, may be difficult to measure, and may not emerge until the participant has progressed to using CAD for teaching. Post-implementation data is required to explore the results of the action after the fact.

The greater significance of achieving these outcomes is that the implementation of such a course could become a stimulus for similar interventions in other institutions of sub-Saharan Africa, in which a wider variety of ICT and technological skills is needed. Teaching computer-based technological design skills earlier in learners' schooling may have greater impact in lifting people out of poverty.

1.12 Overview of the Thesis

Chapter 1 provides the contextual background to the phenomena explored, *viz*: The implementation of a CAD unit in an ICT course for primary-school student teachers, in a South African private higher-education institute, incorporating a critical participatory action-research approach (CPAR).

Chapter 2 provides a review of research literature relating to the background to the development and teaching of CAD in schools; the CPAR methodological approach (Kemmis, 2009; Kemmis, *et al*., 2014); the socio-technical systems theory (Baxter & Sommerville, 2011; Petrina, 2003), and its relevance to teaching and learning of CAD (Petrina, 2003, 2017; Prensky, 2009); and pioneers of action research, critical theory, and emancipatory education approaches (Freire, 1972; Illich, 1976; Roche, 2011). Chapter 2 produces reference material that assists in structuring the study methodology and designing the CAD course for delivery in

an online and offline flexible hybrid mode (Petrina, 2018; Porras-Hernández & Salinas-Amescua, 2013; Redeker, 2018; Young, Allen, & Warfield, 2016).

Chapter 3 presents the theoretical framework that explores and justifies the various perspectives which informed the study, namely: critical participatory action research (CPAR); socio-technical systems theory; and associated forms of critical action-research enquiry.

Chapter 4 presents the methodological approach used to tackle the research questions that direct the study. The CPAR approach is justified as an instrument for exploring practice and practice architectures that make up human learning. The participants are introduced, and their roles clarified in relation to the stages of the process. Instruments for studying both online and offline learning activities are explained.

Chapters 5 and 6 summarise and present the results of the implementation data collection and analysis used in the three macro stages: pre-intervention, implementation, and post-intervention. These chapters present the data under themes finalised in a collaborative nominal group workshop and refined using framework analysis. The results represent disruptive technology (Vratulis, Clarke, *et al.* , 2011 & Erickson, 2011), the implementation of which produced rich data from a diverse population, and generated salient points for discussion. Results relate to CAD education; online and offline modes of learning; teacher education and practice. Results explore and challenge roles that collaborative student/lecturer communities can play, both in bridging traditional educational hierarchies and in providing relevant skills training for teaching practice.

The qualitative results reveal where obstacles exist to critical participatory action research; and how these may be overcome in future. Qualitative results are supported by quantitative data relating to participant demographics and the virtual learning environment's analytic results. These data reinforce the theoretical assertions made in the qualitative analysis and help to counterbalance any bias of the researcher with computer-generated data.

Chapter 7 presents post-implementation results derived from interviews, nominal groups workshops, and participant discussions related to the proposed improvements to the CAD unit, future pedagogies, and strategies for improving students' use of CAD in TPR. The second cycle of CAD was disrupted by the global Covid-19 pandemic. This compelled an institutional move to a flexible hybrid mode of delivery for all subjects, spotlighting innovations used for CAD teaching in the first cycle of the ICT course. Diagramming, produced on *2D Design*, is employed to represent graphically socio-technical systems and institutional change, in summarising pedagogical developments and disruptions in both final chapters.

Chapter 8 discusses the results and reflects on the effectiveness of the CPAR approach in relation to CAD education in other studies. Chapter 8 critiques the pedagogical approach used, and how this influenced design of online modules to mitigate the Covid-19 pandemic's disruption of universities. Results are compared and justified against more recently published literature (Dasgupta, Magana, & Chao, 2017 2017; Hu, 2019; Nieusma, 2018). A research gap is revealed, academic published data being primarily concerned with pedagogies for teaching CAD at either high school or undergraduate level. The concept is novel of training students to apply and teach CAD skills to learners in primary schools to accelerate technological learning.

Chapter 8 concludes with reflection on the sustainability of the implementation of the CAD course as a multi-modal offering. Chapter 8 reflects on the limitations of the study in terms of methods, scale, and the disruption caused by the Covid-19 pandemic. Chapter 8 includes recommendations on how future pedagogical interventions can be collaboratively designed, integrated, and sustained for future classroom teaching. The chapter includes personal reflection on my parallel educational journey with CAD; and how my use of visual depictions of contextual data was innovative, enabling improved understanding of changing socio-technical systems. The study exposes new questions regarding monopolisation of software teaching by commercial companies, lack of teachers' voices in ICT skills development, and issues relating to continuing professional development in schools.

The next chapter focuses on literature which informs the study. The chapter covers three broad bodies of literature relevant to computer-aided design: 1) Understanding computer-aided design 2) The role of CAD in enhancing teaching and learning, and 3) Using CAD to develop teaching and learning resources. It introduces the influential socio-technical systems theories, which arise from the study of CAD, as part of modern technology education. It then introduces critical participatory action research as a methodological approach.

END OF CHAPTER

Chapter 2. Literature Review: Locating Computer-aided Design in Intermediate Phase Teacher Education

2.1 Introduction

The introductory chapter explored the context and background to the study. Chapter One justified the necessity of expanding student-teachers' ICT skillset and encourage greater resourcefulness through the design of personalised teaching resources using computer-aided design (CAD). Chapter One identified the need to develop wider ICT skills to respond to developments in the technological education curriculum, while addressing the need for teachers to be more resourceful in the face of a financially constrained education system.

The focus of this study was to explore the ways in which teaching of CAD in an intermediate-phase teacher education programme might enhance the capacity of student teachers to effectively use ICT to develop teaching and learning material for their teaching practice. The rationale for the study was to explore ways of improving student-teachers' CAD skills, broadening their ICT toolkit to improve technology education in primary schools, thus, enhancing their teaching through development of personalised resources and lessons which include CAD.

The study investigated pedagogical approaches to teaching CAD and students' subsequent use of CAD resources on teaching practice. The study addressed two research

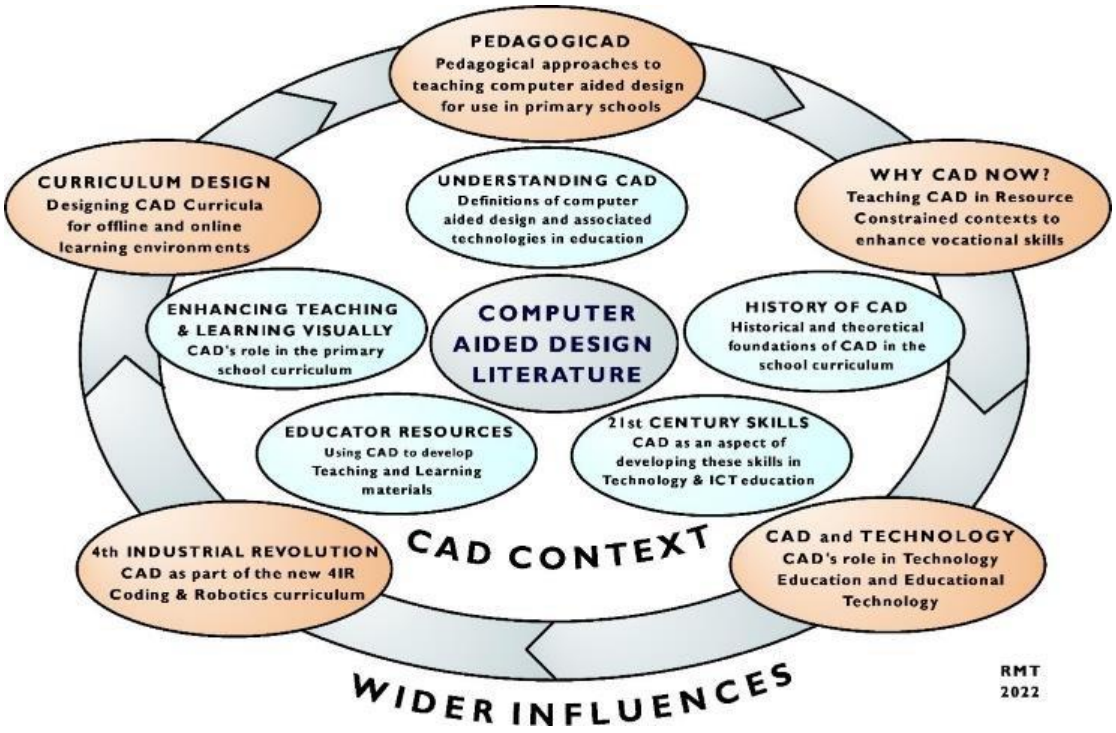
questions: 1) Which pedagogical approaches can best provide contextualized computer-aided design (CAD) education for enhancing intermediate-phase student-teachers' learning?
2) How might the use of CAD help intermediate-phase student teachers to effectively integrate ICT in developing teaching and learning support materials for their teaching practice?

Chapter One introduced the study and the thesis. This chapter presents a review of the literature related to the teaching of computer-aided design (CAD) and technology in schools, together with the pedagogical approaches that experts in the field have identified as effective in teaching CAD in different educational contexts. This study is provisionally located within three broad bodies of literature: 1) Understanding computer-aided design; 2) The role of CAD in enhancing teaching and learning; and 3) Using CAD to develop teaching and learning resources. Understanding CAD requires appreciation of a) the history of CAD and its theoretical foundations in the curriculum; and b) CAD as an element of 21st century ICT skills which form part of a teacher-training degree. The role of CAD in enhancing teaching and learning in primary-school settings is linked to: a) CAD as a tool for creating teaching resources; and b) CAD as a design tool which must be taught to learners as part of their technology and coding and robotics courses. Because the study is in South Africa, it is necessary to contextualise the teaching of CAD in schools which may be under-resourced as a result of historical inequity, due to Apartheid and current socio-economic challenges. Finally, to encourage student teachers to use CAD to produce teaching and learning resources, it is necessary to appreciate how teacher training is structured to promote resourcefulness in student teachers. Such may be through design of practical lessons which incorporate self-produced

resources. Figure 2. 1 summarises the key areas of the literature review listed above, and the themes identified from these areas.

Figure 2.1

Themes emerging from Literature Related to Computer-Aided Design



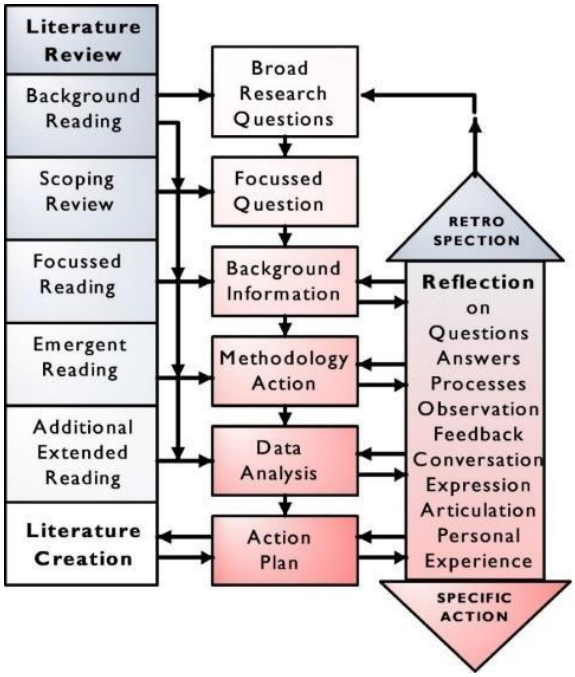
The chapter explores definitions and origins of CAD; and why its teaching has become more prominent in various school curricula. Chapter Two also explores recent educational theories relating to the pedagogies for teaching of technological and computer-based subjects with

modern classroom technology. The study follows a critical participatory action research (CPAR) methodological approach, therefore literature relating to action research in the phenomenon of CAD teaching is mentioned (Gracia-Ibáñez & Vergara, 2016, pp. 1 - 6). Critical collaborative forms of action research are cited in greater detail in Chapters Three and Four as theoretical and methodological background to the study.

In some studies, action research proceeds without a clear research question. This study used initial research questions and searches, which informed literature searches. Additional literature emerged which augments subsequent chapters. Effectively, the literature review became a parallel element to the action research, or a learning process which evolved with the action. The flowchart shown in Figure 2.2 outlines the approach used.

Figure 3.2

Diagrammatic Representation of Literature Review Process followed in this study



I conducted a simplified scoping review approach (Peters *et al*., 2015) to identify existing literature relating to teaching and learning of CAD in primary schools. The review revealed no publications from 2011 to 2022 directed specifically at primary-school teachers' learning or teaching of 2D CAD. Most recent articles cited 3D CAD software being used to improve visualisation in mathematics and science teaching (Benzer & Yildiz, 2019; Kurtuluş, 2019); and in STEM/STEAM activities involving design and manufacture using rapid prototyping

technologies (Chytas, Tsilingiris, & Diethelm, 2019; de Souza Almeida, Junior, Junior, da Silva, & de Mesquita, 2020). This did not surprise me − CAD teaching and learning in technology subjects has previously been exclusive to high schools and institutions of higher learning (Mark, Gross, & Goldschmidt, 2008). CAD has not previously been part of formal primary-school curricula. The scoping review process was valuable as an initial filter to confirm that implementation of CAD in primary-school teacher education was innovative. The review process also revealed that academics were researching CAD pedagogies applied in higher-education settings or three-dimensional CAD taught internationally in wider fields of technology education in high schools and universities. This is illustrated in the sample from my literature database (Appendix 41) shown in Figure 2.3.

Figure 3.3

Screenshot Database of Literature Related to Computer-Aided Design in Primary Education revealed from Scoping Review[ii]

A	B	C	D	E	F	G	H	I	J	K
Authors	Year	Article/book title	Journal title/Publisher	Volume	Issue	Pages	Methodology	Theoretical	Categories	Chapter/s
Barlex, D., & Miles-Pearson, S.	2008	Introducing CAD/CAM into primary schools, part 1 of a case study–developing the curriculum					Case study	Qualitative research in schools	CAD in primary school education	2, 7, 8
Barlex, D.	2011	Teaching young people about the nature of technology	PATT	25		p65-75	Case study	Socio-technical systems	Technology education-primary schools	1, 2
Barlex, D.	2015	Developing a technology curriculum	In *The future of technology education*, *Springer*	Book		p143-167	Opinion piece	Curriculum development	Technology education-General	2, 7, 8
Benzer, A., Yaldiz, B.	2019	The effect of computer aided 3D modeling activities on pre-service teachers' spatial abilities and attitudes to 3D modeling	Journal of Baltic Science Education	18	3	p335-348	Case study - Mixed methods	CAD/CAM quasi-experimental design	CAD in ICT teacher education	2, 7, 8
Bernabei, R., Cappellieri, A., Tenutab, L., Ugur Yavuz, S.		CAD/CAM and Jewellery Design Education	Making Futures Journal, Plymouth College of Art	4			Case study - qualitative	project-based, student-centered, constructionist learning	CAD pedagogy	2, 7, 8
Blikstein, P.,	2013	Digital Fabrication and 'Making' in Education: The Democratization of Invention. In J. Walter-Herrmann & C. Büching (Eds.), FabLabs: Of	Bielefeld: Transcript Publishers				Book chapter	project-based, student-centered, constructionist learning	CAD-CAM in STEM education	2, 7, 8
Brink, H., Kilbrink, N., & Gericke, N.	2022	Teach to use CAD or through using CAD: An interview study with technology teachers.	International Journal of Technology and Design Education	1	23				CAD-CAM in STEM education-Teaching to use CAD or through	2, 7, 8

Literature review refined list

The chapter concludes by discussing the themes or gaps which emerged from literature reviewed; and how these informed, or justified, the key research questions. Some theoretical viewpoints of scholars in the field of CAD education are introduced to highlight the socio-technical systems' theoretical framework which informs interpretation of findings.

2.2 Understanding CAD

Computer-aided design (CAD) is an application of technical drawing technology generally taught in South African high schools and higher-education institutions. CAD software uses mathematical grids or coordinate geometry to enable a student/learner to draft highly accurate, easily reproducible technical drawings on a computer screen, instead of on paper or drafting film, typically using a keyboard and mouse input (Groover & Zimmers, 1983). Early advantages of CAD over traditional manual drawing are cited as: greater flexibility in drawing size and scale: ease of editing and revision of designs, rapid reproduction using plotters or printers; and ease of sharing and collaboration via email or file sharing. More advanced commercial CAD systems may use large high-resolution drawing screens, and tablet and electronic stylus inputs, instead of the mouse for greater drafting speed and accuracy (Downey, 1992). CAD systems taught in high schools use the same complex commercial CAD used in industry.

Within this context, early CAD can be defined as the use of computer systems to assist in the creation modification, analysis, or optimisation of design ideas (Groover & Zimmers, 1983). Computer systems typically consist of hardware and software specifically designed to perform the design functions. Hardware includes: computer or laptop, or tablet (processors); mouse, keyboard, and, occasionally, stylus and graphics tablet (inputs); and a screen (output). Software includes the CAD application, for example, Techsoft *2D Design* (TechSoft, 2021) used in this study, which allows users to create digital drawings. More advanced CAD includes functions such as conducting stress/strain analysis of components, making heat-transfer calculations, and conversion of drawing files to machine-code output files.

CAD was originally developed for motor industry use (Mark *et al*., 2008); CAD has been taught in high schools since the early 1990s. Nowadays, modern manufacturing integrates CAD with CAM (computer-aided manufacture) (Barlex & Miles-Pearson, 2008; R Bernabei, Cappellieri, & Tenuta, 2016). This combination involves designing products on computer, and manufacturing with computer numerically controlled (CNC) machines (Mark, Gross, & Goldschmidt, 2008). Initiatives such as the 'CAD In Schools Initiative' in the UK have sought to accelerate CAD's integration into mainstream technology education, often through local industry links (Breckon, 2000). Including CAD in practical contextualised design -making technological activities in schools, has helped to ease this integration (Barlex & Miles-Pearson, 2008). However, as with most technological systems, CAD's integration into mainstream education has not been seamless (Mark *et al*., 2008). Even in relatively wealthy countries such as the UK, CAD integration has not been uniform − different regions and educational

authorities prioritise technology education according to local needs and resources available (Breckon, 2000).

Traditionally, CAD falls within high school technological education, as part of the further education and training (FET) subject engineering graphics and design (EGD). For example, in South Africa, two-dimensional CAD drafting software is currently recommended in the engineering graphics and design FET curriculum (Department of Basic Education, 2011). However, CAD is not available in many state schools that do not have adequate ICT facilities (Padayachee, 2017; Singh-Pillay & Sotsaka, 2020). Lack of exposure to CAD in schools can limit learners' effectiveness in school subjects such as EGD; but also puts learners at a disadvantage in tertiary subjects such as engineering, design, and architecture which require CAD skills (Hardy & Davies, 2013).

CAD's location in school and university curricula in relation to teaching of manual drawing is a subject of debate (Iyendo & Halil, 2015), alongside discussions about the position and role of technology education in schools (Williams, *et al*., 2015). Although CAD is valued as a tool for making design processes more efficient, it has also been seen as a threat to traditional technical drawing skills and traditional vocations since it was introduced into industry (Groover & Zimmers, 1983; Majchrzak, 1990). Early debate on CAD's disruption of industry revolved around the threat of computers replacing human drafters; and the potential for employers to use computer systems as surveillance tools to monitor staff efficiency (Noble, 1984). As CAD systems and training evolved in subsequent decades, debate shifted to staff health and well-being (from computer usage); and socio-technical issues relating to

computerisation of the design and manufacturing industry (Majchrzak & Borys, 1998). Although resistance to CAD integration has waned globally, there are still pockets of debate which seek to weigh computer-aided design against traditional manual design skills (Iyendo & Halil, 2015); or to view CAD as a low-priority skill for educators compared with other basic ICT skills (Caena & Redecker, 2019). Most recent international studies are no longer concerned whether or not to teach CAD; but rather, studies explore how to teach CAD effectively in different modes, as education shifts to blended online forms of learning (Brink, Kilbrink, & Gericke, 2022; Dagman & Wärmefjord, 2022).

CAD features as part of the critique of design and technology education (Petrina, 2017). CADI compels educators to rethink teaching and assessment strategies for technical drawing and manufacturing (P. J Williams *et al*., 2017). The location of CAD in relation to manual drafting in school curricula is still debated, although CAD has largely replaced manual drafting in industry. The debate features in design and technology education globally; and is not simply confined to South Africa (Benzer & Yildiz, 2019; Brink *et al*., 2022; Thorsteinsson & Olafsson, 2017; Williams *et al*., 2017). CAD dispenses with the need for certain manual drawing competencies, for example, dimensioning drawings to show accurate sizes. CAD drawings enable automatic dimensioning of drawings so long as the drawing is set up to the correct scale. Bypassing time-consuming traditional drawing activities should allow for more creativity and learner freedom in the design process (Schubert & Kolb, 2021). This can sometimes threaten teachers' established traditional schemes of work (Nordlöf, Höst, & Hallström, 2022).

CAD also features outside traditional technology education as part of the suite of tools which can be taught under the umbrella of information and communication technologies (ICT). CAD therefore becomes part of the suite of skills that primary teachers of technology subjects are now required to be competent in, to teach in the modern school environment (Nordlöf *et al*., 2022). In South Africa, CAD has become part of the computer science mix of primary-school subjects that teachers must implement, such as coding and robotics (Department of Basic Education, 2024). Because this subject is piloted in schools (Mzekandaba, 2021), it is cited that teachers need to be taught CAD skills. Such enable development of computational thinking and problem-solving skills, thus transferring virtual ideas to realised tangible solutions (Eryilmaz & Deniz, 2021).

2.3 The Historical and Theoretical Foundations of CAD in the Curriculum

CAD entered high school technology education curricula as part of the technical drawing or engineering graphics and design syllabus in the early 1990s, following its emergence from the European motor industry's computerisation of manufacturing in the late 1970s. This helps position the timeline of development prior to its arrival in schools' curricula (Mark et al., 2008). It took about 15 years to refine industrial CAD systems to a level which could be taught in high schools (Downey, 1992). Early systems required programming of coordinates to create images in the same way graphs are plotted in mathematics (Groover & Zimmers, 1983).

Around the same time as CAD was being introduced to high schools in the UK in the nineteen nineties, the wider debates around computerisation of the workplace, deskilling of the workforce, and replacing of labour with computerised systems were being held (Willcocks & Mason, 1987). The implications of computerisation on the workplace impacted on education − teachers had to embrace computers in management and delivery of the curriculum (Rowe & Thompson, 1990). In industry, CAD was being cited as an example of traditional skills (manual drafting) being superseded by computerised work (CAD drafting) (Downey, 1992; Majchrzak, 1990).

During this period, South African born educator, mathematician, and philosopher, Seymour Papert, was pioneering the constructionist approach to education, which reframed teaching using computers as multidisciplinary tools (Papert, 1987). Papert was a pioneer of artificial intelligence; and developed the early programming language 'Logo' which became the basis for teaching coding and robotics in schools, using systems such as Lego Mindstorms. Papert embraced computers before they were popular globally (Papert, *et al.,* 1971); and saw that educating learners in their use at an early age was essential for developing future societies (Papert, 1990). This later expanded to a rethinking of how schools could operate in the era of the computer (Papert, 1993). Although Papert does not write explicitly about the benefits of CAD, his enthusiasm for all applications of computers, and their use in design and manufacturing, is evident from his earliest writings on the subject (Papert *et al.*, 1971, p. 3). Papert's paper on coding and robotics, authored over fifty years ago, used the 'Turtle' model (p. 7) programmable robot toy to draw shapes. This was a precursor to CAD-controlled printer

plotters, more sophisticated robots, and 3D printers used in schools today. Papert is an example of a computer champion who promoted computer use in schools from an early age; while some researchers of the same period reported that computerisation of drawing using CAD was seen as a possible threat to traditional industries and human skills (Downey, 1992; Majchrzak, 1990). Although CAD is not always the direct subject of the computerisation debate, it is used as an example of changing industrial landscapes in industrialised countries at the end of the 20th century and the beginning of the 21st century (Downey, 1992; Mark *et al*., 2008).

CAD traditionally resides in the technological education curriculum as an advanced design tool for creating technical drawings as part of the design process (Breckon, 2000). However, CAD has been recognised as a tool which can assist with teaching technology and other subjects in order to create more student-orientated classrooms (Allan, *et al.*, 2018; Papert, 1993; Sandholtz, 1997).'Technological education' is not the same as 'educational technology' − the technology that teachers use to teach – which can include computers. Confusion over these definitions has led to confusion over the role of technology education in teacher education in South Africa (Gumbo, Makgato, & Muller, 2012; Gumbo & Williams, 2014) as well as other countries (Jones, 2016, p. 2). Confusion about the location of technology as a subject in the curriculum may have contributed to confusion over the position of CAD in the curriculum. Better understanding of the difference between classroom educational technology to assist teaching and technology as a subject will assist teachers' appreciation of CAD as a tool for exploring the design process. This applies to developing technological knowledge and

expanding learners' experience in other subjects such as mathematics (Ng & Chan, 2019; Wan & Ivy, 2021).

Over the last two decades, teaching of CAD in schools in some parts of the world (Bhaduri, *et al*., 2021 Suresh, & Sumner, 2021) has adapted to changes in CAD technology and graphic rendering of images. Such adaptation has allowed high school learners to develop virtual ideas in fully rendered (realistically coloured) three dimensional (3D) images. These virtual designs can also be produced as prototypes using three-dimensional printing manufacturing technology (de Souza Almeida *et al*., 2020). Much of the development of CAD teaching has occurred in high schools and higher-education institutions, in which commercial software can be used directly by students (Eryilmaz & Deniz, 2021). However, over the last five years, simplified CAD systems have been tested in primary schools as part of digital skills, and coding and robotics curricula (Bhaduri *et al*., 2021).

Given the technical and mathematical skills required to use commercial CAD systems, the refinement and development of user-friendly CAD software for primary-school children has taken longer. TechSoft in the United Kingdom has been a consistent provider of CAD software for middle and high school use since the early 1990s (TechSoft, 2021). This type of software is used effectively by high school learners; however, to date, TechSoft has not developed a package specifically for use in primary schools. During the last five years, commercial CAD software developers *AutoDesk* (AutoDesk, 2022) have responded to the need to produce more accessible user-friendly 3D software for education to introduce younger learners to CAD. Software such as *TinkerCA*D is being used to develop learners' computational

and three-dimensional thinking skills (Eryilmaz & Deniz, 2021). *TinkerCAD* does not require young learners to understand the principles of two- and three-dimensional technical drawing in the same way that AutoCAD professional software used in high schools does.

Specific pedagogies for teaching two- and three-dimensional CAD still reside in the higher-education research space (Iyendo & Halil, 2015) This child-friendly software tends to be researched alongside manufacturing technologies such as 3D printing (Lim & Kim, 2019) and 3D virtual modelling (Benzer & Yildiz, 2019); in new community-based learning environments such as 'makerspaces' (Chytas *et al*., 2019); or as part of wider research into Science, Technology, Engineering, and Mathematics (STEM) education programmes (Ng & Chan, 2019).

Science and Technology Studies (Department of Basic Education, 2024) have often pigeonholed CAD as 'just a tool' (Downey, 1992b; Petrina, 2003, p. 49). However, socio-technical studies have shown that CAD, taught correctly, is much more than this (Petrina, 1998a, 1998b, 2000). CAD is no longer one type of tool − it is an integral part of the technological design process. Definitions of CAD need to be regularly revisited to align with wider understanding of the value and impact of CAD technology and how it is taught (Petrina, 2017, 2018). With two-dimensional CAD taught in high school curricula potentially being superseded by three-dimensional CAD taught in lower school curricula, the way CAD is taught is inextricably linked to the type of CAD taught in the early stages of education (Bhaduri *et al*., 2021).

3D CAD drawing tends to start with a 2D sketch which is extruded or revolved to create a three-dimensional object. Just as learners are taught shapes before complex 3D forms in mathematics, teaching of two-dimensional CAD constructions prior to creating fully three-dimensional virtual products, developing 'spatial thinking skills', seems to be the logical approach for primary schools (Benzer & Yildiz, 2019). The need for learners to develop 'spatial thinking skills' emerges in studies on teaching of manual drawing and CAD software (Singh-Pillay, 2020; Bhaduri *et al*., 2021).

Modern CAD software is more user-friendly and intuitive; and should therefore be easier for younger learners to understand and use (Ng & Chan, 2019). Some studies have looked at integrating CAD into teacher training via general mathematics courses (Benzer & Yildiz, 2019; Wan & Ivy, 2021), as opposed to the general compulsory end-user ICT courses or technology subject specialisms. This points to the continued relationship between modern CAD and teaching of coordinate-based geometry in mathematics. Such integration also points to a diversion from teaching CAD simply as a tool within specific design and technology subjects (Mark *et al*., 2008). These studies have indicated that CAD use in primary-school mathematics education has beneficial effects on learners' computational and spatial- recognition skills (Wan, 2021; Ng & Chan, 2019). Conversely, studies in primary-school teachers' or learners' use of CAD, in design technology specialisms are not widely published. This lack of publication may be due to recent research emphasis on STEM subjects (Botcherby & Buckner, 2012) over specific research in the subject 'technology' (Banks & Barlex, 2020). Lack of publication may also relate to CAD's relationship to teaching of applied mathematics,

which can be traced back to early computer education pioneers such as Seymour Papert, who used CAD to illustrate computer programming outcomes.

In South Africa, there may be a lack of understanding of the breadth of the subject 'technology' by teachers who often learn this as an extension subject within the natural sciences primary-school curriculum (Bantwini, 2017); and learners only opt to study the subject in senior and FET phases at high schools. Learners would then choose engineering graphics and design (EGD) along with mathematics on an architectural or engineering vocational pathway (Stevens, 2006). As CAD is a specialism currently only taught within EGD, its visibility is limited; and appreciation of its value in other subjects requires clearer definition. This theme is adopted by participants in the study.

2.4 CAD as a 21st Century ICT Skill

In South African schools, CAD is generally only taught in the further education and training (FET) phase (Department of Basic Education) as part of engineering graphics and design. In UK schools, CAD is taught routinely from Grade 7. However, the design and technology association (DATA) is keen that CAD and programming be taught in the lower years of primary school (Barlex & Miles-Pearson, 2008). This is reflected in the South African government's recent initiatives to introduce coding and robotics into the primary-school curriculum (Department of Basic Education, 2024). The Curriculum and Assessment Policy Statement for primary Grades 4-6, coding and robotics (Department of Basic Education, 2024), implies that computer-aided design should be taught as part of the key knowledge strand

"Application Skills" (p.15) under "Use and manage applications used in Coding and Robotics" (p.15), using unspecified drawing application software. The lack of specificity of software reflects government's caution to avoid attaching specific software brands to curriculum documents and creating a monopoly for software companies. It may also reflect in-service teachers' and curriculum developers' lack of experience in teaching practically, or using CAD at primary-school level (Mapotse, 2018).

The need for better technological education and improved teaching of ICT skills such as CAD, is recognised in regional and national policy. The World Bank (World Bank, 2016), African Union (African Union Commission, 2015) and Mo Ibrahim Foundation (Mo Ibrahim Foundation, 2016) all reported the ICT skills gap between African school graduates and those from America, Europe, and Asia. The need for more investment in training of primary-school teachers in technology education is identified as a global need (Jones, 2016). Which particular ICT skills constitute an acceptable range of skills for educators and students has been subject to debate for more than two decades (Carretero, *et al.*, 2017; Collins & Halverson, 2009; Guo, *et al.*, 2008; Thomas, 2011). The best pedagogical approach to teaching these skills continues to stimulate different points of view (Blewett, 2016; Caena & Redecker, 2019; Redeker, 2018).

Marc Prensky (Petrina, 2017; Prensky, 2001), an academic specialising in digital gamification and online learning, observes that the higher-educational system was not designed to teach modern students who rely on digital technologies for their socialisation and learning. In the South African context, it is argued that many institutions, primary, secondary, and tertiary, are still stuck in pre-independence modes of learning. Such acknowledge the

importance of digital learning but fail to deliver the resources and skills to drive it (Padayachee, 2017; Takavarasha, *et al.* 2018). Prensky argues that contemporary students are not just different from previous generations in terms of their fashion sense, language, and social interactions. They are different because their conscious worlds differ dramatically from those brought up in earlier generations, in that they "operate in online versus offline and real versus virtual environments" (Prensky, 2001, p. 1). Prensky points to the exponential growth of digital technology over the last decades of the 20th century: 21st century students represent the first generation to have been born into this new technological age (Prensky, 2009). These students have spent their lives surrounded by satellite television, videogames, digital music players, cellphones, computers, digital cameras, and all the techno-paraphernalia of the digital age.

A key element of Prensky's early 21st century research points out that younger generations, born into a computerised life, tend to lose the ability to reflect deeply and to critically reflect on their work because they operate at "click speed". Prensky argues that educators need to build in reflection and critique through "instructor de-briefing" (Prensky, 2001, p. 4). Such need for reflection is highlighted by Stephen Petrina in his later studies of technology education, in which student peer, and instructor critique, are considered valuable to broadening students' socio-technical understanding of their own computer-aided design work (Petrina, 2017, 2018).

Since 2001, the emphasis has shifted away from large-screen interactions on TV and desktop computers, to mobile life, in which students work from cellphones, tablet computers, and laptops. This is acknowledged in Prensky's 2009 paper *H.Sapiens digital: From digital*

immigrants and digital natives to digital wisdom (Prensky, 2009). Prensky devised the term "digital natives" for modern students, who are "native speakers" of the digital language of modern technological devices and online games (Prensky, 2001, pp. 1 - 6). This new language of communication and learning has implications for some older in-service teachers' university educators, or "digital immigrants" in their adjusting to this high-speed hi-tech world in which they can become resistant to a digital lifestyle compared with their students. Prensky pointed out that often, the students are much more advanced in the use of the new tools than their teachers; and that this has potential to cause friction and resistance from educators. This is reflected in studies which decry the lack of integration of ICT into schools (Padayachee, 2016). In the South African context, this is heightened in the schooling sector where intransigent in-service teachers and school managers are often the barrier to schools adopting digital learning strategies (Padayachee, 2016).

Following on from Prensky's observations on the changing digital learning landscape at the beginning and end of the last decade, it can be argued that the 21st century student teacher needs revised specialisms which effectively challenge the use of technology (Lawrence & Tar, 2018). Teachers must also learn to act as agents and promoters of appropriate and efficient forms of learning. Teachers cannot only be consumers of technology: they have to be discerning facilitators of its teaching in classrooms (Adegbenro, *et al.*, 2017). The new student is more likely to have been exposed to an online, multi-faceted, digital world (Hennessy, *et al.*, 2010). This implies that student teachers and learners possibly have a different world view – a digital, often idealised, world view – compared with their older teaching colleagues.

Pedagogical design in teacher-training environments must engage students who have grown up to speak, think, communicate, socialise, and share digitally (Prensky, 2001), acknowledging those with prior experience and enthusiasm. Student teachers globally are taught ICT skills; however, they rarely learn how to teach ICT skills formally as part of teacher training; and ICT skills are not generally a prerequisite for entrance to the teaching profession (Fraillon *et al*., 2018, pp. 33-38). Such teachers may need to compromise on some of their digital life aspirations and use their digital experience to create a more ideal world – for all. Guo, Dobson, and Petrina (Guo *et al*., 2008) point out in their study that established and experienced teachers can also be "digital natives", as early adopters and pioneers of technology use in education. Finnish studies have shown that more technologically experienced students can inspire and mentor other less experienced peers in peer-mentorship programmes (Tynjälä, *et al*., 2021). Collaboration between young novice teachers and established technology literate in-service enthusiasts is likely to produce reliable and sustainable pedagogical solutions. Initiatives which incorporate new technologies such as online games, video instruction, and collaborative interactive assessment activities, are attractive to digitally 'switched-on' new teachers and learners (Thomas, 2011). However, the experienced ICT literate teacher is likely to bring socio-technical experience and deeper understanding of the history and vocational contexts of teaching ICT specialisms such as CAD software (Guo *et al*., 2008).

In the South African context, with one of the largest gaps between rich and poor on the planet (Francis & Webster, 2019), digitally literate students arriving in higher-education institutions can fall into the category of "digital natives", while others come from schools and

communities where digital exposure is limited (Padayachee, 2017); and daily priorities are fundamental needs (Maslow, 1943), such as food, shelter, and water. If a high school graduate comes from an environment where struggling to find basic needs and access to quality basic education are daily pursuits, it is unlikely that advanced digital skills are going to be in their toolkit (Padayachee, 2017). The marginalised students who can gain bachelors' passes in their National Certificate Matric exams would need to fall into a new category: 'digitally marginalised' – if we follow Prensky's terminology. These are students whose circumstances allow them to pass through school in a country that has unequal access to digitally enhanced education; and emerge with limited practical experience of digital technology to apply in vocations or higher education (Padayachee, 2017). Identifying the novice and experienced teachers with ICT skills and enthusiasm; and forming curriculum development peer-mentorship teams around these groups is likely to catalyse and accelerate the integration and adoption of more advanced ICT skills such as CAD (Guo *et al*., 2008).

2.5 Using CAD to Develop Teaching and Learning Materials

There is limited research on the use of CAD specifically for creating teaching resources. The limited data available on teaching resources produced with CAD indicates that they are valued or valuable. Such points to CAD being included as part of collective 'multi-media' terminology for technology which assists with teaching and learning (Mayer, 2017). Using CAD to develop accurate, scaled, reusable teaching resources is a logical step for experienced users or teachers of CAD software (Downey, 1992). Designing concrete contextual examples

which relate to the students' vocational or learners' educational needs is cited as preferable for learning CAD (Petrina, 2003). Using computer or robot-generated drawings as concrete examples to learn programming and other technological subjects is also cited as valuable by early pioneers (Papert *et al*., 1971, pp. 7-15).

Likewise, academics do not always consciously set out to create teaching and learning materials as an academic exercise. The resources often result from the author's attempts to explain some practical process or discovery. This is evident in Seymour Papert's early explanation of the 'Turtle' robot developed at the Massachusetts Institute of Technology (Stager, 2016). Papert uses CAD drawing examples produced by the Turtle to explain how the educational toy is programmed to draw specific mathematical shapes (Papert *et al*., 1971). The researcher may not have been seeking to promote CAD *per se*; instead, he is using CAD examples to promote the use of computing in schools.

CAD has been shown to be useful in informal teaching environments and collaborative learning contexts (Allan *et al*., 2018). Specifically, using drawing applications to teach computing skills has been shown to be effective in teaching basic computer keyboard skills to novice adult female users (Thompson & Alant, 2021). CAD has also been demonstrated as effective in creating resources for technology education for intermediate-phase teachers (Gumbo *et al*., 2019). Linking CAD learning activities to relevant socio-technical contexts is considered an effective way of learning CAD (Petrina, 2003, pp. 64). It follows that student-teachers' learning of CAD through drawing relevant contextual examples should stimulate

production of resources which will have long-term value for the user or teacher of CAD (Downey, 1992).

Recently, the Covid-19 pandemic accelerated the development of resources for teaching online, shifting emphasis from creating real life to online resources. Teachers have been challenged to create instructional videos for teaching CAD alongside traditional resources (Nordlöf *et al*., 2022). Teachers' recording of their own learning journey for sharing with learners is a powerful way of stimulating this resourcefulness (Brink *et al*., 2022). The micro-lecture video lesson or demonstration has become a new kind of resource that teachers of CAD have embraced to compensate for missed contact teaching (Liu, Xu, & Liu, 2021). Some researchers have also integrated CAD to develop resources for teaching other subjects such as geometry in mathematics (Wan & Ivy, 2021). Although CAD is suited to online learning and teachers' development of resources for teaching online, it requires skill and experience to use CAD without creating extra workload (Dagman & Wärmefjord, 2022).

With all the challenges of lost teaching time during the Covid-19 pandemic, development of systems to prevent increased online cheating has taken priority over development of novel resources (Ndovela & Marimuthu, 2022). Experienced CAD users have responded to the pandemic situation to develop relevant and useful resources that assist with emergency online teaching (Brink *et al*., 2022). However, with so many challenges in the resource-limited and unequal education system in South Africa (Soudien, Reddy, & Harvey, 2021), these are likely to be rare examples of good practice rather than standard practice for all.

Developing appropriate resources using CAD requires student teachers to have competence in CAD, and technological pedagogical content knowledge (Koehler & Mishra, 2009) in the subject to be taught with the resources. In higher-education applications, it is easier to build a context around a vocational application, for example, to teach jewellery design with virtual CAD examples on a jewellery design course (Bernabei *et al*., 2016), or building design examples on an architectural course (Downey, 2013).

2.6 The Role of CAD in Enhancing Teaching and Learning

Computer-aided design has enhanced teaching of design and technology studies in schools globally, since its addition to the design technology and engineering graphics curricula in the nineteen nineties (Breckon, 2000). CAD has been identified as a useful tool in teaching three-dimensional visualisation and computational thinking skills in mathematics, science, visual arts, and robotics disciplines (Mark *et al*., 2008). CAD assists learners to create and easily adapt virtual images and models on computer when physical modelling facilities and material resources may not be available. CAD computer files can be saved, shared, and printed, or reproduced, using traditional printing or computer-aided manufacturing techniques. CAD drawings have largely replaced traditional manual technical drawings in most industries globally, and therefore have reduced the need for large drawing offices and associated manual filing systems in businesses over the last thirty years (Downey, 1992; Majchrzak, 1990; Mark *et al*., 2008).

In engineering design and technology disciplines, CAD has become an integral part of the design process as a tool enabling accurate development, modification, and presentation of ideas using high quality reproducible imagery (Barlex & Miles-Pearson, 2008). CAD works well in conjunction with teaching of manual drawing and modelling (Iyendo & Halil, 2015). CAD requires computer skills, software, and physical computer hardware. The application is therefore ideal for advancing students' design skills in well-resourced schools in which staff are well trained, and facilities allow for access to internet and power (Mark *et al*., 2008).

Basic CAD drawing skills can be taught in a few hours if teachers have access to data projectors, and learners have access to software on computer devices. The method does not need to be taught in a formal school environment so long as learners have access to the technology to practise skills (Allan *et al*., 2018). CAD has been effectively taught as part of specific focused design projects; and does not need to be used continuously. CAD can be used at the culmination of a longer project to produce presentation visuals for a larger project; for example, as already stated, to produce folio pieces in a jewellery design course (Bernabei, Cappellieri, Tenuta, & Yavuz, 2016).

Studies since 2018, which attempt to incorporate CAD into pre-service teacher education focus on teachers' visualisation of three-dimensional (3D) solids to teach these in mathematics, technology, and computational thinking lessons (Lim & Kim, 2019; Allan, 2018; Benzer & Yildiz, 2019). These studies do not examine teachers' learning of CAD to teach learners to design objects or products in a technological design process, as this study does. Such studies instead utilise the software to help visualise complex mathematical concepts,

using three dimensional CAD, following higher-education institutional practice (Kurtuluş, 2019). Such studies also assist in learners' and teachers' visualisation of complex systems in science and engineering in a similar manner to engineering students (Magana *et al*., 2021). This filtering down of practice from higher-education scenarios may work in some situations; however, may simply overawe school learners.

These recent studies are worthwhile in recognition of the value of CAD as a multidisciplinary visualisation tool as well as a design tool. The shift from learning two-dimensional CAD prior to learning three-dimensional CAD in the school system may be neglecting teaching the fundamental geometrical drawing skills which link CAD to manual technical drawing (Barlex & Miles-Pearson, 2008). If two-dimensional CAD is neglected in primary education in favour of teaching three-dimensional CAD, as a novelty in coding and robotics curriculum (Bhaduri *et al*., 2021), this may neglect the fundamental drawing layout and construction skills for good quality engineering graphics and design (EGD) required further up the schooling system. Such neglect may lead to a separation of CAD specialisms in primary schools from CAD taught in the formal EGD curriculum in high schools, thus defeating the purpose of introducing CAD to encourage progressive learning.

2.7 Designing CAD Curricula

Designing a CAD curriculum in the South African primary-school context relates to development of established subjects such as technology and information and communications technology (ICT). It is also linked to development of new subjects such as coding and robotics

(Department of Basic Education, 2024). Technology forms part of natural sciences and technology (NST) in the primary curriculum. ICT is a subject which should be taught to learners in primary schools, however, it is not taught formally in all schools (Kirlidog *et al*., 2018). The reason that ICT is not taught in all schools relates to historical inequity and state schooling resource constraints, issues around staff ICT teaching competence (Guo *et al*., 2008), and procurement and security of ICT equipment (Padayachee, 2017). Limited work has been published on design of CAD curricula for primary or high schools (Allan *et al*., 2018). However, research into teaching of CAD in higher-education settings provides a structure to develop a simplified model for schools (Gracia-Ibáñez & Vergara, 2016; Petrina, 2003).

Technology within the NST curriculum includes the teaching of design processes and technical drawing. CAD is a necessary ICT skill as part of a multidisciplinary technological education (Petrina, 1998). CAD can assist with teaching technological design process through design and modelling of contextual examples (Chytas, *et al.*, 2019). CAD can also link directly to industrial automated manufacturing processes which can be replicated in the classroom using scaled down versions of rapid prototyping technologies such as three-dimensional printers or laser cutters (Bhaduri *et al*., 2021).

Ideally, a curriculum for teaching CAD in primary schools enables development of creative design skills and collaboration of ideas; and encourages innovation and enterprise (Brink *et al*., 2022). If CAD is used strategically, it can be taught incrementally in different grades to link with different subject disciplines, and does not need to be confined exclusively to technology design projects (Allan *et al*., 2018). Linking CAD to coding and robotics enables

design of ideas that may only be visualised in virtual spaces, and therefore does not require physical workshop spaces to realise solutions (Nieusma, 2018). CAD's use to aid learners' comprehension of mathematical and computational problems (Eryilmaz & Deniz, 2021) illustrates its multidisciplinary value in schools. In short, CAD should facilitate learning in creative and problem-solving activities in a wide range of subjects.

2.8 Pedagogical Approaches to Teaching CAD

To understand how to develop better pedagogical approaches to teaching CAD it is important to situate the research in theory relating to pedagogy (Banks, Leach, & Moon, 1999; Bloom, 1956; Shulman, 1987), and how this is refined in technological subjects seeking to integrate ICT (Mishra & Koehler, 2006). It is also necessary to look specifically at how CAD has been taught historically (Downey, 1992a; Petrina, 2003; Vanderburg & Khan, 1994).

Shulman categorises pedagogical content knowledge (PCK) separately from content knowledge, curriculum knowledge, and knowledge of learners, recognising that it should be valued distinctly and uniquely to teachers (Shulman, 1986). Technological pedagogical content knowledge (TPACK) was developed from Shulman's model by Koehler and Mishra (Mishra & Koehler, 2006). The model seeks to unify technological, pedagogical, and content knowledge. TPACK has been adopted by scholars seeking to find better ways of developing 21st century learner's thinking and integrating ICT into schools in a more inclusive manner (Angeli & Valanides, 2014). Integration would include using wider contexts (Porras-

Hernández & Salinas-Amescua, 2013), and following a learner-centred approach (Puentedura, 2014).

Pedagogical knowledge, in the 21st century, emerges as the ability to combine subject information, wider educational cues and teaching methods effectively, using appropriate technology. This has been highlighted as a vital missing link in the technological training of teachers in the use of ICT (Blewett, 2016; Goktas, Yildirim, & Yildirim, 2009; L. C. Jones, 2016). Teachers are often obliged to attend training in the use of technology, or to adopt educational technology into their classrooms; however, they are rarely taught how to teach technology or to teach with technology (Caena & Redecker, 2019). Teachers are best able to teach technological subjects if they can teach contextually, with experience and understanding of the wider socio-technical context (Petrina, 2003).

It is proposed that training of teachers, and their subsequent use of CAD in practice, can be constructed, and pedagogical knowledge improved, through a participatory process of learning and reflexive action (Mishra & Koehler, 2008). Pedagogical approaches cited in recent studies of CAD use in higher-education student training tend to point to problem-based learning (Benzer & Yildiz, 2019; Kurtuluş, 2019), such as the design-process orientated learning used in this study. Specific models for CAD education proposed in the last two decades build on Donald Schön's model of reflective practice developed in technology education studies (Schon, 1983; Schön, 1987b). In this model students incorporate structured reflection and critique before, during, and after practice (Petrina, 2003, 2017). Petrina's CAD curriculum models attempt to incorporate more contextualised technological examples to situate teaching in the

communities where the subject is taught; this while introducing students to wider socio-technical and historical background to the practical subject (Petrina, 2003, pp. 68).

Petrina follows Downey's assertion that teaching CAD simply as a skill ignores its importance in the history of technology and manufacturing in the 20th century (Downey, 1992), and its disruption of traditional technical professions (Majchrzak, 1990). Introducing critical debate on CAD's role in society and education relates to its location in 21st century technological history (Mark *et al*., 2008; Petrina, 2017), and acknowledges that the argument about its position and relevance is still not settled (Brink *et al*., 2022; Williams *et al*., 2017).

When CAD pedagogy is linked to other pedagogies related to ICT education, Petrina's stance on contextualised practical education aligns with Papert's early views of ICT education taking a leading role in school curriculum rather than being a second-tier additional subject (Papert, 1993). Papert saw ICT as way of advancing education through practical problem-solving and application of multidisciplinary knowledge (Papert *et al*., 1971). Papert saw computers as tools for deconstructing traditional tired pedagogical approaches, and creating learner-centred classrooms (Papert, 1990). Papert promoted a "constructionist" model in which students learn through practical exploration (Papert, 1993, p. 139). This view of ICT as multidisciplinary tool links to modern views of "activated" ICT-supported learning promoted by academic Craig Blewett (Blewett, 2016), which influenced online learning models adopted in South Africa during the Covid-19 pandemic (Singh, *et al*. , 2020a).

Petrina's models for teaching CAD reflect Papert's later reflective writing (Papert, 1993) which highlights the importance of "instructionism" (p. 140), or better planned and

executed learning events, alongside “constructionism”. Both models encourage students to think for themselves. The former draws on the educator’s and students’ experience, technological contexts, and personal learning journeys. The latter model empowers learners to brainstorm solutions to problems, before constructing, developing, deconstructing, and critiquing ideas and solutions through collaborative means to create better future outcomes (p. 143). The convergence of approaches leads to what one might call a “design thinking” approach, in which ideas and concepts may be developed as concrete or online objects through practical action (Scheer, *et al.*, 2012). The features of CAD software make it ideal for assisting learners to actively apply design thinking and follow the above processes.

2.9 Using CAD to Develop Teaching and Learning Materials

Petrina’s (2003) self-study action research in the teaching of CAD reveals that socio-technical, or contextualised courses, aid in creating more competent, critically empowered, politically informed, and technologically literate educators. Petrina’s work reflects theories from various science and technology studies (STS). Sociotechnical systems theories (STSTs) are grounded in practice; and challenge deterministic conceptions of CAD as a force for change in industry (or school).

Deterministic views might see CAD as merely a tool (Webster, 1991), or as a route to increased productivity (and profitability) in businesses. STTs instead, point to social and technical processes contributing to innovative use of CAD. The socio-technical systems’ theoretical framework matches participatory research approaches which seek to draw on micro-

, meso-, and macro-level viewpoints from various participants, which incorporate societal values (Vanderburg & Khan, 1994). Petrina's work points to Downey's early ethnographic studies of students' and lecturers' learning and teaching CAD (Downey, 1992a, 1992b). Both experts use CAD education as a route to break down artificial boundaries which exist between humans, society, and technology. It is seen as neglectful if only technical content is taught in technical courses (Petrina, 2003).

Well-taught CAD exemplifies the hierarchies of learning identified by scholars (Corey, 1953; De Bono, 2015; Dewey, 1913; Nevid, 2012; Shulman, 1987; Skinner, 1953), in that it promotes creativity and praxis. The acquisition and application of knowledge through practical problem solving, using appropriate contexts, is a recurring theme in the development of ideal forms of learning. In the African context, this is promoted in studies seeking to transform the curriculum by infusing indigenous knowledge (Gumbo, 2015) and embracing the opportunities afforded by improved access to computers and mobile communications technologies (Blewett, 2016; Mitchell, *et al*, 2017).

Literature has revealed that training of teachers to use and teach CAD is focused mostly on secondary or tertiary education (Allan, 2018; Mark *et al*., 2008). Modern pedagogical approaches evident in literature will be useful in developing a primary school CAD pedagogy (Blewett, 2016; Hardy & Davies, 2013; Sandholtz, 1997). TPACK provides one model for understanding the complexity of developing teachers' competencies in the modern context (Voogt, *et al*., 2013 Tondeur, & van Braak, 2013; Yeh, *et al*, 2014 Hwang, & Lin, 2014), but has not been researched in CAD training for primary schools. Socio-technical studies point to

the need to help learners develop technological skills within a wider socio-technical context to stimulate innovation, respond to society's needs, and to address the shortage of graduate engineers and product designers (Petrina, 2003, 2017).

Petrina's suggested contextualised models for teaching CAD to higher-education students may transfer to teaching basic CAD skills to student teachers for their own use (Petrina, 2003, pp. 62 - 64). The basis of Petrina's models is that technical skills, such as CAD, should be taught within a socio-technical context to give meaning to practical activities and to enable users to understand where and how technology fits into society. Further research is required to identify which pedagogical approaches may be best for primary-school teacher training if student teachers are to teach CAD effectively to learners.

2.10 CAD in the 21st Century Primary School Curriculum

Introducing new ICT skills and changing content is difficult in any established education system. The South African CAPS curriculum follows a process in which foundational content is introduced in the early stages; and is repeated and augmented with more elaborate content and advanced assessment as learners pass through foundation, intermediate, senior, and further education and training phases. Introducing ICT skills at the earliest stages of education assists with locating the subject in this educational continuum; and enables addition and subtraction of specialist technologies and skills, such as CAD, at different phases (Department of Telecommunications and Postal Services, 2016). Understanding what to introduce and when to introduce it requires understanding of national and global trends (Ainley,

Schulz, & Fraillon, 2016), and competence of teachers who are expected to deliver the curriculum (Hennessy *et al*., 2010).

Introduction of CAD in primary-school curricula responds to the increased computerisation of schools and computer literacy of children – digital natives (Prensky, 2001). These digital natives have grown up with computer technology and are able earlier than before to learn applications. More recent research introduces broader views on the role CAD plays in digital cognitive enhancement (Dasgupta *et al*., 2017; Prensky, 2009). In classrooms in which students can access the internet and learn online, CAD becomes part of a palette of various applications which extend pupils' learning (Thomas, 2011). Specific models for teaching CAD in primary schools are hard to locate in literature. This may be due to technological lag in design of applications for younger learners for learning CAD (Mark *et al*., 2008). This may be due to the difficulty in finding suitably qualified teachers, or teacher trainers, for technological subjects (Adegbenro, *et al*., 2017; Stevens, 2006).

Studies on the integration of CAD into the curriculum worldwide (Barlex & Miles-Pearson, 2008; Bleakley, 2015; Jones, 2016) reveal that systems in so-called developed countries (USA, U.K., Australia, and Finland) are not ideal. National and regional training policies are often not applied consistently; teachers' qualifications and ability to teach CAD are varied; and different regions have pockets of excellence rather than equitable distribution of skills and resources. What does emerge is that the Techsoft *2D Design* CAD software, chosen for use in this study is seen as a reliable and effective option for introducing CAD into schools (Bleakley, 2015; Breckon, 2000). Teaching of CAD software for younger users

encourages interest at an early stage; and promotes use of more advanced methods higher up the school system (Bhaduri *et al*., 2021). This approach has been revived using three-dimensional CAD, to align with the modern coding and robotics curriculum (Bhaduri *et al*., 2021; Eryilmaz & Deniz, 2021).

The South African high school system already specifies the use of CAD in the FET subject engineering graphics and design (EGD). It is therefore logical to incorporate teaching of basic CAD skills into primary-school subjects which align with EGD, such as technology, geometry (mathematics), and coding and robotics. Learners with prior experience of ICT systems traditionally find it easier to apply this learning in more complex applications higher up the school system (Padayachee, 2016; Ramesh & Dibaba, 2017). South Africa will continue to struggle to provide appropriate exposure to relevant age-appropriate ICT skills until historical inequities are confronted; and corruption in educational procurement and service delivery is stamped out (Padayachee, 2017). However, there is also need for in-service teachers to improve momentum in ICT integration through promoting its use in teaching; and through pressurising managers/providers to meet their commitments (Kirlidog *et al*., 2018). Primary-school heads and managers must accelerate and promote ICT provision by lobbying for reliable power supplies, internet connection, and securely located hardware (Thompson & Alant, 2016; Thompson, 2021).

2.11 Teaching CAD in Resource-constrained Contexts

South Africa's school education system still reflects the inequity of the Apartheid system. Apartheid was abolished in 1994 when the African National Congress party replaced the National Party (Soudien et al., 2021, pp. 306-307). Almost 30 years later, seventy-five per cent of learners attend no-fees schools; while twenty-five per cent attend privileged fee-paying schools which were previously reserved for Whites (Spaull, 2019). Although privileged schools can no longer exclude Black and mixed-race learners, the legacy of poor education and resources remains for the poor Black majority attending no-fees schools. The gap in quality of teaching, resources and facilities between schools has closed somewhat since 1994; however, large inequity remains, in particular, in resource-intensive areas such as ICT education (Thompson & Alant, 2021).

Computer-aided design has traditionally resided in male-dominated professions such as engineering and architecture (Majchrzak, 1990; Mark *et al*., 2008). Locating CAD in teacher education can be interpreted as a way of exposing more young women (student teachers) and learners to these skills earlier in the education system. Such will enable greater opportunities for women to enter these professions in future (Brink *et al*., 2022). South Africa's post-Apartheid society has brought more opportunity for young women to take charge of their own destinies; nevertheless, women are still operating in a society which has not set them free (Mo Ibrahim Foundation, 2017).

To teach and learn CAD effectively, computers and data projectors are the most efficient resources. CAD software can be installed permanently on devices or accessed via the

internet. Teaching CAD comes at a price, which excludes many under-resourced and marginalised schools often staffed by local women teachers. In the case of ICT resources, the Department of Basic Education reported in 2019 that 12, 587 schools had no computer centres for learners (Department of Basic Education, 2019). The Covid-19 pandemic, and subsequent prolonged school closures, exposed this technological access gap further: students without access to computer technology commonly missed half of their school year (Parker, Morris, & Hofmeyr, 2020).

Primary schools, globally, tend to have more female teachers than males compared with high schools (World Bank, 2016). South Africa's resource-limited schools are commonly located in rural areas or peri-urban townships, which often have a higher population of women: men migrate to cities to seek employment, leaving women to care for children and seek an income with local employers (STATSSA, 2017). Teaching in resource-limited settings is often the prerogative of women. For many women, teaching in primary schools in these locations is one of the few options available for permanent employment without having to relocate (Padayachee, 2016). Therefore, the plight of women teachers is linked to the inequities of ICT integration in resource-limited settings (Padayachee, 2017).

Young women in rural and urban communities are seeking to improve their ICT skills, to improve their career prospects and raise children (Thompson & Alant, 2021). The institution's demographic relating to enrolment of young women versus men in the teacher-training course covered in this study (Appendix 12: Student demographic profiles for Durban campus 2018) reflects a much higher proportion of young women enrolled than men. This

could be interpreted as progress regarding inclusion of women in the workplace. It can also be seen as an indication that young women need to seek employment as teachers in their communities to break out of poverty in a country where both young men and women are increasingly unable to find long-term employment (Francis & Webster, 2019).

When we apply this situation to learning CAD, there are immediate barriers of perception to overcome. CAD is associated with engineering and design professions, which are traditionally male dominated (Downey, 1992; Majchrzak, 1990). CAD is normally taught in technical departments, in high schools, by men to young men who aspire to work in the aforementioned professions (Mapotse, 2018). Moving the teaching and learning of CAD into primary schools is an attempt to remove it from the traditional context and present it for what it is – a useful tool for creative people of all sexual and racial orientations (Gracia-Ibáñez & Vergara, 2016). Providing access to such technology earlier in the school education system benefits both women teachers and learners: such access moves CAD away from traditionally male-dominated subjects such as engineering graphics and design (Singh-Pillay & Sotsaka, 2020).

Providing better ICT training and facilities for teaching and learning ICT in primary schools should also enable the country to grow its ICT competency in communities from the bottom up (Department of Telecommunications and Postal Services, 2016), instead of attempting to impose it from the top down (Goktas *et al*., 2009). Ensuring that there is effective integration of ICT in primary schools requires a socio-technical approach in which multiple stakeholders not only use the resources provided, but maintain and secure the resources for

learners and teachers (Kirlidog *et al*., 2018). Teachers also need to be made conscious that ICT skills are now an integral part of their requisite teaching toolkit; and their competency must be enhanced at both pre-service and post qualification in-service training (Lawrence & Tar, 2018).

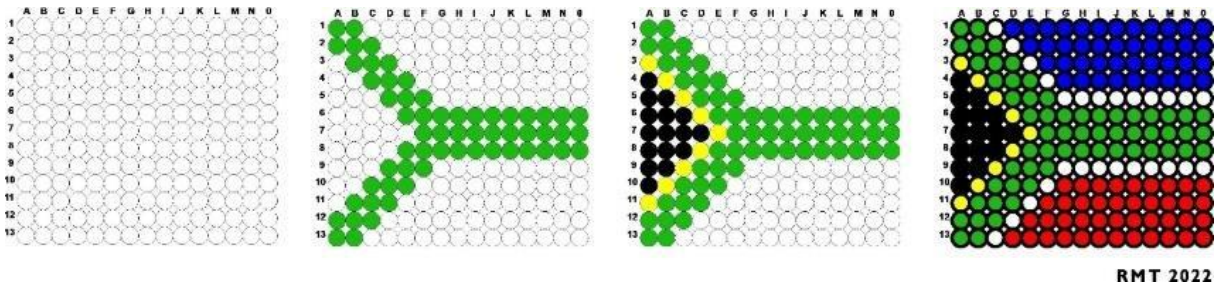
The South African Statistics office (STATSSA) published its *Vulnerable Groups Indicator Report* in August 2017 using research completed in 2016. Vulnerable groups, in this report, are defined as: children, the youth, women, older persons, and persons with disabilities. This source revealed that the plight of women, especially women from rural resource-limited areas, was not improving. In the present education context, the plight of women in society is inextricably linked to the discussion of appropriate teaching pedagogies and resource-based teacher-training initiatives (Kirlidog *et al*., 2018). Pressure from global initiatives to empower, remunerate, and promote women equitably (Botcherby & Buckner, 2012) is starting to change the political dialogue in South Africa. Here, women, particularly black, Indian, and mixed-race groups, have suffered gender and racial discrimination, which was concentrated and cultivated during the years of government-sanctioned institutional Apartheid (Panday, *et al.* , 2009 & Letsoala, 2009).

Better education in science, technology, and mathematics (STEM) specialisms has been cited repeatedly as vital for empowering women and girls to enter engineering and science professions, reducing poverty, reducing the male-female income gap, and improving gender equality (Botcherby & Buckner, 2012; Moletsane & Reddy, 2008; Thompson & Alant, 2021). Empowering women to become self-sufficient and financially independent in the digital age requires targeted ICT education (Mishra *et al*, 2017). Greater exposure to ICT specialisms such

as CAD will further enhance women's opportunities in STEM professions (Tomblin & Mogul, 2020). For example, introducing contextual applications of CAD which promote a wider range of vocational opportunities beyond traditional engineering, such as textile design, interior design and jewellery design, can make CAD more attractive to a wider range of users (Bernabei *et al*., 2016). To illustrate this, the example in Figure 2.4 below uses CAD to plan a traditional beading design to create a South African flag brooch as a computational thinking exercise. If one uses the same example in a different context and scale it could be applied as a design for an illuminated flag sign to greet tourists arriving in the country.

Figure 3.4

CAD-assisted Design of a Beading Layout for a South African Flag Brooch



Although women are not the only victims of under-resourced and unequal education systems in sub-Saharan Africa, their exclusion from the technological learning opportunities which are more available to men is well reported (Ainley *et al*., 2016; Kessy, *et al.*, 2006; Kirlidog *et al*., 2018; Padayachee, 2017). These studies point to the need to design improved systems for

providing and teaching ICT education, and subsequently CAD skills, to account for the deficits in resource-limited communities. Designing pedagogies which are inclusive and contextualised to fit the needs of women, and other marginalised groups, should assist in addressing some historic and social inequities. Access to hardware, software, and adequate training, are fundamental to meeting this need; however, additional sensitivity to socio-cultural issues in different settings is also required (Padayachee, 2017). In resource-limited and marginalised locations, simply accessing computer hardware and power to run devices is still the primary concern.

2.12 CAD in the 21st Century Primary School Curriculum

During the last five years, the South African Department of Basic Education has moved to merge teaching of ICT skills with the coding and robotics technology education curriculum (Department of Basic Education, 2024), including these as 'digital skills' taught within weekly coding and robotics lessons. Until recently, ICT skills have not been part of a formal curriculum in primary schools, but have been taught in better resourced schools as part of the life skills suite of activities (Padayachee, 2017). The coding and robotics curriculum makes digital skills part of a compulsory weekly subject; and brings CAD into the foreground as a design and visualisation tool for teaching of the subject. As with all ICT applications, the ability to teach CAD is directly linked to the way in which it is taught in teacher-training institutions (Fares, *et al*., 2021). The new curriculum has moved out of an experimental phase which began in 2019, after 1000 schools trialled the draft curriculum for foundation phase Grades R to Three

(Mzekandaba, 2021). This resulted in redrafting and gazetting of the curriculum in 2024. As part of this new course, CAD is introduced as part of teaching modern robotics, design process skills, and introducing learners to ICT skills through drawing and design activities.

AutoDesk, producers of *AutoCAD*, the most commonly used commercial CAD software in South African high schools, have developed a more user-friendly and age- appropriate 3D CAD software for primary school *TinkerCAD* (AutoDesk, 2022). Research on the use of 3D CAD in primary schools is in its infancy in South Africa. Most recent globally published work refers to use of such software in trials by university students (Eryilmaz & Deniz, 2021). However, Korean research in elementary schools has shown that technology education using *TinkerCAD* and 3D printing produced improvements in learners' computational thinking after learning with 3D CAD (Lim & Kim, 2019). Although the technology and software is available to teach CAD effectively in primary schools, constructive teaching approaches and sustainable management plans are required to resource schools so as to teach it effectively.

The teaching of two-dimensional CAD either versus, or alongside three-dimensional CAD is further explored in this study as part of the discussion of the best pedagogical approach to use for teaching in primary-school settings. The classroom technology and teacher-training implications of using various types of CAD are influenced by a variety of socio-technical factors (Barlex & Miles-Pearson, 2008). Because CAD is a form of computer software, its incorporation into students' and learners' devices can take different forms: it can be licensed for downloading directly or accessed via cloud computing subscriptions. In South African

school environments downloading software for offline use is often the preferred option, because of unreliable and expensive internet provision (Allan *et al*., 2018).

2.13 Discussion

The literature reviewed in this chapter reveals that designing appropriate pedagogies to teach computer-aided design (CAD) to primary-school teachers is challenging, there being limited published material relating to its use in primary schools. The subject is still in its infancy in South African state high schools; although CAD has been taught in schools globally since the early 1990s (Breckon, 2000). This situation is not unique to South Africa − school systems globally have been inconsistent in their inclusion of design tools in teacher-training courses (Fraillon *et al*., 2018; OECD, 2019). This may simply reflect a lack of subject integration compared with countries in which CAD is established in high school subjects such as design technology, graphic communication, or visual communication. Although CAD exists in the formal CAPS curriculum for the high school subject engineering graphics and design (EGD), there has been no formal integration of CAD into the primary-school curriculum. This indicates a lack of understanding of CAD's role in technology, both functionally and historically. The growth of the subject coding and robotics has brought renewed interest in the teaching of CAD, and a shift from two-dimensional CAD to three-dimensional CAD (Eryilmaz & Deniz, 2021) . Three-dimensional CAD allows students to visualise design solutions quickly, and to test ideas virtually. This means that traditional manual engineering drawing and CAD skills taught on two-dimensional software can be neglected, in accessing solutions which can be

manufactured quickly, or rapidly prototyped, using computer-aided manufacturing (CAM) systems (Allan *et al*., 2018). Although the move from 2D CAD to 3D CAD has taken over thirty years in high schools and industry, the shift from no CAD to 3D CAD use has been accelerated through the redesign of the primary-school curriculum to include coding and robotics (Eryilmaz & Deniz, 2021).

CAD in primary schools has changed from being a peripheral activity, confined to technology subjects in more affluent schools, into a subject which complements the teaching of coding and robotics, which is becoming a compulsory subject in all phases in SA schools. In the South African context, designing a pedagogy to teach CAD to student teachers requires consideration of the application of CAD in different subjects and contexts (Petrina, 2003). Where CAD was previously the preserve of design and technology (D&T) subjects taught by D&T specialists, it now has application in the arts, sciences, mathematics, computer science, coding and robotics (Wan & Ivy, 2021). Teaching computer skills within different subjects is not new; computing does not exist as a separate examined subject in primary schools such as FET subjects Computer Applications Technology (CAT) and Information Technology (IT) do in high schools. CAD should therefore be promoted through multi-disciplinary activities.

For primary-school student teachers, learning CAD is a new experience: this has not previously been included in traditional ICT, natural science and technology, or art courses. Universities and private higher-education institutions are only recently starting to include a variety of multi-media software in their end-user computing courses as the coding and robotics curriculum is rolled out. Student teachers with prior CAD knowledge and skills are most likely

to be from well-resourced private schools which teach CAD in EGD. A small number may be self-taught; or have prior vocational experience from engineering or architecture professions before entering teaching.

With most research of CAD teaching in higher education linked to engineering or architectural professions, the training of student teachers to use and create resources with CAD allows for opportunities to explore alternative approaches to learning using both online and offline methods. Borrowing from existing studies, the approaches to learning CAD up to now have emphasised the use of collaborative practical problem-solving design projects to assess students beyond basic competence in the use of CAD tools. Previous studies have also stressed the importance of learning CAD through practical contexts; and assessing students' performance using group critique activities. Critique of CAD work by teachers or lecturers follows the tradition of critique used in art and design and architecture schools. Peer critique has developed from this tradition. Open-group critique by both lecturers and peers could be seen as a logical evolution from the former examples; however, this approach is largely unresearched. Online teaching has revived peer critique through virtual peer-assessment activities. CAD outcomes can be assessed in both online and offline spaces.

Use of CAD in primary-school teaching can be observed and assessed in various ways. Student teachers can develop resources using CAD to teach and assess concepts in different subjects. Student teachers can use CAD solely as a tool for teaching technological design process skills to design products. These teachers can teach CAD as part of ICT (digital skills) or coding and robotics as an additional ICT subject specialism. Teaching student teachers to

use CAD is different from teaching them to teach CAD to primary-school learners. Designing a pedagogical approach to teaching CAD should ideally consider all the above. The logical pedagogical approach to follow in the modern higher-education environment seems therefore to include multiple modes of learning using a variety of resources to simulate classroom teaching scenarios. In doing so it should be easier to instill the consciousness that teaching any practical subject to primary learners should be inclusive and adaptable to different learning styles and ability levels.

At a practical level, designing any practical intervention for South African schools requires awareness that there is no level playing field in a country that is still trying to rise out of a segregated and unjust Apartheid education system. Resourcing the teaching and use of CAD in schools requires a wider understanding of the implications of teaching subjects which use computer technology, and the associated educational technologies and facilities required to teach such subjects. Understanding socio-technical systems at play in primary schools enables better understanding of how best to teach subjects such as CAD; and how best to apply CAD to produce resources. This helps policymakers understand the need to invest in creating resourceful teachers as well as resourcing classrooms.

In developing pedagogical approaches for student teachers to learn ICT skills such as CAD, one should consider how the various social, political, and epistemological viewpoints from the last few decades impact on policy- and decision-making at a tertiary level. More recently, introduction of more technological and computer-science-related subjects at primary level have highlighted the urgency to train student teachers to operate in environments in which

technological literacy and technological skills are essential. It is also necessary to understand that momentum has increased to train student teachers in ICT skills and design skills, thus improving their teaching practice toolkit. These skills may equip teachers to use CAD software for their own purposes; however, they may not equip teachers to teach CAD to learners effectively. To teach practical skills effectively normally requires the teacher to have some prior experience of application of these skills. Student teachers can gain this contextual experience, and bolster their ability to teach CAD, by producing teaching resources as part of their institutional CAD learning.

Various academic views on teaching computer applications such as CAD globally, from academics, such as Petrina, Prensky, Schon, and Shulman, tend to take the view that academia must adapt, because students have changed, demanding novel ways of learning and developing themselves during higher education. The general view is that this 'user-led' approach to learning will make student teachers better, more productive, and more inclined to inspire learners in schools. Educational institutions are without doubt subject to massive pressures to provide better digitalised, neatly packaged forms of learning, which utilise state-of-the-art technology. The pressure to adapt is not just coming from students. It is coming from governments wishing to gain popularity and to provide better vocational training for unemployed youth by promoting technology-led education initiatives.

Training students to do new tricks is beneficial, if this knowledge permeates back into society and helps a country to develop. South Africa, as with most developing nations, must build strategies and policies which ensure that graduates apply their skills in South Africa; and

do not simply use their tertiary education as a springboard out of the country, contributing to the ‘brain drain’ (Marsh & Oyelere, 2018), and advancing the decline of the skilled workforce. Strategies must include development of more inclusive and targeted ICT training which responds to the needs of women and other marginalised or vulnerable groups.

The next chapter explores how the socio-technical systems theory, used by academics in previous CAD education initiatives, fits as a theoretical lens to better understand the study and to address research questions. The chapter explains ways in which the theory can be used, together with critical participatory action-research methodology, to interpret integration of CAD into a higher-education course for student teachers; and their subsequent application of their new knowledge in teaching practice − critical participatory action-research methodology.

END OF CHAPTER

Chapter 3. Socio-Technical Systems Theory as a Framework for Computer-Aided Design Integration

3.1 Introduction

The aim of this study was to explore the implementation of a computer-aided design (CAD) course in an intermediate-phase primary-school teacher-training degree programme. Specifically, the study addresses the question: *How might the use of CAD in teacher education enhance student-teachers' capacity to use ICT in developing teaching and resource materials for their classrooms?* Using a collaborative critical participatory action-research (CPAR) methodology, the study investigated pre-service primary-school teachers' learning and integration of computer-aided design (CAD) into their practice. The study explored the ideal pedagogical approach to employ in adapting to social, institutional, organisational, and technical constraints. The collaboration with students and lecturers, in design, implementation, and critique of the course, aimed to expose how best to ensure that student teachers optimised their learning experience, and produced their own teaching resources using CAD.

The previous chapter presented a review of local and international literature related to the teaching of CAD in schools. The review explored the background to CAD education, the recent justification for inclusion of CAD in primary-school curricula (Department of Basic Education, 2021a, 2021b), and literature relating to CAD as a specialism in technological

education and integration of CAD technology in education. From these broader topics, literature focusing on CAD teaching in schools and higher-education settings revealed strong links with a tradition of critical appraisal of technology and technical education using socio-technical systems theory (STST). For example, Petrina's work critiques the "rigid technocratic and formulaic assessment approaches" used in traditional design technology curricula (Petrina, 2017, p. 15). Socio-technical systems theory, instead, advocates for greater awareness of social and historical context, contextualised teaching, and collaborative critique to give students agency in developing and improving their learning and teaching of CAD.

This chapter presents the theoretical framework for understanding pre-service intermediate-phase primary-school teachers' learning and integration of computer-aided design (CAD) into practice, in their teacher-training programme. Researching their integration of CAD into their teaching practice required a theoretical framework that enabled micro, meso, and macro systems to be viewed critically. Specifically, my thesis adopts the socio-technical systems theory (STST) as a lens for analysis. STST complements and reinforces the reflective and reflexive theorising which is inherent in action research. The socio-technical systems theoretical lens enabled a structured and layered view of where power resides in a collaborative course design process, and how this influenced pedagogical decision-making. The chapter presents both early and recent research literature that uses STST as a lens. The chapter juxtaposes this literature with technology education research that critiques STST or presents an alternative perspective. Chapter Three concludes with a reflection on the effectiveness of the theoretical approach adopted in this study.

Socio-technical Systems Theory's Background in Critical Theory Analysis in this thesis is broadly framed by critical theory. Critical theory, relating to technology, has its roots in the Frankfurt School (Callaghan, 2016; Kemmis, 2009). Building on Karl Marx's critical theories responding to European power struggles, worker alienation, and capitalist industrialization (Giddens, 1971, pp. 10 - 11), critical theory seeks to locate human rights, emancipation, and democratic participation at the centre of social activity. Mid-20th century philosophers, such as Max Hoekheimer and Theodor Adorno (Horkheimer, *et al*., 2002), developed critical theories in the *Dialectic of Enlightenment* in the late 1940s, to find meaning in society and culture, as countries rebuilt themselves in post-war Europe. Jurgen Habernas's more modernistic interpretation relates Horkheimer and Adorno's critical theories to growth in globalisation and consumerism observed in the 1960s (Habernas, 1972). Critical theory scholars have critiqued computer technology education as disruptive and imposed on previously colonised countries through post-colonial globalisation (Jobson, 2006, p. 724). From this perspective, appropriate technological systems integration is considered a crucial part of a sustainable socio-political agenda (Callaghan, 2016; Feenberg, 1991).

Critical theory is used to critically assess the value of technology to human users and to argue its application in society (Feenberg, 2005). For example, South Africa is still heavily influenced by global capitalist trends which push for technological change through computerisation of learning environments and workplaces (Callaghan, 2016; Czerniewicz *et al*., 2020). In formal education, this was accelerated by the Covid-19 pandemic emergency online learning compelled by school and university closures (Singh, *et al*., 2020b). Using a

critical theoretical base enables consideration of the social and organisational effect that technology may have on participants, by observing and sharing how it influences them individually and collectively (Petrina, 2003). Critical theory enables critique of CAD technology in relation to human emancipation from forms of work which potentially enslave them to modern technology or, conversely, enable acquisition of new skills to rise out of poverty. Critical theory should also allow space for appreciation of unexpected change catalysed by unplanned events.

Socio-technical systems theory, in this study, is influenced by foundational critical theories. These sought to challenge "socio-economic inequities" in capitalist societies which hide past failures and continue to maintain socio-economic barriers to progress for people of colour, women, and marginalised communities (Tyson, 2015, p. 55). STST identifies opportunities in which systems can be improved to improve human agency and inclusion in technological development. STST, as a line of critical theory, crucially identifies where human agency may be overlooked, with technology being implemented in systems to improve efficiency and profitability (Downey, 1992).

The critical approach employed in this study enabled consideration of the socio-technical factors influencing student-teachers' learning and application of CAD. Such an approach revealed that learning and use of CAD were linked to mode of course delivery and assessment; students' prior learning; access to computer technology; and access to online and offline resources in institution, at home, and in placement schools. Access to technology and resources for education are historically linked to wider social and political issues which relate

to race, gender, and social marginalisation. The socio-technical filters I applied to this study revealed human and technical deficiencies, as well as positive outcomes in the system.

3.2 Early Socio-Technical Systems Theory and Theorists

Analysis in this thesis is informed by the socio-technical systems theory (STST) which has roots in critical theory. STST is found in studies of computer-aided design integration in higher-education settings and workplaces. The theory posits that both social and technical factors should be studied in the design and implementation of systems which utilise technology to achieve sustainable results, for example, in Petrina's study of CAD teaching pedagogies in university courses (Petrina, 2003). In this case, STST is used to study the higher-education institution CAD course, in which student teachers learn theory and skills. Their experience from school classrooms where they apply their knowledge and skills using various pedagogical approaches also comes under study. The socio-technical systems theory evolved as a pragmatic critical response to deterministic predictions of the impact of technology on society in the middle of the 20th century. This theory grew from research by behavioural scientists at the Tavistock Institute in London, observing results of the integration of technology in industrial workplaces (Cherns, 1976; Trist, 1978).

The ideal socio-technical system is designed to address the needs of the human users, thus enabling the technical sub-systems within an organisation to work efficiently, achieving the system's goals (Van der Zwaan, 1975, p. 152). Achieving the ideal system can be complicated when the complex needs of humans are factored into a system. These include:

fair renumeration, health and safety, social recognition, meaningful work, and opportunities for growth and autonomy. To enable this to be achieved, the system, sub-systems and system boundaries must be clearly defined and negotiated (Hartley, 1990).

Tavistock Institute researchers, Albert Cherns and Eric Trist, used the socio-technical systems theory to redefine harmonious working conditions, and to address social inequities, high-volume production methods and computerised technologies impacting on workplace in the late 1970s (Cherns, 1976; Trist, 1978). Because they were researching during a period of conflict between unions and employers, these researchers steered clear of formal political issues. Cherns and Trist concentrated on adjusting systems and contexts to adapt to change, instead of disrupting organisational hierarchies (Petrina, 2003, pp. 53). Their emphasis on worker empowerment indicated alignment with a social emancipatory viewpoint which may be historically labelled socialist (Trist, 1978), but may now be considered socially aware (Fawns, 2022).

Building on systems theory, early socio-technical theory viewed technology integration into the workplace as a design process which involves social and technical subsystems in organisations (Bostrom & Heinen, 1977). Inevitably, these systems are informed or influenced by the economic and political systems in which they reside (Hartley, 1990, p. 69). Although systems thinking can be traced back to early philosophers, the systems approach provides ontological, epistemological, and axiological structure in research; and is more commonly used to justify the role and influence of technology in 20th century societies (Churchman, 1968). For example, the representation of all systems as a collection of inputs, processes and outputs

coincided with rationalisation of products, such as computers, with standardised electronic printed circuit board manufacture (Rowe & Thompson, 1990; Salzman, 1989). Churchman argued that systems methods, which concentrate purely on technical efficiency, ignoring humanist viewpoints, "tend to lead to conflict and inefficiency" (Churchman, 1968, p. 18).

The use of CAD in schools and universities, as a more efficient way to design, can be generative if one looks purely at the merits of the software (Mark, *et al*., 2008). For example, drawings can be easily edited, copied, shared electronically, and revised, if necessary. However, this does not consider the wider systems of staff training, computer resources, software availability, etc., which can make CAD software seem more inefficient than drawing with a pencil. Scholars confronted these issues when CAD was first introduced into industry (Majchrzak, 1990; Salzman, 1989). The issues re-emerge in the school context in countries with a history of social inequity and poorly resourced education systems, such as South Africa (Padayachee, 2017), which are still trying to integrate computers into mainstream education (Williams *et al*., 2017).

The cornerstone of the socio-technical systems theory is that efficient integration and use of technology is only possible if there is joint optimization of the social and technical elements of the system (Hartley, 1990). Early theorists stressed the importance of humanistic principles applied to industrial human-machine interaction (Cherns, 1976). As the theory developed, and computer technology became a universal reality, organisational-managerial (Mumford, 1995), ergonomic (Clegg, 2000) and environmental (Bronfenbrenner, 1992; Mumford, 2003) principles were explored in wider social and industrial settings.

3.3 Petrina's Socio-technical Systems Theory

Drawing on the early pioneers' work, covering wider technology education and educational contexts, Petrina's socio-technical systems theory (STST) focuses specifically on computer-aided design (CAD) and design technology (D&T) education (Petrina, 2000, 2003, 2017, 2018). In his chapter, "From Crit to Critique", in the *Handbook of Technological Education,* Petrina provides an overview of theories relating to technological education dating back to the late nineteenth century. The researcher identifies late 19th and early 20th century scholars' (Dopp, 1902, p. 171; Wright, *et al*., 1906) use of the term "industrial intelligence", which he reframes in the 21st century as "technological literacy" (Petrina, 2018, pp. 3-5). These nineteenth-century scholars define industrial intelligence as the mental power to holistically appreciate technology while completing the task at hand. The need to appreciate the wider context while acquiring new technological knowledge and skills, or "technological literacy", is a recurring theme in STST.

The educational approach used to encourage and cultivate "industrial intelligence", which Petrina tracks through various international examples of schools of technological education, incorporates "demonstration (demo) and the critique (crit)" (Petrina, 2018, p. 4). The approach involves lecturer demonstration and students' practical application, followed by a group critique of the results. This approach has metamorphosed into an assessment exercise undertaken by tertiary design and architecture schools to collaboratively evaluate design projects and present solutions to a critical informed audience (Williams *et al*., 2017).

This collaborative approach to imparting and assessing knowledge is lauded as an example of the subtlety and sensitivity of technology education over generations. Such an approach is observed in both formal and informal education settings teaching traditional skills such as blacksmithing (Andrews, 1994), martial arts (Ueshiba & Ueshiba, 1985), and, not surprisingly, design and technology education (Petrina, 2018). Petrina's justification for this approach, as a definition of "technological literacy", comes from earlier school and technical college studies. These indicate the emancipatory value of practical technological education, reinforced by shared experience, constructive criticism, and debate (Dopp, 1902; Haney, 1905; Hervey, 1908).

Petrina (2017) acknowledges that the crit lesson has a powerful effect on learning by helping students to learn to reflect and take responsibility for their own work. In teacher training, this could be considered an essential process: a student teacher cannot realistically be considered qualified until assessed by mentors or teacher educators. Collectively, these professionals assess students' readiness to accept responsibility for teaching in a classroom. In the wider education field, this is extended to the teaching practice 'crit lesson', which is supported by educational philosophers such as Dewey:

"The crit lesson (or student recitation) becomes the social clearinghouse, where experiences and ideas are exchanged and subjected to criticism, where misconceptions are corrected, and new lines of thought and inquiry are set up." (Dewey, 1900, p. 65).

Critique as part of the specific learning assessment process is one element of STST recurring in teacher education. Critique of the wider systems in which learning is designed and

delivered is an additional element discussed in subsequent sections. Specifically, STST challenges overly-optimistic views of technology which align with globalisation of the world's economies, and consumerist ideologies promoting the interests of the largest multinational technology companies (Jobson, 2006). Figure 1.1 in Chapter 1 illustrates the micro, meso and macro levels which are considered influential in socio-technical systems. The diagram illustrates multiple interacting systems that produce a desired outcome in any socio-technical system. For example, judging pedagogical approaches purely by students' technical proficiency in CAD is not enough (Downey, 1992b). Additionally, students' critical appreciation of the value of CAD in 21st century design and manufacturing is necessary (Petrina, 2003). Students also need awareness of the historical context, societal impact, and physical and human costs related to workplace computerisation (Willcocks & Mason, 1987; Rowe & Thompson, 1990).

In the 20th century, research into CAD teaching, and its application in industry and education, followed the social-political theme, in which CAD was viewed as a threat to traditional drawing skills and drafting jobs (Salzman, 1989), along with all forms of computerisation of work (Rowe & Thompson, 1990). Many of the studies from this period also addressed the technocratic versus the humanistic approach to teaching technical subjects (Salzman, 1989; Majchrzak, 1990; Majchrzak & Borys, 1998). In the 21st century studies, technological knowledge is accepted as valuable, but the studies emphasise that societal context, human needs, and agency should be taught alongside technical skills (Nordlöf, 2022; Allan, *et al*., 2018). Studies which adopt STST as a lens through which to understand the

teaching of CAD and related technology disciplines, move beyond the traditional debates about the relationship between technological change and its impact on humans (Schubert & Kolb, 2021). These studies also consider societal transformation and its influence on technological development (Feenberg, 2005). From this perspective, the studies view CAD teaching as a technological discipline which can be taught using traditional offline as well as online approaches − for example, the use of practical demonstrations, student project-based learning and group critique (Petrina, 2003), and online video instruction (Wan & Ivy, 2021) as different pedagogical methods.

From a socio-technical perspective, ideal pedagogical approaches for teaching 21st century technologies are judged on how they address the broader social, political, cultural, and environmental issues surrounding the chosen teaching contexts (Petrina, 2000, 2017, 2018). Student-teachers' use of CAD in developing resources for teaching specific lessons can demonstrate their practical understanding of its value in various contexts, for example, in creation of accurate, scalable, repeatable shapes which would be difficult to draw manually (Benzer & Yildiz, 2019). Primary teachers also need to be aware that CAD drawing has evolved from engineering drawing standards taught at high school (Department of Basic Education, 2011), which are necessary to efficiently develop products both nationally and internationally.

In this study, I wanted student teachers to use CAD to develop resources for teaching specific lessons. This was based on my assumption that this would encourage understanding of its practical value in different learning contexts. The socio-technical view of CAD education in schools may be represented diagrammatically as shown in Figure 3.1 below. This asserts

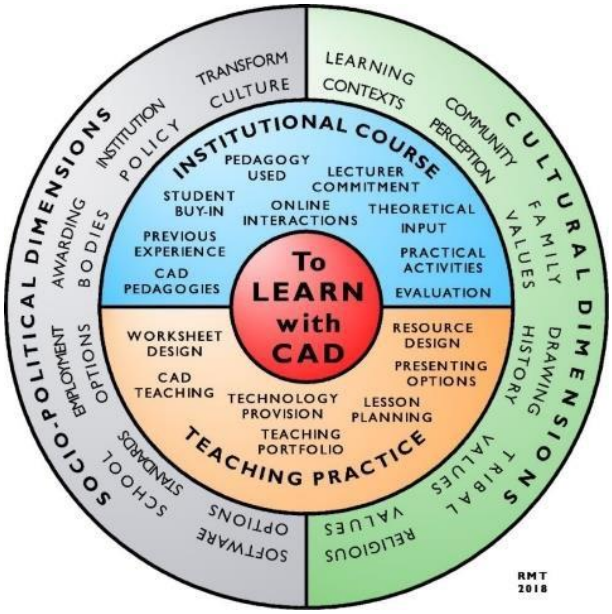
that innovation in CAD technology education can be best understood if its relationship to wider socio-political dimensions is included.

In Figure 3.1, the point of departure is that the learning and teaching of CAD does not happen in isolation. Rather, it is a multidimensional process comprising many systems which may influence learning outcomes. In the centre of the system is the main (micro) activity or studied process. In turn, this is encircled by other systems, which influence the process at a meso and macro level. Following Petrina's, Salzman's, and Majchrzak's interpretations of the teaching of CAD in higher-education courses, the effects that learning and applying CAD skills has on students' employability are recurring themes (Salzman, 1989).

For student teachers in this study, employment remains a focus; however, it intersects with institutional factors such as prior learning, software availability, and school policy on ICT. Together, these factors influence the way in which students respond to learning CAD, and how they interpret its value as a tool for creating resources and teaching design within the curriculum.

Figure 3.1

Socio-Technical Theory suggesting that Innovation in Teaching Of CAD is only understood when Various Dimensions are Considered (Adapted From Majchrazak & Salzman, 1989 In Petrina, 2003, P. 56).



As Petrina explains: “The full benefits of CAD are likely to be realised only when situated among other cultural and organisational changes made throughout the entire design process.” (Petrina, 2003, pp. 59). This thesis uses STST to analyse ways in which participants learned to use CAD to develop their own teaching resources; and the factors that influenced their ability to contextualise, integrate, and critique CAD in creating resources for teaching practice in schools.

3.4 Socio-technical Systems Theory and Social Critique in Technological Education

In Petrina's articles, "From Crit to Critique" (Petrina, 2018) and "Critique of Technology" (Petrina, 2017), the author explores how socio-technical theory has informed and influenced the development of the social critique as an integral part of design and technology education. Petrina uses the work of scholars such as Schön (Schön, 1983, 1984), Stevens (Stevens, 1995), and Martin and Owen-Jackson (Martin & Owen-Jackson, 2013) to situate socio-technical systems theory alongside action research and reflective practice, thus debating the teaching of procedural and propositional technological knowledge.

The practical teaching of technology in schools and higher-education institutions tends to be misinterpreted as students copying a sequence of time-honoured logical procedural processes. These processes form a significant part of the curriculum as a systematic approach to problem solving. When CAD replaces manual drawing activities it can reduce the complexity and number of problem-solving steps required. For example, CAD used in electronic circuit design provides easily repeatable results (Salzman, 1989): accurate component drawings can be stored in electronic libraries and re-used in different design solutions. Experienced teachers of technological subjects know that designing involves utilisation of a wider repertoire of verbal and graphic language and thought processes (M. Gumbo *et al*., 2019). Further, CAD enables educators and learners to problem solve in various ways, facilitating reaching a solution more rapidly. However, CAD is a form of computer

software which requires hardware, electrical power, and refined computer skills. It therefore replaces manual drawing at a significant cost.

As mentioned in the rationale for this study in Chapter 1, Donald Schön's *The reflective practitioner: How professionals think in action* (Schon, 1983), premises that educators learn their theoretical and pedagogical knowledge through experimentation, reflection, and reinvention. Schön's collaborative model promoted master-peer self-critique before, during, and after practice (Schön, 1987b). This researcher promoted technological education as a social and socialising process requiring experts to work with novices to improve practice (Hartley, 1990). Schön's critique of "technical rationality", theorised that professional activity involves practitioners maintaining an illusion of competence through the selective application of scientific theory and technique – what he calls a "mystique of practical competence" (Schon, 1983, p. vii). Using critical action research, Schon demystified design and technology teaching through observation and recording. His publication, *Educating the reflective practitioner* (Schön, 1987b) defined an ideal reflective educational practitioner as someone who develops, through coaching and encouragement, to reflect deeply on practice, and its social implications, thus learning in a more profound way. Schon's inclusive teacher-training models informed the work of Petrina and other researchers, who aligned reflective practice with collaborative socio-technical critique.

In this study, involvement of students in design and self-assessment, or critique, of lessons and outcomes, revealed various approaches to teaching and assessing CAD. Provision of learning opportunities in online and offline spaces encouraged students to consider their

optimum space for learning. Petrina's critique of modern researchers' attempts to conduct critical research, in the wake of Schön's pioneering work, is that there is "a disconnection between the empirical task of documenting practice and the conceptual task of theorizing how this practice might lead to critique*"* (Petrina, 2018, p. 8). Petrina's view is that the commonly employed pedagogical tool, the student critique (of a piece of design work or a lesson), should be used as an emancipatory tool in encouraging critical engagement with the wider issues surrounding practice as well as the practice itself. Paraphrasing Schön, he asks: "How does the crit incorporate critiques of Design & Technology (D&T) as phenomena for discussion over a setting, site or situation?" (Schön, 1988).

Petrina uses examples from research in design and technology and CAD to look critically at contradictions in his own teaching of CAD (Majchrrzak and Salzman, 1989; Darrah, 1996; Majchrrzak and Borys, 1998). Petrina's purpose is to justify contextualised teaching of technological subjects. The researcher compares traditional conservative technical teaching with previous interpretations of the purpose and value of technology education. Petrina eventually settles on a proposal that deterministic technical education should be scrapped and replaced with "technology studies education" (Petrina, 2003, p. 70). Petrina presents a new curriculum which involves teaching technological theory and skills within different contextual settings which relate to the community in which the education is taking place. This mirrors developments in design and technology education in the UK where CAD was introduced in the early 1990s (Breckon, 2000). Petrina highlights studies by Barlex, Keirl and McLaren, in the book *Technology Education for Teachers* (Williams *et al*., 2015), as

examples of modern researchers using critical pedagogy and STST thinking in critiques of D&T curriculum and instruction.

More recent studies follow Petrina's example; and explore the teaching of technology subjects using contemporary themes, for example, emphasis on environmental impact and indigenous knowledge systems. Some studies highlight the potential risks of wasteful over-production behaviour in classrooms being transferred to the wider world (Pavlova, 2009; Stables & Steve, 2015), pointing to environmental consciousness as part of the socio-technical mix in technological education. Some focus on incorporating indigenous technologies into the teaching of design and technology (M. Gumbo, 2015; Seemann, 2015) to give greater socio-cultural emphasis to projects. Others look at the gender bias in the formal and constructed D&T curriculum (Braundy, 2011; MacDowell, 2015), and try to promote more inclusive technical professions.

3.5 Using STST to Understand the Teaching of CAD

This section reviews ways in which STST is used by researchers to explore human use of computer-aided design technology in various organisational and institutional settings. In the CAD education field, Petrina cites technology experts Schon (1983), Downey (1992b, 1998), (Haney, 1905), and Salzman (Salzman), who used both quantitative and qualitative methods for observing socio-technical, economic, and environmental factors influencing teaching of technical drawing prior to and during CAD's introduction to school curricula.

Haney's very early studies of technology education examined the value of teaching technical drawing, to relate design to industrial manufacturing standards (Haney, 1905). In a socio-technical sense, making a direct link between what is taught in schools and what is conducted in industry was quite radical at a time when traditional subjects taught theory and little vocational knowledge. Haney writes that technology teachers need to "develop power to judge (practical work) according to definite standards" (Haney, 1905, p. 190). Ever since, using national standards to judge work has been a keystone to teaching vocational technical drawing. The same rules should apply to drawings using CAD when taught in the engineering graphics curriculum (Department of Basic Education, 2011). Being able to refer to one quality standard for assessment is an ideal scenario for teaching. CAD enables teaching of drawings in a standardised way, in that it allows users to work within pre-set parameters, for example, millimetres or inches for automatic dimensioning. Conversely, using CAD as a design tool can move it away from rigid assessment against industrial drawing standards; and allow for alternative forms of critique which align with socio-technical ideals (Petrina, 2003).

Assessing technical drawing in schools using simplified versions of national standards as the reference for evaluating quality of drawings has been common practice for more than 30 years. In STST terms, this could be considered an industrial contextualised approach. Assessing the originality of CAD drawings is more difficult than for manual drawings, the CAD drawings hiding the artistry and human variances seen in manual drawing (McLaren, 2008). Petrina advocates for peer critique as a reliable way of discussing standards and in aiding the learning

of CAD (Petrina, 2017). This can be heightened in school settings in which learners use locally produced commercial drawing examples to practise their manual or CAD skills.

3.6 Developing Understanding of CAD's Social and Historical Significance

Salzman examined CAD from the end-users' viewpoint in industrial applications during a period when CAD was seen as a threat to manual drafting jobs (Salzman, 1989). Salzman used comparison of employment statistics, CAD investment in businesses, and training trends in automotive and aeronautical industries, to discuss prevailing socio-technical views with drafters, CAD replacing traditional drafting (Majchrzak, 1990). Salzman compared arguments that CAD led to deskilling of drafters and isolated them from other engineering professions, which was reflected in wider studies of the period examining computerisation of work (Rowe & Thompson, 1990; Willcocks & Mason, 1987). At the time, workplace change was manifested in CAD drafters working separately from drawing offices to enable their use of computers. Salzman surveyed managerial attitudes that CAD would reduce human resource costs by merging design and production functions and reducing the need for drafters. Salzman's work showed that CAD did not automatically bring a reduction in drafters or deskilling of their jobs. Drafter retrenchments were linked to wider economic factors rather than simply the introduction of CAD. Understanding how and why CAD was integrated into industry enabled better contextualised training of CAD students in universities (Petrina, 2003).

Downey's work in the 1990s tracked the changing socio-technical viewpoints as CAD was adopted by North American industry; and higher-education institutions adapted their

technical drawing courses in engineering and architectural specialisms to mirror industry (Downey, 1992a). Downey used ethnographic studies to observe pedagogical approaches used by lecturers of CAD, and how their students reacted to the various contexts used to justify and teach CAD. Downey also explored ways in which teaching applications of CAD, using practical computer aided manufacturing (CAM) approaches, could improve students' engagement with commercial manufacturing contexts (Downey, 1992b). Downey's experience of researching CAD and CAM as part of socio-technical systems is brought together in his book *The machine in me: An anthropologist sits amongst computer engineers* (Downey, 2013). Downey's view was that the socio-technical systems approach allows researchers to view CAD integration in education beyond positive, negative, or neutral interpretations. Downey proposes that such studies "allow better understanding of the artificial boundaries placed between humans, society, and technology" (pp.18 – 22).

3.7 CAD Pedagogies Evident from Socio-technical Systems Studies

Several studies have used STST as an analytical lens through which to explore the design of suitable teaching pedagogies and assessment processes for the teaching of CAD in higher and secondary education sites (Downey, 1998; Allan *et al*., 2018; Mark, Gross, & Goldschmidt, 2008). These studies draw on wider social issues and humanistic elements impacting on EGD learning. Studies focus on purely technical elements of a formal taught drawing curriculum. For example, some studies complement Petrina's view that CAD should be taught in context, not in "overdetermined" isolation (Petrina, 2003, p. 54). These studies

treat CAD as part of a collective group of tools and skills which may be required to deliver more creative collaborative science, technology, engineering, and mathematics lessons (Allan *et al*., 2018; Nieusma, 2018). The studies promote guided practical problem-solving activities and collaborative learning as most effective ways of teaching CAD when incorporated into computer-aided manufacturing technologies (R Bernabei *et al*., 2016). Enabling learners to see products they have designed on CAD being manufactured automatically (CADCAM) is an ideal form of contextualisation if it matches actual commercial processes. CADCAM can also be used to attract girls and young women to previously male-dominated design and engineering professions (MacDowell, 2015).

Most recently, teaching of CAD applied technology to younger learners within coding and robotics curricula, has been reported to promote teamwork, communication skills and collaborative design activities (Allan *et al*., 2018; Bhaduri *et al*., 2021 Suresh, & Sumner, 2021). In these case studies, researchers use three-dimensional (3D) CAD systems, as opposed to two-dimensional (TechSoft) CAD, research being focused on high school or tertiary teaching of CAD linked to engineering design or architecture courses. Involving students of CAD in manufacturing of their designs using CAM has been a common element in modern classroom teaching and community makerspaces (Benzer & Yildiz, 2019; Chytas, Tsilingiris, & Diethelm, 2019). Visualisation of design solutions on a computer allows more rapid technical development and sharing of ideas. When combined with sketching, annotation, and model making, such visualisation encourages learners to apply literacy, numeracy, and creative skills in solving practical problems. This reinforces my assumption that addition of CAD to a

learner's toolkit, rather than replacing manual with computer activities, appears to have produced the most beneficial outcomes (Barlex & Miles-Pearson, 2008).

CAD has been used successfully for teaching outside traditional technology education (Wan & Ivy, 2021). Conversely, this positions technology subjects, which use CAD, as the location in which to apply mathematical and scientific learning within practical contexts (Singh-Pillay & Sotsaka, 2016). CAD software provides practical contexts that demonstrate applied coordinate geometry and vectors to produce realistic, repeatable, and accurate drawings. Bhaduri *et al*.'s study of *TinkerCAD* (Bhaduri *et al*., 2021) employed qualitative case studies involving surveys, screen-capture video recordings, exemplar work, and interviews. The study explored learners' socio-technical challenges in learning and applying CAD, using manufacturing technology. Taking real-life problems (designing animal prosthetics), to provide context for design activities improved learners spatial thinking and their three- dimensional modelling skills. This pedagogical approach is influenced by socio-technical ideals in which CAD is applied organically to ideate, detail, and manufacture collaboratively designed solutions for real-life contexts.

Broader socio-technical studies of the relationship between pedagogy and technology in education (Dron, 2022; Fawns, 2019, 2022) point to the "entanglement" of pedagogy with technology. This implies that neither pedagogy nor technology alone lead in creation of sustainable teaching (Fawns, 2022, pp. 721-723). Ideal pedagogy and the technology used to teach and learn are seen as fluid evolving "assemblages of material, social and digital activity" (p. 723), in which all stakeholders have agency, and values are shared through appropriate

contextual teaching. Fawns' model asserts that separate technological and pedagogical models of education are "illusions"; and "entangled" models of implementation are more realistic (p. 719). Fawns also points to ethics as an "aspirational" consideration (p. 718) in sustainable models of technological education, and cites studies reporting that ethics is under-resourced and poorly understood by educators (Adams, 2020). Including ethical considerations in the socio-technical system adds an additional layer of knowledge to be acquired by teachers. This also implies that greater stakeholder engagement and collaboration is required (Dron, 2022).

Petrina's study of CAD education (Petrina, 2003) explored various pedagogical approaches to teaching and contextualising CAD comparatively: "technical approach, social and technical approach and socio-technical approach" (pp. 60 – 66) through taught courses and literature. Petrina's findings value inclusion of taught sociological, historical, and psychological contexts in CAD teaching. More recently, Iyendo and Halil's (Iyendo & Halil, 2015) comparison of positive and negative views of CAD in architectural education, uses metadata from international sources to justify that CAD should not replace traditional drawing and modelling skills, but augment these through better visualisation of design ideas. Teaching manual and computerised drawing together, rather than as separate discreet stages of a curriculum, requires a pedagogical shift and a change in the way CAD is viewed contextually. This approach reflects my commercial experience of using CAD as a designer and technical author, in which ideas are sketched out quickly on paper and formalised on CAD.

Reflecting on the fluid nature of pedagogy and technology as a socio-technical system, CAD can be considered a tool for teaching or learning. CAD can also be a context itself if

learning about it includes background history and commercial examples of application of CAD. STST enables observation and discussion of this multi-faceted view of CAD. For example, my CAD drawings are not simply for teaching CAD; they have been used to teach CAD itself, as well as mathematics, natural sciences, robotics, and technology.

3.8 CAD as a Multidisciplinary Tool for Teaching and Learning

Science and technology studies (STS) have tended to pigeon-hole CAD as simply a tool to augment technology education or technical drawing outcomes (Downey, 1992b; Iyendo & Halil, 2015; Petrina, 2003, p. 49). To address this, studies informed by the socio-technical systems theory (STST) have highlighted the value of the contextual teaching of CAD so that learners appreciate the social, historical, and political history and wider implications of what they are learning in other subjects (Petrina, 1998a, 1998b, 2000). Multidisciplinary teaching embraces socio-technical ideals, in which technology is contextualised to add value to subjects (Petrina, 2003). CAD could therefore be seen as a technological link to enable diagrammatic interpretation of concepts in different subjects, as well as a tool to apply knowledge for designing solutions to practical problems. When and how CAD should be used depends on the skill level of the teacher and the resources available for teaching and using technology in schools (Fawns, 2022).

Researchers studying the use of CAD as a tool for multidisciplinary contextualised teaching and study (Bhaduri, 2021; Barlex & Miles-Pearson, 2008; Wan & Ivy, 2021), indicate a deficit in training of primary-school teachers in the use of CAD, even though CAD is present

in curriculum descriptors (Barlex *et al*., 2008, p. 1). The potential that CAD holds to augment and accelerate learning in other subjects is a socio-technical theme which can inform institutional policy and may disrupt traditional views of the curriculum.

Barlex and Miles-Pearson's study involved developing a CAD teaching partnership between a high school technology college and three feeder primary schools, in which secondary teachers taught units of work with *2D Design* CAD to primary learners. The above researchers' case studies reported socio-technical issues relating to teachers' and learners' ability to learn and use CAD in multidisciplinary design, and to set up activities in schools which were not equipped with technology labs. The researchers used qualitative interviews to explore how teachers designed their units of work and recorded dialogue to discuss learners' engagement. These researchers revealed how different contexts and design approaches influence outcomes, and how visualisation and prototyping with CAD/CAM manufacturing technologies improved students' ability to solve problems. The study reported positive results in primary learners' ability to use CAD, within defined project parameters, in which the teacher could manage the project within a concrete context or design problem. Barlex and Miles-Pearson (2008) pointed to the limitations of using guest high school educators to teach CAD/CAM in primary schools, as there was "no national scheme to provide in-service training for primary-school teachers in CAD-CAM" (Barlex & Miles-Pearson, 2008, p. 1).

Recent South African studies on high school engineering graphics and design (EGD) teachers' understanding of spatial awareness and design skills (Singh-Pillay, 2020; Singh-Pillay & Sotsaka, 2016) point to teachers' background education, technical qualifications, post-

qualification training and professional development, as socio-technical factors influencing ability to teach engineering content. This supports the assertion that teachers' prior exposure to CAD, as part of the EGD specialisms or in wider subject contexts, will have a direct influence on ability to teach effectively. The proposition that early exposure to CAD will improve learners' ability to visualise complex geometry and solve design problems later in life, is reinforced in more recent case studies using CAD as a tool to improve learners' visualisation of mathematical geometry problems (Benzer & Yildiz, 2019; Ng & Chan, 2019).

The above examples match more recent studies which position CAD as a transdisciplinary resource for extending problem-solving and design skills across school subjects, and locations, hence viewing CAD not simply as a tool for teaching of the subject technology. STST encourages consideration of social, technical, organisational, institutional, and human factors in understanding of technology education. Switching the context in which CAD is taught enables better understanding of its value and limitations in school education.

3.9 How Socio-Technical Systems Theory is Used to Understand CAD Teaching and Learning through Raising More Questions

A common methodological thread in studies of CAD, using STST as a theoretical lens, is use of data from both quantitative and qualitative sources to build a comprehensive picture of its position in the classroom, education policy, wider society, and industry. Modern studies show a need to revisit definitions of CAD in theory and content to align with changing technology and policy on teaching technology subjects (Barlex, 2008, 2015; Dagman, 2022 ;

Petrina, 2017, 2018). For example, Barlex's positive-design project-based case study outcomes in primary-school teaching of CAD/CAM are juxtaposed with less active schools, surveyed nationally in the UK at the time, in which he reported their failure to teach or use CAD due to lack of in-service teacher-training and ICT facilities (Barlex, 2018, p. 4).

Using STST raises additional subliminal questions around the key research question as humans interact with CAD technology, and technology influences pedagogy as well as human and organisational practice (Petrina, 2003). These wider issues help form a deeper and wider appreciation of the original question; however, they also challenge the definition of the question. For example, Downey's ethnographic studies point to the need for teachers and students to be able to use CAD, justify its use, and understand how it is applied in industry (Downey, 2014) In CAD drawing terms, the success of a student in reproducing a drawing example is different to their ability, and willingness, to explain their drawing process, and to justify a design solution to an audience of peers with different social backgrounds.

The use of STST draws pedagogy, content, and context together by taking a wider view of the learning process through its social, historical, and environmental influences alongside technical considerations. This can be achieved by comparing various hypothetical and theoretical views from multiple studies (Fawns, 2022), or by drawing socio-technical themes out from a specific exemplar study (Benzer & Yildiz, 2019). In this study, my analysis followed a single intervention to develop socio-technical themes. It raised related questions such as: (1) Should CAD be taught simply as a tool to assist student teachers in resourcing lessons, or should it be taught using socio-political contexts? (2) Is CAD part of a continuum of

consumption of materials, tools, and machines, in the name of technological progress? (3) Is the perceived infallibility of modern technology and consumerist economics perpetuated in the school system as a form of social programming of learners?

From an action-research (CPAR) viewpoint, it is expected that human evaluation of work practice and systems should lead to critical feedback, more questions and, hopefully, improvement in the next cycle of action (Kemmis *et al*., 2014). Using the STST lens, these bigger questions must be debated by stakeholders as an essential element of understanding how and why technology is situated in their workplaces and lives (Hartley, 1990; Petrina, 2003). Supporting this reflection and enabling constructive transformation of the workplace or learning system often involves "socio-technical integration" (Fisher *et al*., 2015, p 39), with experts within organisations, working collaboratively with the users and teachers of systems (Dagman & Wärmefjord, 2022). This is discussed further in the next section.

3.10 STST Links Transdisciplinary Collaborative Research to Technological Education Pedagogies

Outside computer-aided design (CAD) education, socio-technical studies tend to be transdisciplinary in nature, with an emphasis on collaborative approaches incorporating a range of methodological styles. More recent studies emphasise technological innovation as a process of "collaborative integration" (Fisher *et al*., 2015, p. 52) which requires maintenance of human agency and mutual learning, or cooperation between experts and the system's users (Fawns, 2022). STST researchers follow empirical, case study, action research or mixed methods

approaches, to achieve greater understanding of the socio-technical systems interacting to effect change in society and workplaces.

For example, Fisher, O'Rourke, Evans, Kennedy, Gorman and Seager's mapping of socio-technical collaborative studies across a wide range of research projects and fields (Fisher *et al*., 2015) used a comparative conceptual framework of "values and capacities" (p. 49) to analyse various socio-technical studies. The researchers analysed participatory studies across humanities, social science, science and technology, and managerial fields. The above researchers revealed that "communities of integration" (p. 40), involving close interaction with experts, were a commonality. The team posit that "mutual learning" (p. 44), in which experts learn as much as other participants, and orientation of collaboration "explicitly in societal contexts" (p. 52) creates reciprocal relationships in which "reflexive integration" takes place. These findings reflect Hartley's earlier studies of continuing professional development, in which it was identified that raising employees' awareness of the social and contextual issues surrounding their profession, enabled better appreciation of the value of their specific complex technical skills in society (Hartley, 1990).

Hartley's work pointed to the combination of behaviourist "technicist" and socio-political "socio-technicist" pedagogies (p. 69) to better transfer knowledge and improve industrial relations in professions where technical skills were applied. Hartley's pedagogical approach combined skills training with wider sociological aspects to "extend professionality", moving away from an organisational tendency to use the technical complexity of their work to legitimise new systems and to "abdicate responsibility for the social consequences of their

actions" (pp. 67 – 68). Alongside other studies of the time (Rowe & Thompson, 1990; Willcocks & Mason, 1987) which predicted the increased depersonalisation and bureaucratisation of the technicist workplace, Hartley's study points to socio-technical training as a method of maintaining the human workforce's agency. This is repeated thirty years later in Tim Fawns' call for educators to be trained in wider systems and ethics to improve educators' contextual awareness and agility in modern technology-enhanced teaching environments (Fawns, 2022).

Supporting Hartley's stance, Fisher *et al*. reveal that socio-technical approaches in various studies take a common form, in which learning and unlearning practice and behaviours is undertaken with stakeholders working in "close proximity" within a clearly defined context, to achieve some "practical transformation" (Fisher *et al*., 2015, pp. 41-42). Bringing together experts, practitioners, and novices to collaborate in socio-technical studies reflects critical participatory action-research (CPAR) approach, in which "communicative action" leads to workplace transformation (Kemmis *et al*., 2014, pp. 34 - 37).

Lowe *et al*. (Lowe, Chiu, & Oreszczyn, 2018) exemplify the close collaborative approaches promoted in socio-technical research which is highlighted in meta-analyses (Fisher *et al*., 2015). The above researchers worked with residents of low-cost housing projects, exploring the relationship between retrofitted green design solutions and human comfort, as occupants of the buildings. Using a mixed-methods case-study approach, the researchers drew data from focus groups in ten sample dwellings, occupant interviews, and technical data. Lowe *et al*.'s study used a framework analysis matrix (p. 474) to develop institutional knowledge,

engage with occupants, review appropriate technologies, and revise strategies collaboratively. The study revealed the value of "interactive design adaption" (p. 481) through dialogue with users. Lowe *et al.*'s study exemplifies a user-centred approach to inclusive community-based design which promotes social and cultural awareness in technological experts and technical fluency in the user community. This approach draws parallels with technology education studies in which stakeholder dialogue helps to improve course design outcomes.

Parallel with Petrina's studies in Canada, Tomblin and Mogul explored integration of socio-technical systems thinking into science, technology, engineering and mathematics (STEM) undergraduates in North America (Tomblin & Mogul, 2020). Following a "responsible research and innovation" framework (p. 118), these researchers encouraged students to develop socio-technical thinking skills, and to adopt postures of "humility, openness, criticality and action" (p 120). Tomblin and Mogul's ethnographic methodological approach included interviews, observations, focus groups, visual imagery, and narrative analyses to share and impart STS skills and enhance STEM educators' abilities. By empowering students to observe, discuss, and question technology in the past, present, and future, the researchers revealed that students became confident to "locate power in different systems" and to question technology's influence on individuals and society over time (p. 122). This study concluded with students mapping socio-technical systems and presenting their findings in "STS parties" (p. 123), in which knowledge and experience could be shared and discussed using social gatherings.

More recently, Nordlöff, Höst and Hallström's Swedish schools' study used an online focus-group methodology to consider how nineteen technology teachers talked about technology education (Nordlöf *et al*., 2022 2022). The research team used "heuristic and thematic" analysis (p. 7) to develop a socio-technical framework for interpretation. Their interpretative framework mapped technical skills taught, technological knowledge, and contextual socio-ethical and technical understanding of technology. Nordlöf *et al*. used professional vocational examples to contextualise various practical activities. Their study showed that teachers found it easier to contextualise when teaching modern technologies, for example, programming in robotics (p. 18), over traditional engineering. Nordlöff *et al*.'s study reflects Petrina's earlier work highlighting how good technology education combines wider socio-technical understanding of the "civic capabilities" of technology with "engineering capabilities" (p. 19). Nordlöff *et al*.'s study also highlights the value of focused critique and discussion as methods of empowering educators to confront their wider technological knowledge and skills limitations (Petrina, 2018; Williams, 2017). Nordlöff *et al*.'s study concludes with a visual representation of their findings. A three-dimensional rectangular prism, with each face representing a different form of competence, is used to represent a multifaceted teacher (p. 18).

The examples in this section present socio-technical systems theory as a filter which contextualises, rationalises, and legitimises CAD as part of technological education in various settings. Commonly, change agents need to work directly with users of systems to collaboratively interrogate and integrate change through discussion and constructive critique

as a common departure point. In this study, interpreting the integration of a computer-based technology in pre-service teacher training required such a collaborative dialogue. CAD is akin to learning a language of graphic communication. Understanding the wider social, political, historical, and cultural contexts around this form of communication assists in contextualising CAD for student teachers. Once teachers know how to use CAD, they are freed to explore its use in wider design contexts. Sharing what CAD can do alongside its historical development and commercial applications assists in expanding its application to wider fields of education.

3.11 Computer-aided Design's Socio-technical Position in the Primary School Curriculum.

Socio-technical studies have highlighted the value and location of CAD in relation to traditional technological education (Barlex, 2015; Iyendo & Halil, 2015; McLaren, 2008: Tomblin, 2020). These researchers argue for CAD to be more integrated into technology education at an earlier stage in subject curricula, thus improving learners' understanding of technology applied in commercial design and manufacturing systems. These researchers also encourage socio-technical systems approaches, to encourage reflective and reflexive practices, and to situate technological awareness in professional teacher development as a form of collaboration. Finally, diagrammatic visualisation with CAD for teaching and studying CAD is presented as an example of the interdependency of technology and pedagogy in creation of multimodal educational systems.

3.11.1 Integrating CAD into primary schools to stimulate technological development

Firstly, David Barlex uses his primary-school case studies (Barlex, 2008, 2011, 2012) to argue the place for CAD and CAM education for teachers and learners in his proposals for developing a technology curriculum (Barlex, 2015); hence, using a socio-technical structure to teach technological subjects in a manner which adapts to technological change. To promote the school subject 'technology', Barlex advocates that learners develop skills while learning the social and historical context in which it is located. Barlex also advocates for teachers to better understand the wider nature of technology; and argues for a more flexible curriculum which adjusts to developments in technology in the wider world. Supporting contextualised study, Barlex cites socio-technical case studies which bring mentors from industry into schools (Barlex, 2012) to engage with young people on the nature of technology beyond the traditional curriculum (Barlex, 2011) More recently, Barlex and Banks (Banks & Barlex, 2020) used socio-technical reference points in a book, to train primary educators to teach through multidisciplinary science, technology, engineering, and mathematics (STEM) subject collaborations and school-industry links. This mirrors approaches higher up the educational ladder, in which school-industry partnerships are used to inspire students to follow STEM professions (Tomblin & Mogul, 2020).

3.11.2 Socio-technical theory's relationship with reflective and reflexive practice

Secondly, STST is linked to reflective and reflexive practices which are common in primary-school action research. Personal reflection and collaborative reflexive activities recur

in many studies, STST using critique to identify more democratic or holistic ways of interpreting technology and addressing issues of human need and agency within systems (Petrina, 2018; Nordlöf *et al*., 2022; Tomblin & Mogul, 2020). In primary-school teacher education, personal reflective research is encouraged as part of professional development (Pegrum & Oakley, 2017). Reflexive practice with mentors and teacher educators is encouraged as part of formal teacher training. Integrating technology, such as CAD, into teaching and reflection on this, using online and offline systems individually and collaborative, enhances student-teachers' teaching and entrepreneurial skills (Mapundu & Musara, 2019). Recording personal reflections in a socio-technical framework is considered promoting more collaborative reflexive processes (Nordlöf *et al*., 2022).

Petrina, for example, reviews his own practice alongside changes in teachers' and students' perceptions of technology education (Petrina, 2018, p. 3). Petrina shifts from "critical self-reflection" of practical work produced, or processes followed, in the social group 'crit' through assessment of solutions presented to peers and/or teachers/lecturers. Petrina desires that students and teachers view CAD learning as a form of "social critique*".* In CAD, this human activity is only achievable with the assistance of technical systems, for example, projecting students' work onto a wall to allow group assessment using digital projectors; or printing drawings for manual team marking using printer copiers. Critique of CAD is technology-dependent; however, social interaction lies at the heart of the process.

The collaborative reflexive nature of self and group critique in creative settings, is a recurring theme in Petrina's STST research in assessment of design students (Petrina, 2017).

This is evident in Petrina's collaborative studies involving critique in design technology subjects (Williams *et al.*, 2017), and application of technologies such as CAD in the wider social and environmental context (Petrina, 2018). Judging whether action supports critical self-reflection or reflexive activity requires careful planning of individual and collaborative processes (Koen, 2021). The educational process alone is not sufficient without collaboration and a degree of self-awareness. Petrina's socio-technical approach supports participatory studies in technological subjects, requiring participants to adopt a collaborative positionality that CPAR aspires to. The methodologies adopted for STST studies also reveal the researcher's reliance on technology as part of the wider system, in facilitating, managing and communicating findings. This reinforces the idea that technology and pedagogy are "entangled", with both elements part of the interdependent socio-technical mix that forms educational practice (Fawns, 2022).

3.12 How CAD Supports Socio-Technical Interpretation through Diagramming and Multimodal Learning

STST studies also highlight theoretical, or philosophical, tools that may assist in interpreting different systems' influence on human activity. Researchers employ visual tools to summarise themes and findings which may form theories. For example, Steve Keirl points to analysing socio-technical studies of technology education using "binarial hermeneutics" (p 1) as assisting in interpreting technology by incorporating wider political, historical, and cultural relationships (Keirl, 2015). Keirl proposes that socio-technical approaches help

technology educators to explain, understand, and visualise technology better by: (1) identifying and locating key aspects of human-technology interactions; and (2) using these to inform future decisions.

In this study, my interpretation of socio-technical change is supported by diagrams which summarise human, social, technical, and organisational influences. These were used to illustrate how the changes in location, resources, and mode of delivery influenced students' ability to learn and apply CAD. Diagrammatic interpretation is also used as a tool to communicate hypothetical multimodal teaching approaches which demonstrate socio-technically conscious pedagogy. My socio-technical viewpoint, supported by diagrammatic summaries, enabled better communication and interpretation of the layered processes and experience of conducting action research. These elements combined to facilitate meaning-making at a deeper level, and to "actively critique (technologies) from multiple perspectives" (Keirl, 2015, p. 2).

Williams *et al*.'s socio-technical focus on the student critique (Williams *et al*., 2017) inspired an appropriate visual pathway for reviewing the practical CAD drawing outcomes in this study through online peer assessment. Foregrounding participants' reflections on their own and others' visual practice, using online peer assessment tools, enabled observation of outcomes as part of learning. Reflective online peer review and interview activities representing the 'student critique' were undertaken as both individual and group activity; and reveal socio-technical themes. Reflexive discussion was also enabled online using the *WhatsApp* group. The course was collaboratively designed, delivered, and refined, using

technology. Although students were learning CAD, it also assisted their learning through instruction illustrations in guides and narrated video recordings of CAD in use. CAD assisted in creating a multi-modal learning experience as a technological and pedagogical tool.

3.13 Critiques of Socio-Technical Systems Theory

Socio-technical systems theory (STST) has been adapted to interpret systems operating in diverse contexts, including manufacturing, financial industries, environmental research, and technology education. Critique of STST in technology education manifests in action and policy. Critique encourages traditional vocational approaches separating technical knowledge and skills from appreciation of the wider socio-political contexts influencing global design and manufacturing industries (Petrina, 2003). Critics suggest that a broad-brush view of human activity can dilute interpretation of action, and overlook the reality on the ground (Van der Zwaan, 1975). These critics point to research analysis and design of systems that lead to new systems being imposed before the original system is fully understood. This has the same effect as an extreme technicist approach which might blindly implement a new technology without testing it first (Hartley, 1990). Critics emphasise the need to understand the boundaries between various elements of a system, to avoid over-simplification of sub-systems. In simple terms, drawing on too many sources of data, or trying to understand too many interconnected sub-systems can be seen as providing a superficial, or cluttered, overview, instead of concentrating on elements of great importance. The overly broad view can also lead to an ambiguous

definition of subsystems which may contain too many variables to allow clear interpretation (Van der Zwaan, 1975).

3.13.1 Technical Determinism Keeps Politics Out of Technological Education

The counter argument to STST, technical determinism, existed before STST was defined as a theory. Technical determinism sought to keep politics and history out of technological education (Petrina, 2003). STST challenged determinism in the 1980s and 90s (Salzman, 1989). Determinism, in its extreme state, assumes that material and physical laws will cause technology to develop in a predetermined way. Determinism tends to exclude human and societal influences. Early 20th century determinists, and some modern empirical scientists and engineers, did not consider humanistic-social element of systems as important to efficient operation of technical systems in serving wealth creation and growing economies in a post-war era (Churchman, 1968; Snow, 1998). This was highlighted by C.P. Snow at Cambridge University's Rede lecture "The Two Cultures and the Scientific Revolution" presented in 1959 (Snow, 1998). Petrina refers to this lecture as a major influencer of late 20th century science and technology education theory which counters socio-technical theories (Petrina, 2003).

3.13.2 Socio-technical Systems Theory as Over-Simplification of Complex Systems

Critiques of STST suggest that studies often require overly complex forms of data collection and categorisation to enable a broad view of multiple sub-systems influencing research outcomes, which can lead to dilution or over-simplification of results. Linked to this,

Van der Zwaan's early critique of the Tavistock researcher's socio-technical systems approach pointed to the need to better understand the boundaries between human, technical, social, and organisational elements of systems. Van der Zwaan posits that the boundaries between workers and machines, for example, are as influential on the system as the human personality and the features of the machine. In subsequent research in computerisation of work, this is referred to as the "human/machine interface" (Rowe & Thompson, 1990, p 71). In a wider sense, this includes human factors: ergonomics, or systems designed to comfortably fit the human user (Flinchum, 2000).

Van der Zwaan's overriding criticism is that the analysis of systems in this way can lead to an assumption that systems are, or should be, flexible, thus enabling "joint optimization" (Van der Zwaan, 1975, p. 150). It is often the case that the technology is considered inflexible when it may instead be human-organisational inflexibility which hampers progress (Hartley, 1990). This critique of STST points to lack of clear systems definitions, bias towards human needs over efficient systems analysis, and a lack of acknowledgement that humans are an intrinsic part of the technical system as creators of systems. Van der Zwaan points to human complicity in designing hardware (technical systems), and their imposition of social norms in the design of the systems which reflect the desired behaviour or policies of the organisation (Van der Zwaan, 1975, pp. 154).

Van der Zwaan pointed to the need to clearly define all elements of the system, thus formulating meaningful hypotheses, and verifying the theory (Van der Zwaan, 1975, pp. 152). The researcher identified that the management of boundaries between parts of a systems is

often overlooked in STST studies, in which system dynamics are explained through various interpretations of the "equilibrium or ideal steady state" for smooth operation (p,150). Van der Zwaan's criticism can be summarised by saying that the socio-technical systems theory is only possible with clear understanding of boundaries and interconnectedness of sub-systems. This can be difficult to manage at scale without large teams of specialised researchers. In this study, data was collected from multiple online and offline sources; and a large variety of data was produced. In most research projects, the process of defining systems forms part of the research question, research objectives, and research design. Analysing the variety of data sources was only manageable with a clear research question and direct involvement of participants.

3.13.3 Overemphasis of Social Issues Can Distract from Vocational Imperatives to Learn to Use Technologies such as CAD

John Pannabecker's studies of the teaching of technology education and CAD in the late 1980s and early 1990s reviewed determinist and socio-technical viewpoints (Pannabecker, 1991). Pannabecker identified that deterministic interpretation of technology commonly referred to the impact of technology on society taking a converse view on humanity's influence on technology. The researcher argued that deterministic views of technology as the active participant was an inappropriate metaphor; technology in isolation is inanimate, while humans are the change agents in society. Pannabecker explained that critics of STST saw weaknesses in its approach when social, environmental, and political themes were over-emphasised; and the multi-faceted interaction of social and technical themes were overlooked (Bijker, 1987).

Many technology teachers in the 1980s and 90s came to the vocation as retrenched engineers from globally relocated industries (Jobson, 2006). To avoid politicising education, social issues and politics were kept out of the technology curriculum. These teachers focused on vocational technical knowledge and skills acquisition, to upskill the workforce (Becker, 1988). In 20th century CAD education, opponents to socio-technical and political interference in technical education held positions of strength in redeveloping post-industrial societies (Pannabecker, 1991). Some proposed systematic practical CAD teaching pedagogies which taught traditional drafting skills parallel with the computer-aided design, as vocational tools (Becker, 1988). Determinists did not consider that teaching CAD in social contexts was necessary. This view has pervaded CAD education research and teacher education for subsequent decades (Barr, 1999; Gumbo *et al*., 2019). It could be argued that a technicist view still dominates in South African technological education, especially in the high school teaching of engineering graphics and design. Following CAPS guidelines (Department of Basic Education, 2011), CAD should be incorporated uniformly; however, this has not yet materialised thirty years after its introduction in UK schools. This has perpetuated the teaching of traditional manual drawings alone in under-resourced schools; and increased the gap between learners who are adequately prepared for vocational design-drafting professions and those who are not.

3.13.4 Over- emphasis on Addressing Social Issues May Impact on Impartiality and Lead to Conflict

In Fisher *et al.*'s overview of STST studies (Fisher *et al.*, 2015) critics suggest that collaborative approaches to integration of technology, using the STST approach, lead to loss of critical distance or impartiality (Guston, 2014). This manifests itself in experts' over-investment in a project, or detachment from wider issues, while focusing on their area of interest (Nordmann & Schwarz, 2009). Some argue that collaborative participatory socio-technical approaches inevitably have limited scope and reach, due to their personalised nature (Valve & McNally, 2013); and may lack appropriate interdisciplinary objectives (Taebi, *et al.*, 2014 Dignum, & Pesch, 2014). Van Oudheusden's study, while sympathetic to STST, reinforces the criticism highlighting the risks of relational dynamics and organisational power structures derailing projects and reducing the opportunity for "responsible innovation" (Van Oudheusden, 2014).

Criticism of STST in action research points to a potential conflict between the social and technical orientation of the action (Kemmis, 2014. p. 75). This can be determined by whether the action is engaging with human problems (social) or imposing an alternative technology or scientific management process (technical) (Van der Zwaan, 1975. pp. 154). This points to the need for a clear definition of the problem and an acknowledgement that social and technical influences on a system are not mutually exclusive (Hartley, 1990), but interdependent (Fawns, 2022). In this study, I had to be aware of the potential conflict that could have arisen

from students' critique of lecturers' work in designing and implementing the CAD module; as well as the resistance to technological change that potentially could come from both groups.

The fluidity of the site of learning and application can gain more impact as learning moves away from contact learning to more hybrid forms of learning (Bednar & Welch, 2020). Lack of definition of the site can make it difficult to categorise elements of a system, define boundaries between subsystems, and identify sustainable practice. STST helps to interpret systems by a process of systematic categorisation, for example, by looking at systems simply as INPUTS – PROCESSES – OUTPUTS with FEEDBACK (Churchman, 1968). It can be difficult to draw neat conclusions when systems and their surroundings are in a state of dynamic flux, and researchers are themselves engaged in the action. Bednar & Welch highlight this in their study on 'Smart Working' (Bednar & Welch, 2020): "Our interpretations of context are individually unique and continually changing over time" (p. 284). In this study, diagrammatic mapping of the observable ICT teaching sites enabled me to better appreciate changes that were influencing evolving sites of interaction. However, deeper understanding of the effect of change on participants only came through dialogue and cross-referencing of their feedback in a framework.

Oosthuizen and Pretorius's criticism of STST, assessing the impact of new technologies (Oosthuizen & Pretorius, 2016), proposes that design of new on top of old systems is flawed, unless the new is modelled first. The researchers' argument is that implementing change without modelling it first can make the system too complex with too many variables to analyse. Modelling systems enables better understanding of dynamic relationships "between people

themselves, between people and technology and between people and the environment" (Oosthuizen & Pretorius, 2016, p. 15). In this study, initial modelling of content was enabled using critique from a 'critical friend'. Modelling for students from other years and programmes only became possible as the course was implemented. The first iteration became the model. One can argue that action research, which allows for a process of continuous improvement of the system in action, is more effective than virtual modelling. It depends on how 'modelling' is defined in relation to real experience of a system in action.

3.14 Responding to Criticism of Socio-technical Systems Theory

In response to the criticisms of STST, some recent studies have suggested a more focused analysis using systems-of-systems modelling (Iwanaga *et al*., 2021). This translates as methods of improving researchers' consciousness of project scale and reach. It requires efficient division of analysis tasks to make better holistic interpretations and produce actionable outcomes using analytical software. In this study, NVivo12 and Excel enabled better structuring and sharing of the data, using framework analysis (Srivastava & Thomson, 2009), while the nominal group workshop (Delbecq & Van de Ven, 1971) enabled more collaborative analysis of findings in a face-to-face event. Additional interrogation of findings came through supervisor and co-supervisor critique of reporting and thesis chapters.

In this study, my intention was to broaden the experience of student teachers through their participation in the integration of CAD, thus improving their resourcefulness and employability. Measuring resourcefulness brought challenges − it is difficult to observe

resourcefulness in action, unless one shadows participants in their teaching practice. Relying on students' and lecturers' honest feedback on their application of CAD required trust in the validity of participants' self-observations. STST and CPAR tend to encourage empowered collaborative teams as part of organisational redesign. This can be interpreted as "ethical ambiguity" as teams can be "complicit in their own exploitation" (McLoughlin, Badham, & Couchman, 1999, pp. 235-236). This potential weakness of STST highlights the need for careful selection and design of teams, as well as encouraging willingness to adapt and respond to criticism from within collaborative teams. The implication is that socio-technical systems must encompass shared responsibility and include devolved decision-making powers. To be successful, collaborative teams need clear objectives and roles.

In my case, vigilance and good communication had to be maintained with participants to enable adaptation to unplanned events and recording of change in the CAD course as it happened. As the place or mode of learning changed, or context shifted, the need for consistent thematic reference points became greater. This is discussed later in the chapter when considering the effectiveness of STST as an interpretive theory to use in critical participatory action research.

3.15 Discussion

This study brought student teachers together with lecturers to critically analyse their learning of CAD in a variety of communicative spaces. To do this, my analysis is informed by socio-technical systems theory (STST). STST argues that social and technical factors must be

considered in the implementation of technology if it is to be sustainable and relevant. In the CAD context, this means that student teachers should not only be taught CAD skills: they should also be able to apply such skills in school teaching; and to justify its use in various social and organisational contexts. This could involve teaching CAD as a tool for design and technology activities; using it to teach graphic concepts in different subjects, and teaching the value and the societal implications of CAD to learners. The supposition behind the theory is that better understanding of the social and technical aspects of CAD should assist teachers to use it and to teach about it effectively and innovatively.

STST theory involves systematically analysing how humans integrate with technology in social and organisational structures to perform specific tasks (Oosthuizen & Pretorius, 2016). The theory provides a framework for analysing complex systems by categorising the macro system into two sub-levels: social and technical, located within an organisation and wider environment. These sub-levels are further subdivided to include physical-technical, work-task design, organisational-social and human-social categories (Figure 3.1).

Key socio-technical systems explored in this study were the collaborative design and delivery of a CAD module, using online and offline modes of delivery, and students' application of their CAD skills in design and use of resources for teaching practice. Because the module was delivered during a period of social, organisational, and technological disruption, there are many socio-technical facets to view. As will be discussed in Chapter Four, the inputs to these systems included the design of computer-based and manual resources as well as human-centred planning, teaching, and learning activities on physical and virtual

campuses (learning management system). The main activities included face-to-face meetings, practical lectures, workshops, and online teaching using video and documentary resources. The outputs included student activities to demonstrate their skills, revised and new course materials, and changes to lecturer and student practice. From an STST perspective, these were the visible systems. The subliminal systems influencing the activity at different levels included institutional policy changes, technical developments on physical and virtual campuses, schools' practice and policy, national education policy, and participants' own socio-technical situations.

My analysis is premised on the assumption that well-taught technology education exemplifies the hierarchies of learning (Corey, 1953; De Bono, 2015; John Dewey, 1913; Nevid, 2012; Shulman, 1987; Skinner, 1953) and promotes reflective creativity and praxis (Schön, 1987b). The acquisition and application of knowledge through practical problem-solving, using appropriate contexts, is a recurring theme in the development of ideal forms of technological learning (Petrina, 2003; Schön, 1984). In the African context, this is promoted in studies which seek to transform the curriculum by infusing indigenous knowledge (M. Gumbo, 2015; Seemann, 2015), but simultaneously embracing the opportunities afforded by improved access to computer technology (Blewett, 2016). My personal bias towards more practical contextualised education therefore influences my socio-technical interpretation as an invested researcher and participant.

It is the author's view that CAD should have equal emphasis as manual drawing in the South African school curriculum to match the contextual reality in industry. The current South

African high school EGD curriculum locates technical knowledge and traditional drafting before CAD (Singh-Pillay & Sotsaka, 2020); while socio-technical contextual teaching is gradually being redefined using indigenous and contextualised knowledge systems (Blikstein, 2013; Gumbo *et al*., 2019). This can be better achieved by early adoption and careful contextualisation in helping learners to understand that CAD is not replacing indigenous systems; CAD is augmenting them by providing efficient and repeatable methods to achieve a technical design goal. This additional post-Apartheid socio-cultural imperative adds a layer of complexity to socio-technical interpretations of technical education in a socially and economically unbalanced society (Gumbo, 2015). Integrating IKS into the technology curriculum is a local acknowledgement that STST is influencing the critique of technology education (Williams *et al*., 2017). Taking technological education beyond technological pedagogical content knowledge (TPACK) to include socio-technical systems knowledge (STSK) is one way of developing a better contextualised, culturally sensitive education system (Petrina, 2003).

As discussed in Chapter 2, improving contextualisation is not a new idea in educational systems critique. Dewey, Freire, Illich and other educational theorists promoted this as part of general educational reform which aligns classroom education more closely with the real world. Technological education is heavily influenced by industrial development and the systems and standards created to optimise such, for example, in promotion of standardised manual technical drawing as well as CAD (McLaren, 2008). Teaching students and learners to understand why these systems and standards coexist helps to structure socio-technical viewpoints (Fawns,

2022), and to separate CAD teaching from the narrower deterministic approach, which simply views CAD as a computerised drawing skill.

Deterministic views of CAD as simply a tool for increasing productivity in vocational settings (Webster, 1991) are not completely negative. Technologically deterministic policy can help ensure that technology is implemented in schools. It can also reward the resourceful teacher as technology saves schools money and increases efficiencies in the system. However, policy must be followed through; and resources distributed fairly. From a STST stance, resourcefulness can be equated to student-teachers' emancipation from reliance on prefabricated resources designed by third-party providers, presenting an opportunity to explore cultural identity through technology. Teachers who can adapt and develop their own resources freely are also more desirable in a financially constrained and unequal education system such as South Africa's (Padayachee, 2017). Primary-school teachers who can design culturally stimulating resources using modern technologies such as CAD, may be able to improve understanding of culture and history of technology at an earlier stage in learners' technological education, while promoting greater humanity (Adegbenro *et al*., 2017). As illustrated in my study, identifying resourcefulness requires not only evidence of application of CAD technology, but participants' ability to justify its use in their own practice.

Criticism of the socio-technical systems approach argued that it can fall short of identifying all factors influencing a system (Van der Zwaan, 1975). It may also over-simplify systems by taking overly holistic viewpoints. However, the emphasis on the human decision-making processes guiding technological change makes STST a valuable interpretive tool in a

system when change is planned or expected. As Pannabecker indicates, studying technological impact in isolation following a deterministic route is limited, in often coming after the human damage has been done (Pannabecker, 1991). The ideal technological implementation appears to involve participants who have agency to steer the process as it happens and help manage the impact using collaborative human reasoning. However, the user-centred design approach can also potentially instigate conflict between participants and organisations in which systems are being implemented.

Using processes which encourage human interaction, such as group critique (Petrina, 2018), workshops, and both synchronous and asynchronous discussions, ensures that the human role in technological change is real and acknowledged. In primary-school implementation of CAD, Barlex highlights ways in which peer mentoring and group critique can enable more collaborative forms of learning in design activities (Barlex, 2008, p. 4). The ways in which STST is used in organising, interpreting, and understanding the organisational, structural, technical, social, and human factors involved in implementing a CAD course for student teachers is explained further in the following chapters.

3.16 Synthesis

This chapter discussed how socio-technical systems theory (STST) enables a better understanding of the teaching of CAD. Using this ‘wide-angle’ lens, the pedagogical approach to teaching technical subjects is clearer. The approach draws on evidence of participants looking critically at their actions, whether individually or as part of the group, as well as

demonstrating understanding of the context in which they are teaching. A better understanding of practice and participant attitudes, and appreciation of issues which have affected integration of technology in education over time, is attainable through structured framework analysis.

Applying STST in critical participatory action research (CPAR) enables integration of theoretical approaches which share common academic roots and goals. STST encourages systematic pragmatic interpretation of data from the study, from human, organisational, social, and technical angles. CPAR creates the generative structure in the action-research cycle, enabling more efficient extraction of meaning over time. STST studies show that collaborative 'demonstration – practice – critique (or evaluate)' technological design process models work in practical learning environments, and transfer well into online learning spaces. The need for technological education to be more collaborative and inclusive is a recurring theme in socio-technical studies. From a teaching perspective, STST emphasises understanding of technological teaching pedagogies and technological contextualisation or understanding where CAD has come from and why it is necessary as part of a practical ICT course. Peer and lecturer critique is used as an effective approach to assessing CAD outcomes alongside traditional lecturer assessment. This emerged as a vital source of socio-technical data. Tracking use of CAD in schools as a visual resource for teaching generally, and in teaching of CAD, is identified as a research gap. The next chapters outline ways in which a critical participatory action-research (CPAR) approach assisted in gaining a deeper understanding of the best pedagogical approaches for training of teachers in the use of CAD. They reveal how CAD training can be applied in resourcing teaching practice. CPAR and socio-technical systems

theory combine to provide a theoretical and analytical framework for exploring CAD teaching, learning, and application.

END OF CHAPTER

Chapter 4. Research Design and Methodology

4.1 Introduction

This study explored how the teaching of computer-aided design (CAD) in an intermediate-phase (Grades 4-7) teacher education programme using both online and offline modes of learning might enhance the capacity of student teachers to effectively use information communication technology (ICT) to develop teaching and learning material for their teaching practice. The main research question was: *To what extent and in what ways might the use of CAD in a teacher education programme enhance intermediate-phase student-teachers' learning and their capacity to use ICT in developing teaching and learning support materials for their classrooms?* To address this question, two critical sub-questions were asked:

1. Which pedagogical approaches can best provide contextualized computer-aided design (CAD) education for enhancing intermediate-phase student-teachers' learning?
2. How might the use of CAD help intermediate-phase student teachers to effectively integrate ICT into developing teaching and learning support materials for their teaching practice?

The previous chapter set the theoretical scene for using a CPAR (CPAR) methodology to address the questions. It explained the socio-technical systems theory (STST) as a theoretical lens for analysis in the study, to view the action-research cycles. The socio-technical theory is

broadly underpinned by critical theory. This chapter outlines the research design and methodology used to address the research questions posed in the study. The chapter begins with a reflection on the research paradigm and methodology, followed by the description of the location of the study, the research design, and the intervention we implemented; the critical participation action-research project undertaken, the data-generation methods used in each of the cycles of the project, and the data-analysis methods applied. The chapter concludes with a discussion of the ethical considerations and limitations of the project, and how these were addressed to ensure scholarly rigour throughout the research process.

4.2 Research Paradigm

The study is located within the critical paradigm. However, the study takes on a pragmatic form with action research in physical and online spaces over two cycles producing both qualitative and quantitative data (Morgan, 2014a). The critical paradigm comes from critical theory (Cohen *et al*., 2007), which, as discussed in Chapter Three, is based on the notion that there are multiple realities from varied perspectives constructed on the basis of issues of power (for example, in any research setting); and that the researcher must attempt to obtain as many of these perspectives as possible through the research process implemented (Creswell & Poth, 2018). Critical theory, as it relates to technology education, has its roots in the Frankfurt School (Habernas, 1984, 1987; Kemmis, 2009; Callaghan, 2016), building on Karl Marx's early critical theories on institutional power, worker alienation, and capitalist industrialisation (Giddens, 1971, pp. 10-11).

Critical theories, such as those presented by Jurgen Habernas, seek to locate human rights, emancipation, and democratic participation at the centre of social activity. Habermas proposed critical engagement in social settings and workplaces to involve civil society and private individuals in public affairs in a new form of democracy, as an essential component of the paradigm. Habermas's work sought to improve individuals' lives through "communicative action" and engagement with institutional stakeholders in "public spheres" (Habermas, 1987), such as workplaces, in which new manufacturing technologies such as CAD impacted on peoples' jobs (Petrina, 2003).

Originally located in the critical paradigm, the study analysed in this thesis aimed to empower the student teachers and collaborating lecturers to learn CAD as a subject and to develop contextually relevant resources. In addition, participants discovered how to use CAD in primary-school classrooms to improve teaching and learning. In a context such as South Africa's in which classroom resources are often scarce, this was necessary to expose student teachers to new technological resources. CAD also improved their technological pedagogical content knowledge (Koehler, Mishra, & Yahya, 2007), helping student teachers to become agents of change for a better education system. As we had to share lived experience prior to critiquing it, a pragmatic process evolved as participants adapted to changes in teaching and learning conditions; and data was produced from a range of sources (Kaushik & Walsh, 2019).

Informed by the critical paradigm, and based on the above understandings, analysis in the study is informed by Petrina's socio-technical systems theory developed through critical participatory studies of computer-aided design integration in the workplace (Petrina, 2003). As

discussed in Chapter Three, the socio-technical theory evolved as a pragmatic critical response to optimistic predictions of the impact of technology on society in the middle of the 20th century. The cornerstone of the theory is that efficient integration and use of technology is only possible if there is joint optimization of the social and technical elements of the system. This collaborative approach leads to the use of action-research methods in researching technological training using different contexts. Petrina's action-research work focuses on computer-aided design and technology education specifically (Petrina, 2000, 2003, 2017), but draws on the early socio-technical systems pioneers' work. This inspired a critical but pragmatic approach which sought to reveal how the changing learning environments, institutional policies, and technology provision arrangements influenced the participants in the implementation of CAD teaching.

Because this study drew on data from both qualitative and quantitative sources, to explore CAD implementation in changing face-to-face and online environments, a pragmatic approach was adopted (Morgan, 2014b). This allowed analysis of diverse qualitative critical views relating to the research question from participants. Analysis was supported by observation of the changing learning environments and quantitative data showing evidence of activity and student success in learning to use and apply CAD.

Research in the critical paradigm seeks to enlighten researchers and participants on the effects of unequal human and institutional power relationships in collaborative work, and to challenge these (Mertens, 2007). In this study, I asked participants to collaborate in open critique of a variety of blended online learning approaches in a CAD course I had developed,

which provided a choice of learning pathways or a variety of pedagogical approaches to understanding and applying CAD in primary-school education. It was important that I had established this critiquing as an emancipatory process to release participants from perceived, or actual, hierarchical positions imposed by the institution and individuals' perceptions of their role therein. I sought to provide participants with an opportunity of openly critiquing what they were learning and teaching together, throughout the learning process. Typically, students only provide critique of courses in institutionally managed course evaluations completed at the end of the module. However, it would be naïve to assume that this research released all participants from their predefined, or institutionally imposed, roles. My hope is that participating in this study did allow some to experience more diverse opportunities for learning in an environment which provided added choice and allowed their voices to be heard.

4.3 Critical Participatory Action Research Methodology

Informed by the critical paradigm, the study used a qualitative methodology and adopted a critical participatory action-research (CPAR) design (Kemmis *et al*., 2013) to document, reflect on, and possibly improve the integration of a computer-aided design (CAD) module into an existing ICT course. Action research has long been established to promote a view that humans that inhabit and use a system are better situated than outsiders to critique and solve problems within the system (Lewin, 1947; Petrina, 2003, 2018). Additionally, system users are more effective when empowered to critique and improve their own work, and when they collaborate with peers to solve problems (Watts, 1985, p185). Participants in CPAR are

actively critical in research, both individually and collectively (Kemmis *et al*., 2013). This means that their critique is recorded and discussed, ultimately leading to collaborative improvement of the system they are researching. Action-research methodology also aligns with the pragmatic paradigm in which research guided by a research question can draw on multiple sources of data generated by participants and the results of their actions. This study drew on various data which emerged through action in changing teaching and learning environments compulsorily altered by the Covid-19 pandemic. The study ultimately takes a pluralistic pragmatic viewpoint as it cannot assume that the collaborative implementation will guarantee educational success or greater freedom for the participants (Koenig *et al*., 2019).

According to Kemmis *et al*. (2014, p.12 - 28), CPAR involves six key tenets. First, participants are involved in critical reflection on human social and power dynamics in a system in which they operate. Second, participants should participate democratically in all stages of the research process. Third, participants should be empowered through the activity and active participation to instigate change though contextual understanding while promoting social justice and equity. Fourth, research should follow a flexible and iterative approach which acknowledges, adapts to, and promotes change. Fifth, research should follow ethical considerations which acknowledge human agency, celebrate participants' contributions, and promote knowledge production through dissemination of research findings. Sixth, research activities should encourage long-term commitment to ensure sustainable change. Effectively, informed by the critical paradigm, CPAR is rooted in a commitment to social transformation, pursuit of justice through community engagement, and participative action.

CPAR draws on socio-political, socio-technical, and environmental issues affecting research. CPAR employs the term "practice architectures*"* (Kemmis *et al*., 2013, p. 7), which involves critically interrogating practice within the circumstances we operate in. In this study, this assisted me with understanding an ICT-dependent education environment. CPAR combines research in three areas: participants' understandings of their practice expressed through dialogue; activities which individuals engage in as the action; and reflection on the situations in which the action takes place (Kemmis, 2014). Combining these elements enables an understanding of the impact of change for participants and encourages more longer-term reflection on the wider impacts on people in socio-technical systems.

In planning this study pragmatically, CPAR was chosen as a research design that fitted the action to existing institutional management systems and timescales, in responding to the research question. The aim was to engage the participants through investigating and experiencing their learning and teaching of CAD, so as to constructively experience and critique a new reality from within (Borda, 1979). CPAR involved me, the researcher, and participants (or co-researchers) as the primary instruments in this effort. Collaborating in course design, data generation and analysis, meaning was found through personal and shared experience, through description, and induction (Creswell, 2014).

As the main researcher, I explored participants' collaborative learning experience through their contributions to design and critique of the course in both online and offline dialogues we had together, and CAD resource-design outcomes. I combined these with my observations and the discussions of their use of CAD to produce teaching resources. Multiple

viewpoints provided rich data and wide contextual experience to interpret findings within a socio-technical framework. By observing and recording dialogue, learning scenarios and activity against a changing situational background, it was possible to see how the action(s) "hung together" as a woven pattern of human activity (Schatzki, 2002, p. 87) that built the thesis analysed in this writing.

4.4 Research Context

The study was located on the Durban campus of the Higher Education Institution (HEI). I was granted permission to conduct research at the campus (Appendix 4: Gatekeeper Permission Letter-PhD Research October 2018) as it was then my primary place of work, and headquarters of the School of Education (SoE). The site provided me access to the largest population of contact learning students and lecturers. At the time, the campus had two full-time ICT lecturers and one contract ICT lecturer lecturing in two ICT tutorial rooms with digital data projectors. As reported in Chapter One, when I began this PhD journey, I was the discipline leader in the mathematics, science and technology department at Campus-1. In 2017 academic departments were instructed to develop a flagship 'online course' using an established module. To this end, my mathematics, science, and technology (MST) department chose to review and redevelop an end-user computing module, CPT101, which was available in contact and distance-learning mode. CPT101 was a first-year semester-long end-user ICT course which Higher Certificate students were required to take as part of their programme. Information and communications technology for educators (ICTE200), a yearlong module and

subject of this study, is similar to module CPT101, but is studied by second-year diploma, foundation, and intermediate-phase degree student teachers. One Campus-1 lecturer (Lecturer-1) coordinated and converted ICTE200 into an online course parallel with CPT101 so that he could reuse common resources (e.g., lecturer-produced instructional Microsoft Office videos).

While the ICT lecturers were developing the online ICT courses, I was also developing coding and robotics modules[iii] for intermediate and foundation phase programmes for the MST department. In 2018, the SoE considered it prudent to incorporate the teaching of computer-aided design (CAD) into CPT101 and ICTE200, to upgrade the two Microsoft Office-dominated end-user computing modules, and add multimedia skills for utilisation in future coding and robotics courses. This decision was based on the understanding that CAD is an essential tool in the design of robotic systems and any modern design/engineering professions (de Souza Almeida, *et al*., 2020).

The study was located in the ICTE200 module thus exploring the best pedagogical approach to introducing CAD to intermediate-phase primary-school student teachers; and in observing how they might use it to develop resources for their teaching practice in schools in the weeks following their ICT lectures (see Chapter One). With my 20 years of experience as a design technology educator, technology lecturer and course designer in teaching and resourcing CAD education, my belief was that CAD should be introduced to primary-school teacher-training programmes to assist with implementing the new South African coding and robotics curriculum. The South African coding and robotics curriculum was officially drafted in March 2019. The draft curriculum was trialled for Grades R to 6 from 2021[iv], and finally

gazetted as part of the National Curriculum in 2024. My motivation for introducing CAD into our existing ICT courses was to improve and broaden computer skills among collaborating lecturers and students, and to prepare them for planned coding and robotics modules and delivery of courses in schools.

At the time of the study, campus facilities were not traditional ICT laboratories with computer hardware, office furniture, and computer benches. Instead, ICT lecturers used general purpose classrooms equipped with single seat exam tables and plastic chairs. The lecturers taught ICT theory classes in larger lecture theatres to accommodate larger module group sizes. The move from using purpose-built computer labs to general purpose classrooms and lecture theatres took place when the institution relocated between 2017 and 2018 from its previous site to the larger Durban campus. The move was a conscious decision by the institution to reduce capital costs. For the students, especially those with limited resources, the change had some negative implications: the introduction of the 'bring your own device' (BYOD) policy compelled students to purchase their own computer laptops or electronic tablets for learning and completing assessment tasks.

Pedagogically, expecting students to bring personal devices to campus added another layer of complexity to teaching, learning, and assessment of ICT and CAD. For example, students were no longer taught and tested on standardised devices controlled by the institution. Thus, on one hand, this policy enabled wider institutional utilisation of spaces previously allocated as computer rooms; and on the other, it delegated the expense and responsibility for managing devices onto the students and their families, thus reducing costs for the institution.

In terms of institutional resources, notwithstanding the many challenges this policy brought for the diverse student population, the change freed up on-site IT support contractors to concentrate on staff computer systems management. Furthermore, the implementation of the BYOD policy stimulated an academic board-level strategic move to offer a blended online learning experience, using a *Moodle*-based learning management system (LMS) and an online student information management system (SIMS).

The study took place during a period of growth and expansion in that the School of Education was merging with a larger public-listed company, along with other South African private higher-education institutions. This merging of separate private institutions took place between 2017 and 2021 and was intended to broaden school leavers' access to higher education using various modes of learning[v], thus increasing the national footprint of the separate institutions through sharing of facilities. During my data collection, the Durban campus was one of three fully operational contact learning campuses in South Africa. Two other campuses opened between 2021 and 2022 in the Western Cape and Gauteng. The institution has significant numbers of distance-learning students from South Africa and Namibia. At the time of writing this thesis, registered students in contact and distance learning modes of learning exceeded 46 000.

The programmes and modes of learning offered by the institution have evolved from two separate traditions within the organisation: traditional contact learning (from the parent company) and distance learning (after merging with institutions specialising in distance learning). During 2019-2020, these were more aligned in terms of module coordination, online

assessment and marking. The merger created a blended online learning experience which suited the integration of computer-aided design into ICT teaching. The merger was motivated by the commercial success of subsidiaries in the distance learning market. The institution's ability to enroll large numbers of students is enabled by the finite number of student places for teacher training at state universities. The Council on Higher Education (CHE)[vi] and Department of Higher Education and Training (DHET) expects private higher-education institutions (HEIs) in South Africa to offer inclusive 'open learning' opportunities (Department of Higher Education and Training, 2017). Thus, the institution sees this as an opportunity of justifying its enrolment targets and providing access opportunities for learning to a more diverse student population, a move appreciated by its trustees, the CHE, and taxpayers. Furthermore, providing the same teaching modules in contact learning and distance learning mode makes business sense: it caters for both students who want a 'social' campus education and those preferring to study remotely. This flexibility allows the deployment of the same lecturer to deliver content in both modes using an online learning management system (LMS), thus, further saving costs for the institution.

In summary, the CPAR I analyse in this thesis was conducted in a teacher-training institution in Durban. The campus is a multipurpose higher-education site with one large 200-seater auditorium, and seven smaller lecture rooms. One of the lecture rooms is equipped as a science laboratory and art room. There are no purpose-built computer laboratories on campus. Instead, ICT courses are delivered in general purpose classrooms equipped with single-seat exam tables and chairs.

4.5 Participant Recruitment

The main participants in the study were ICT lecturers and students in the intermediate-phase (IP) teacher-education degree programme. Participant recruitment was based on individuals' free will to participate fully, partially, or not at all – or voluntary sampling. The data produced with participants varied according to their level of involvement and engagement with specific research tools. Because some participants did not maintain the same level of engagement, the data chosen for analysis was purposefully extracted for its relevance to the research questions, or novelty. Merriam sees this purposeful "non-probabilistic sampling" as a way of gaining most from what is learned in the research process (Merriam, 2009, p. 77). Although all participation in the study was voluntary, all the lecturers who participated in the study, except the mathematics lecturer, were involved in teaching CAD on the ICT courses, and were therefore purposefully approached or requested to participate. Curwood *et al*. (2017, p.91), citing Patton (2002), suggest that the value of purposeful sampling relies on clear research questions to guide the choice of "information-rich cases for study in depth". For this thesis, individual participants are referred to by pseudonyms or identity codes (e.g., Lecturer-1, Student-1, etc.). Identity codes (Saldana, 2013) were applied to ensure anonymity and used to structure the framework analysis of findings to distinguish between lecturers and students in Cycles One and Two (Appendix 31 – Framework Analysis-Identity Coding).

As primary researcher, I began informal recruitment of ICT lecturers during the reconnaissance period in 2018, the year before the official recruitment for the research project.

I introduced ICT lecturers in my department to the potential research project during our departmental meetings in January 2018 and was open about it being for my proposed PhD studies. As the ICT lecturers were going to be involved in the CAD implementation as part of an ICTE200 module, I needed to give them experience in advance of how to teach CAD. As the head of department, I chaired an ICT course review webinar in the first semester of 2018, with lecturers from all campuses, at which inclusion of computer-aided design (CAD) in all ICT courses was proposed for the following year. To introduce CAD teaching methods, I organised a trial staff training workshop to showcase the newly purchased Techsoft 2D CAD software to lecturers. I also invited third- and fourth-year IP students to attend voluntarily with the assistance of the Student Representative Council (SRC). This was because I believed that it would be beneficial for them to experience the software before leaving the institution. Following the formal process of seeking gatekeepers' permission from the institution, and the Human Sciences Research and Ethics Committee (HSREC) from the University of KwaZulu-Natal (UKZN) in December 2018, the formal recruitment and planning stages of the 2019 action research began.

Although my department was introduced to CAD in 2018, I formally initiated the CPAR and recruited all participants to the research study in 2019. In my first departmental meeting in January 2019, I informed all mathematics, science, technology, and ICT lecturers of the impending CAD research project as my PhD study and the voluntary nature of the research activity. The formal recruitment of lecturers and students for the study took place through three activities: a focus-group meeting with Campus-1 ICT lecturers; email

communications with remote ICT lecturers; and recruitment workshop with students. These three activities took place in April 2019, prior to teaching of the CAD unit in May.

4.5.1 Lecturer recruitment

Although all participation was voluntary, all the lecturers who participated, except for one, a mathematics lecturer, were involved in teaching CAD on the ICT courses; and were therefore purposefully selected to participate. Curwood *et al*. (2017, p.91), citing Patton (2002), suggest that the value of purposeful sampling relies on clear research questions to guide the choice of "information-rich cases for study in depth". First, I invited ICT lecturers within the mathematics, science and technology department on the Durban campus to participate in the study. I focused on ICT lecturers as they were potentially going to implement CAD in the ICTE200 or CPT100 modules they taught. To establish their interest in the research project and to discuss the action-research process, I conducted informal participant reconnaissance in 'office and corridor conversations'. These preliminary conversations were vital in establishing CPAR relationships, in that participating in the research project and teaching on the module were not the same. One was a voluntary activity, while teaching CAD would be part of the ICT lecturer's regular job. These interactions helped set the scene for the formal recruitment in a focus-group meeting I invited the lecturers to in April 2019.

Lecturer participation was impacted by staff movement between campuses, and new staff recruitment for new campuses as the institution expanded its business. During 2018 and

2019, additional campuses were established in Pretoria and Greater Johannesburg in Gauteng Province, South Africa. This affected lecturer workloads and roles on the campus; and led to the recruitment of new staff, which I, as HOD, had to oversee. At the end of 2018, Lecturer-3, the module coordinator for the ICTE200 module, relocated from Campus-1 to the new campus (Campus-2) in Gauteng[vii] to become a part-time lecturer and counsellor. Lecturer-1 succeeded her as ICTE200 lecturer and module coordinator at Campus-1 in 2019. Lecturer-3's vacant position was filled by a new full-time ICT lecturer, Lecturer-5.

Following the changes of ICT module coordination roles instigated by Lecturer-3's move and Lecturer-5's appointment, in April 2019, I invited Campus-1 ICT lecturers to a focus-group meeting in the departmental meeting room. I sent consent forms by email to all ICT lecturers on the three campuses. Three ICT lecturers came to the meeting: Lecturer-1, Lecturer-5, and Lecturer-2[viii]. In the meeting, we discussed the study and the best pedagogical approaches to the teaching of CAD. I also reassured lecturers that I was researching with them collaboratively; and that they should feel free to communicate with me as an equal, not as a departmental manager. I presented the purpose, aims, research methodological approach, and proposed tools to be used for the research project. I used a whiteboard to present research questions, explain the CPAR procedure, and brainstorm lecturers' envisaged involvement in research processes (Van De Ven & Delbecq, 1971). Data recorded 'on the wall' was left as a visual reference at the campus throughout the study, the meeting room being an integral part of the department office. From this meeting, all three Campus-1 lecturers, two full-time and one part-time, agreed to participate fully throughout the study. Part-time lecturer, Lecturer-2,

offered to provide an ICT lecturer's perspective from outside the organisation. He contributed as a 'critical friend', in reviewing and testing the documentation and resources, and took part in the nominal group workshop at the end of the first cycle to assist with evaluation of the course. From this meeting, all three agreed to participate in the study: two full-time lecturers (Lecturer-1 and Lecturer-5) on the Campus-1 assisted with introducing CAD into their ICT modules (ICTE200 and CPT100); and part-time ICT lecturer Lecturer-2, who acted as a critical friend reviewing course material and trialling it himself as a new user.

Following the Durban campus meeting, I sent follow-up emails to the participating lecturers on all contact learning campuses to encourage them to participate in the study. In the follow-up emails, I again explained the purpose of the study and the online and offline data-collection processes. I wanted to enable a deeper understanding and negotiation of individual roles and contributions, and to reassure lecturers that their participation was voluntary. From this process, a further three lecturers agreed to participate in the study: two additional ICTE200 lecturers: Lecturer-3 and Lecturer-4, from Campus-2 and Campus-3 in Gauteng, who agreed to participate through an email consent process; Lecturer-6, a mathematics lecturer on Campus-1, who participated in trialling resources in 2018, and reported on his use of CAD with mathematics students.

Lecturer-3 and Lecturer-4 agreed to critique the lesson plans and CAD content, and to provide feedback on their experience of teaching CAD using the resources provided. These lecturers committed to communicate via the *WhatsApp* group and email communication. Their contributions provided some operational reflections on teaching CAD. Their survey responses

gave me data on preferred mode of delivery and pedagogical approach at two remote campuses with different facilities for teaching ICT.

In summary, various ICT lecturers were invited and agreed to contribute to different aspects of the research project. The lecturers assumed different roles in the project and in the teaching of CAD. For example, Lecturer-1, Lecturer-5, and Lecturer-2, were involved in implementing the CAD course directly as module coordinator, subject lecturer, and internal moderator, respectively, for the greater ICTE200 module. All three were involved in editing new CAD content for the LMS as part of the project. Lecturer-1, the 2019 module coordinator, assisted me in loading CAD content and in designing the online student learning experience. Finally, Lecturer-6, the mathematics lecturer, provided input on his impressions of students' learning of CAD in a different context, following his inclusion of CAD in an assignment to model geometrical nets in his elective mathematics module.

4.5.2 Student recruitment

The second phase of the recruitment process involved inviting students to participate in the study. Second-year intermediate-phase degree students were recruited from the ICTE200 cohort that would be learning CAD in the 2019 academic year on Campus-1. To facilitate this face to face, a recruitment workshop was organised in the largest lecture theatre on Campus-1. All students registered for the module at the campus were invited via the learning management

system announcements and email, using a module mailing group organised by Lecturer-1. Participating ICT lecturers were also asked to invite all 131 students to attend during regular face-to-face tutorial sessions with ICTE200 IP groups. Because the CAD course was operating for the first time in a blended online format, with optional 'open learning' tutorial opportunities with students, the face-to-face recruitment workshop was used to ensure that all students were given the opportunity to participate. Forty students of the total group of 131 attended the workshop; and 12 eventually returned consent forms. The student sample was therefore randomised within the module, as students voluntarily self-selected after attending the workshop.

To recruit the students at the workshop, I presented examples of CAD resources produced for my own teaching and staff training to show how CAD could be applied to create visual teaching aids (Appendix 5: 2D-Design Tools-Slide Presentation-Sample). The purpose of the workshop was to introduce the project and to inform potential student participants of the benefits of CAD. The workshop was also an opportunity for students and staff present to receive hard copies of the information letter outlining the research project (Appendix 6: Recruitment workshop - Outline and Form), and consent forms to complete, should they agree to participate in the project (Appendix 2: Informed Consent Letter).

The workshop used a briefing format, involving a *PowerPoint* presentation (Appendix 5) followed by an open discussion. I informed the participants about the CAD research project using an illustrated presentation. I explained the ethical issues relating to research participation and issued informed consent letters. I reminded the students of the voluntary nature of

participation, and their autonomy to opt out at any time. Students were also informed that they would be collaborating as equals with the researcher and lecturers as co-researchers. I informed students that they would be invited to join a *WhatsApp* group, respond to emails, contribute to a survey, attend an optional face-to-face interview, and that they may have their ICTE200 CAD outcomes scrutinised as part of the research project. Once student participants consented, a *WhatsApp* group was created to develop a running dialogue between participants.

I had anticipated that some students who may have wished to participate would miss the campus event. I learned from the ICT lecturers that some high-achieving students were studying online and not attending campus lectures. To provide these students who missed the campus event with an opportunity of joining the research group, the workshop recruitment event was followed up with additional email invitations sent to all ICTE200 module students. Following this process, another three students returned signed consent forms. Thus, the CAPR analysed in this involved 17 participants (n = 17), including myself as the main researcher. Thus, there were two categories of co-researcher participants in this CPAR: ICT lecturers (n = 5) and Researcher (n = 1) and ICT students (n = 11). Of the 11 students who consented to participate directly in the study, there were two male and 9 female participants.

The demographic distribution was formed organically through the voluntary participation of members of the student group. I acknowledged contributions from all, regardless of their depth of commitment to the study. Of the 17 participants recruited for the study, three ICT lecturers and four students (two male and two female) were interviewed; 10 completed the online survey. The two *WhatsApp* groups involved 17 participants (n = 17).

Additionally, Lecturer-6, a mathematics lecturer, took part in an interview to gain some additional perspective from lecturers who had attended the 2018 CAD training with me. Although not directly involved with the research, his insights into his inclusion of CAD teaching in mathematics provided useful comparisons with ICT lecturers' experience.

4.5.3 Soliciting critical friends

To ensure scholarly rigour, CPAR can include the engagement of 'critical friends' who may operate either online or offline. This encourages participation across organisational hierarchies to enable understanding of roles and subsequent action (Morse, Barrett, Mayan, Olson, & Spiers, 2002). Critical friends in the study included: 1) the managing director of the CAD suppliers; 2) Lecturer-2, a Campus-1 contract lecturer and IT graduate from the University of KwaZulu-Natal; and 3) the head of the Student Representatives Council (SRC-1). These critical friends contributed either via email or *WhatsApp* communications. This process reflects Bloom's Digital Taxonomy (Churches, 2008) in which social media assists with 21st century learning; and creates comfortable online spaces in which participants contribute freely to critical debate. All helped mediate our actions on the action-research plan and assisted in ensuring that the research was fully participatory at the various stages (Kemmis, *et al*., 2014, pp. 190-191).

The critical friends provided me with alternative perspectives at different stages of the process. For example, the UK-based manager of the CAD software had a commercial interest in the effectiveness of teaching CAD to primary-school teachers, as the software designed for

schools had not been previously sold to South African schools (Appendix 8: *2D Design* Director dialogues). The CAD software manager's support enabled the provision of software to both contact- and distance-learning students, which is ongoing. The SRC student leader assisted with communications via student *WhatsApp* groups with students for the trial in 2018 and the research project; and gave feedback on the CAD study guides as a student user. Contract lecturer, Lecturer-2, provided most editorial feedback on course content and CAD guides (Appendices 7-9 and 20-21) via email, and in his survey responses as an experienced online ICT lecturer. Lecturer-2 also attended the nominal group workshop to assist with interpretation of data.

To understand practice and practice architectures across the spectrum of experience, student participants from the Campus-1 ICTE200 module cohort were invited to collaborate as a diverse sample group. Recruitment was based on individuals' free will to participate fully, partially, or not at all – or to participate in voluntary sampling. The data produced varied according to participants' level of involvement and engagement with specific research tools. Because some did not retain the same level of engagement, data I chose for analysis was purposefully extracted for its relevance to the research questions, or novelty. Merriam sees this purposeful "non-probabilistic sampling" as a way of gaining most from what is learned in the research process (Merriam, 2009, p. 77).

4.6 Research Design

As discussed above, to address the research questions posed in this study, critical participatory action research CPAR was adopted as a methodology. In this section, critical participatory action research and its tenets are defined and justified as an approach to this study's research. This is followed by a critical description of and reflection on the CPAR intervention undertaken to: document the collaborative implementation of computer-aided design (CAD) in the intermediate-phase teacher education programme; explain what was achieved in the CPAR cycles; and reflect on what was learned from the process. The findings are presented in Chapters Five and Six.

4.6.1 Critical Participatory Action Research

This study employed a critical participatory action-research (CPAR) design. CPAR is a modern refinement of Kurt Lewin's action research (McNiff, 2005) that employs methods of enquiry designed to change social practice through the active participation of people being studied in the research process. The design emphasises the collaboration and empowerment of participants. CPAR is reflexive, requiring participants to examine and systematically discuss their practice following cycles of planning, action, observing, and reflecting, as developed by Corey and Lewin (Corey, 1949).

Participants in CPAR are actively critical in their roles in research both individually and collectively (Kemmis, McTaggart, *et al*., 2014). CPAR draws on socio-political, socio-technical, and environmental issues affecting research. CPAR employs the term *practice*

architectures (Kemmis, McTaggart, *et al*., 2014, p. 7), which involves critically interrogating practice in the various circumstances or conditions participants find themselves in. CPAR often draws on *reconnaissance* (p. 92) to understand context and system structures prior to engaging in research; and relies on the input of *critical friends* (pp.188-190) to provide support, technical input, and assistance at key stages of the research. This can involve researching and observing practice in both online and offline learning locations (Gerber *et al*., 2017, pp. 91-93).

Action research assumes that educators are more effective when they are involved in identifying the problems that face them or their classrooms and institutions, or when working collaboratively to solve those problems, and in assessing their own work (Watts, 1985, p. 185). In this study, the project explored the introduction of a new subject, CAD, to an established ICT course in a manner that encouraged collaboration with lecturers and students, explored students' pedagogical choices, and enabled critique. The critique by all informed negotiated transformation of systems both for the benefit of the group and for non-participating students. Findings were analysed to inform pedagogical approaches to teaching and learning in blended online modes, as well as in face-to-face learning events, which altered the course itself and influenced teaching and learning over multiple programmes. CPAR was valuable in an education environment in which facilities were set up for BYOD (bring your own device) learning. Timetabled ICT teaching was conducted in both large lecture theatres and smaller classrooms instead of in purpose-built computer classrooms.

4.6.2 Undertaking the intervention

This thesis analyses a CPAR project known as *Learning to use CAD and Teach with CAD Resources in the Intermediate Phase,* which aimed to understand how the use of computer-aided design in a teacher-education programme might enhance intermediate-phase student-teachers' learning, and their capacity to use CAD in developing teaching and learning support materials for their own classrooms during teaching practice. To do this, I collaborated with 12 students and five ICT lecturers who taught their students CAD in their ICT module for the first time. We undertook our CPAR in two cycles in both 2019 and 2020. The first cycle followed a blended online and offline campus-based model of teaching; and the second cycle was delivered fully online involving online collaboration between lecturers from the three campuses. Traditional research tools used to gather data are detailed in Appendices 3: Research Design, 9: Research Tools - Questionnaires and 10: Interview Schedules.

4.6.3 The curriculum-development phase

To effectively teach coding and robotics in their own classes, student teachers need to understand computer-aided design (CAD). CAD, or computer-aided drawing software, is identified as one of the design skills required in the Department of Basic Education's CAPS for coding and robotics[ix] (Department of Basic Education, 2019, p.19). As discussed in Chapter One, I had previously taught CAD for 20 years in high schools; and had expertise in developing resources for teaching the subject. Because the institution did not teach either coding and robotics or CAD in any ICT courses, in 2017, the Chief Executive Officer of the institution

asked me to develop a coding and robotics module and associated short courses for primary teachers. Between 2017 and 2018 I developed practical CAD unit content for common use in both ICT and coding and robotics courses.

I demonstrated this content in a 2018 staff training workshop as a form of illustrated CAD drawing study guide (Appendices: 7, 21 and 22). The materials included draft lecturer lesson plans, 2D and 3D drawing examples, and a step-by-step manual for teaching these examples. From the workshop I ran with the campus lecturers from my department in 2018, I developed the initial draft ICTE200 ICT course CAD resources we would later use in 2019. Early in 2019, during the planning phase of the CPAR, I shared these resources with the participants before the workshops, using the students' LMS, and by email to lecturers, to gain their input. Feedback came via email and *WhatsApp* communications. As indicated above, Lecturer-2, one of the lecturers, acted as a critical friend, and gave editorial input on the CAD study guide during this phase (Appendix 13: CAD Course-Online Guide-*2D Design* V3-Lecturer-2 edits).

From 2016 to 2018, alongside my HOD job, I was also the academic administrator of the *Moodle* learning management system (LMS) online campus. From this position, in 2018, I was able to motivate for a budget to acquire CAD software (*2D Design*) and to drive the training for staff to use the new software. When we implemented CAD, we could install the *2D Design* as standalone software on student and staff devices using a campus licence paid for by the institution. This meant that CAD could be taught in online or offline sessions to students either on campus or remotely. This flexibility of provision was negotiated with Techsoft UK

manager (Appendix 8); and enabled development of resources for a new version of ICTE200 which was to be offered in blended online mode for the first time in 2019.

The revised formal 2019 course design was filed institutionally in November 2018; and CAD was included formally in the ICTE200 course documentation for 2019 (Appendix 7: ICTE 200 Study Letter 2018-19 E1). From 2019, CAD was timetabled into the foundation phase and intermediate-phase lecture calendar (Appendix 22: Second Year timetables-2018 example). In consultation with the lecturers, I allocated two double contact periods and one single theory period per taught week to the teaching of CAD. This allowed for two 90-minute practical sessions and one 45-minute theory session per week to teach basic *2D Design* CAD skills, thus enabling students to draw simple products. As a team, we made provision for learning online by developing LMS-based study materials.

The participants contributed to the planning and development of the CAD course by participating in meetings and workshops, and by reviewing lesson plans and resources in the run-up to teaching the course. Lecturers contributed to planning by editing content, contributing to lesson plans, sequencing the activities and preparing resources taught in both face-to-face and online sessions in the focus-group meeting. Students were asked to participate in planning the course in a workshop, and to respond via email or on their *WhatsApp* group. This involved reviewing the lesson plans and sequence of activities offered via the learning management system to refine the pedagogical plan prior to learning CAD.

Attendance registers and minutes, edited CAD course documents, LMS page content and transcripts of *WhatsApp* and email dialogues provide evidence of the results of planning.

We developed a blended course which included lectures and tutorials at campus complemented by resources produced for campus-based offline or remote online study via the LMS. I assisted the ICT lecturers to action the new course as a blended online multimodal course using a choice of modes of learning: live lectures, tutorials, one-to-one sessions, slideshows, manual drawing guides and instructional videos. I tracked lecturers' and students' initial spontaneous responses to resources using *WhatsApp* groups. Students provided feedback via the *WhatsApp* group; and lecturers contributed by email throughout the research phases.

The lecturers and students collaborated with me in planning of CAD course content prior to, during and after the period of teaching and learning CAD at campus and online. During the first cycle in 2019, students followed a week-in-week-out blended contact and practical school-based teaching practice model; and reported on their experience at the time in *WhatsApp* communications and an online survey. This allowed practical skills taught in tutorials to be trialled in the following week's teaching practice should students be motivated to do so. In Cycle 1, students' learning was augmented by resources provided online via the LMS. Lecturers and students critiqued the resources, their learning experiences, and the experience of applying CAD at the time of learning which allowed re-planning. These lecturers and students also assisted in the analysis of Cycle 1 data in a nominal group workshop which set up planning for Cycle 2.

4.6.4 The collaborative research planning phase

To initiate the action-research project, in 2019, following formal institutional gatekeeper permission to locate the research on Campus-1, and the recruitment and enrolment of the participants (students and lecturers) in the study, I organised a series of meetings with staff and student workshops to collaboratively plan the implementation of the intervention. Campus-based lecturers were first briefed about the project in a meeting in April. I then organised a more detailed focus-group meeting a fortnight prior to organising a workshop for students.

4.6.4.1 The pre-planning phase

To collaboratively implement the CAD course requires some pre-planning and initial situational analysis of the practice, perceived problems, and opportunities for research in the setting, or what Kemmis and colleagues refer to as *reconnaissance* (Kemmis, 2014, p. 92). I made it clear to my colleagues in the department that I was initiating a PhD study. This was to enable the colleagues to decide whether they wanted to participate in the research aspect of the project, or whether they wanted only to contribute to curriculum development and implementation as part of their roles at the school of education. As the main researcher in the study, reconnaissance involved that I attempted to know colleagues and students better, introducing the software, and gauging interest in implementing CAD as part of the ICT course.

As discussed above, I had already introduced the idea of learning and teaching CAD to the lecturers in departmental meetings in earlier discussions about coding and robotics, and in

ICT course review meetings. In 2018, I ran two training sessions to train staff and senior students as CAD users and developed initial draft resources (Appendix 5: 2D-Design Tools-Presentation). This initial user training in the year prior to Cycle 1 of CPAR, which involved the ICT lecturers teaching CAD to novice students, prepared the way for this study. Additionally, I conducted technical and physical reconnaissance to ensure that action research was possible using the learning management system (LMS) and in desired physical locations (i.e., meeting rooms, lecture theatres and computer laboratories. Emails, meeting minutes, gatekeeper permission slideshows, CAD drawings and draft CAD course content resulted from reconnaissance). These initial activities enabled me to discuss online resources to be used in lectures; and for development of the LMS-based online learning with the lecturers and students as part of the preparation.

4.6.4.2 Planning with the participants

Planning with the participants in this study involved reviewing existing ICT course content, introducing staff and students to CAD, and discussion of the location of CAD in the curriculum in meetings and training sessions. This helped to gauge interest and develop initial draft resources to use in the project and for teaching CAD in ICT modules. These planning CPAR stages allowed me to collaboratively research with participants; in turn, these stages enabled participants to work with me as my co-researchers "who gave authentic accounts of their practice" and shared their perceptions of the socio-technical systems influencing practice "in terms of their own values and hopes" (McNiff, 2013, p. 21).

Firstly, in the staff briefing meeting, we brainstormed the best pedagogical approaches to learning to use in computer-aided design (CAD); and to applying CAD resources in schools as part of students' scheduled fortnightly teaching practice. In addition, I shared the draft guide I had developed for teaching a clock example from the 2018 staff training discussed above. I reported that Techsoft, the CAD software suppliers, were willing to provide us with access to their tutorials in PDF form as an additional guide. Together, these would give students alternative resources and methods for learning CAD skills, which I provided on the LMS system. These two resources, and the practical tutorials offered on campus, were aimed at providing students with opportunities of learning CAD using similar strategies to those the institution was using to teach Microsoft Office tools.

Following this meeting, I organised a second meeting with Campus-1 lecturers, in which I discussed the initial plan for delivery of the module with the participants; and solicited their feedback on the lesson plans and resources. At this meeting, the module coordinator and lead ICT lecturer, Lecturer-1, suggested that we develop additional instructional videos to accompany the written illustrated guides (Appendix 16). At this stage, we resolved that the best way of exploring the various pedagogical approaches was to share everything with the students at their workshop; and to use the *WhatsApp* groups for discussing the plan, revising it if necessary.

Thirdly, in the student workshop, I shared CAD drawing examples in a slideshow; and explained how students could critique the lesson plans and resources via the LMS and research *WhatsApp* group prior to the CAD unit being taught. Sharing the lecture lesson plans before

the unit was taught was unusual practice − lecturers are not obliged to produce these as part of their workload. In hindsight, given the increased importance of teaching portfolios for higher education (van Dijk *et al*., 2020), I could have utilised this activity better as a planning activity, and as part of my workload. During both the lecturer and student meetings we discussed the application of CAD, and how to develop resources for teaching practice as part of learning this content. We resolved that the best way to engage with students on their use of CAD was through their feedback in surveys and interviews.

Finally, as the main researcher in the CPAR, I was keen for the lecturers and students to provide feedback on the lesson plans and course content before the course started, so that the feedback might be able to influence the final taught course. Such an approach is not encouraged or expected at my institution. As lecturers, we are not expected to involve our students in curriculum planning or development. However, in this CPAR, and informed by critical theory, I wanted the students to be involved right from the inception of the project. For this to happen, I set up *WhatsApp* groups immediately after the student workshop. In addition, Lecturer-1 and I set up the learning management system to allow participating students early access to the CAD resources so that they could review such. I enabled students to assist with planning remotely, by encouraging their feedback through online means (e.g., via their *WhatsApp* group or via direct emails to me) (Gerber *et al*., 2016). This way, both the lecturers and students were involved in the planning of the intervention; and as described in the sections below, throughout the research process.

4.7 Data Generation

In addressing the research question: To what extent and in which ways might the use of CAD in teacher education enhance student-teachers' capacity to use ICT in developing teaching and resource materials for their classrooms ?, as discussed above, critical participatory action research (CPAR) was employed. This was specifically to generate data which addressed the two critical research questions (1) Which pedagogical approaches can best provide contextualized computer-aided design education for enhancing intermediate-phase student-teachers' learning? and 2) How might the use of CAD help intermediate-phase student teachers to effectively integrate ICT in developing teaching and learning support materials for their teaching practice?), we considered our collaborative course design, teaching, and learning of CAD on campus and in the blended online mode, involving the student teachers, the participating lecturers, and myself as discipline leader and researcher in the study (Semester 1: 2019 & 2020). In addressing the second question, we analysed the students' reports and observations, and use of CAD resources for teaching practice. Together, I posed these two sub-questions to map students' and lecturers' experiences of learning, teaching, and applying CAD in their teaching contexts. For the lecturers, my aim was to observe and document their action and feedback on the action; and to ask them to document their own teaching in ICT modules. For the student participants, our aim was to observe and document their teaching during the teaching practice period in primary schools in Semester 2 in 2019, and again in Semester 2, 2020.

Aligned with the critical paradigm, in both years of the module, I deliberately provided some flexibility in the mode of learning and resources for learning; and worked with the students and lecturers as co-researchers to explore the pedagogical routes they most favoured for developing CAD resources for teaching practice in their own teaching. I used the workshop process to prepare the participants for the action-research project, creating "public spheres" (Kemmis, 2014, p. 37), or action-research spaces which were "inclusive, self-constituted, voluntary and autonomous" (pp. 37-40). For me, this meant inviting participants to attend voluntarily, locating the recruitment workshop conveniently in the campus auditorium, and encouraging the students and ICT lecturers to discuss the project together in an informal manner. I tried to stimulate "communicative action and public discourse" (p. 40), by encouraging the participants to communicate freely (pp. 42-43), in addressing a "legitimate deficit" (p. 39) or research problem.

To encourage socially situated democratic critique (Schatzki, 2002; Kemmis *et al*., 2013), and to provide participants with an authentic sense of understanding of their learning environments, and the opportunity to "evolve in their [teaching] practice" (Kemmis *et al*., 2014, p.19), I encouraged the participants to collaborate meaningfully in co-designing and critiquing the multimodal pedagogical approaches to learning provided, and applying CAD in teaching practice settings on campus and in schools. The CPAR project was implemented in two cycles, with Cycle 1 taking place in 2019, and Cycle 2 in 2020.

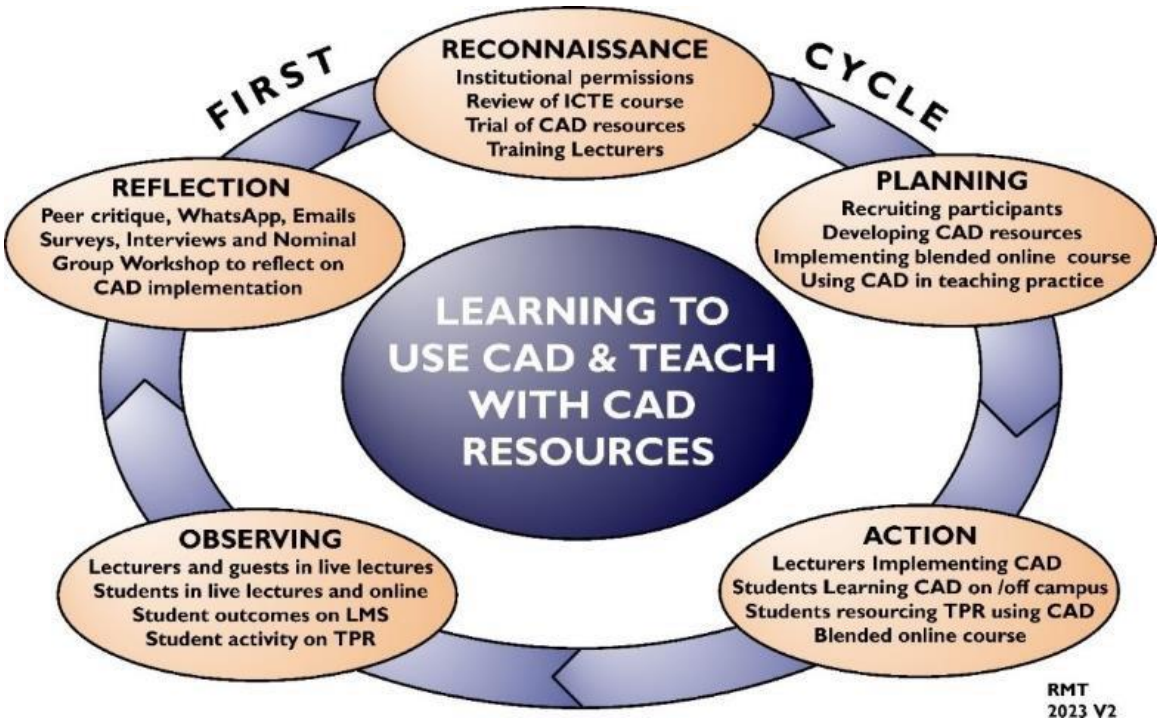
4.7.1 Cycle 1: Learning to use computer-aided design

To implement the CPAR intervention, which I have called *Learning to use CAD and to teach with CAD resources*, as discussed above, I recruited intermediate-phase student teachers from our existing ICT course (ICTE200). The intervention took the form of CPAR, following two cycles in 2019 and 2020. In 2019 we undertook Cycle 1 of the intervention in Semester 1. This involved two main activities: 1) The participants (student teachers, lecturers) learning CAD as a new topic in their ICT module; 2) The participants (student teachers, lecturers, and me) collaborating in developing resources for teaching, using CAD skills taught in lectures and tutorials, as well as online via the LMS.

While the lecturers used the resources in their ICT courses, the students were expected to use these resources in their teaching practice sessions in Semester 2 in their assigned schools. Figure 4.1 illustrates the stages of the first cycle:

Figure 4.1

CPAR Cycle 1: Learning to Use Computer-Aided Design



Cycle 1 of *Learning to use CAD* took place in five stages: reconnaissance, planning, action, observing and evaluation. Stage 1 of this cycle involved *reconnaissance and planning* (discussed above and in section 4.6.1.1 below). Stage 2 of the cycle involved *action* (the intervention), in which we (the students, staff and I) learned computer-aided design (CAD) as a subject, how to develop classroom resources using CAD, and how to use these to improve our teaching in our own classrooms. Stage 3 involved *observation* of the action during learning

and application. In this stage, the lecturers and I were to observe the student teachers implementing what they had learned in their own classrooms during their teaching practice. In Stage 4, we *reflected* together as a group on learning CAD using various modes of learning and resources and applying CAD skills to produce resources.

Stage 1: Planning

Stage 1 of the cycle involved two planning phases: reconnaissance and planning (described above). The post-reconnaissance planning stage involved refinement of the initial plan − to teach with face-to-face lectures and online study guides as a form of blended online learning. This followed lecturer feedback in informal office meetings; and feedback from the student recruitment workshop provided via *WhatsApp*. This additional planning was needed to schedule the development of additional CAD resources specifically for the ICTE200 course; and for setting up participating student access to learning management system (LMS) resources in a way which enabled them to see all resources in advance. Two specific changes to the plan were implemented during this additional planning: 1) at the students' request, a students-only *WhatsApp* group was established to allow direct communication with me; and 2) Lecturer-1's suggestion that we produce instructional videos to expand pedagogical choice meant that additional planning was required to produce the videos, trialling these with students on the LMS (Appendix 16). This additional planning involved face-to-face discussions with lecturers − Lecturer-1 and Lecturer-5 − in the staff office. I explained changes to remote lecturers, Lecturer-2, Lecturer-3, and Lecturer-4, via email. I informed students via their *WhatsApp* group

of adjustments to the plan. All participants were asked to comment and provide suggestions via the *WhatsApp* groups. Lecturer and student contributions mostly informed the presentation of the resources on the LMS.

Stage 2: Action

The action phase in the *Learning to use CAD* project involved four activities with and by the participants: 1) the construction of the online course on the learning management system (LMS); 2) the delivery of the blended online course by lecturers using live lectures and tutorials, and online resources; 3) students' learning of CAD using a multimodal approach; and 4) students' application of CAD during teaching practice. Data used to evidence these stages included: online LMS course content (Appendix 14: CAD Course-Online Guide-*2D Design* V3); additional instructional video CAD resources **(**Appendix 16: *2D Design* Instructional Video Planning and Play List); CAD lesson plans (Appendix 15: CAD Lesson Plans 1-3); lecturers' and students' feedback from registers (Appendix 17: Student Attendance-5 Face-to-Face sessions); and *WhatsApp* and email dialogues shared after taught sessions (Appendix 19: Participant-Dialogues-Email-*WhatsApp*).

In this cycle, Cycle 1, I supported the participating lecturers on Campus-1 by co-teaching in face-to-face tutorials as a guest lecturer in their CAD units. I also worked with Lecturer-1 and Lecturer-5 in face-to-face sessions to assist and encourage the students to develop CAD resources that would be contextually relevant to their teaching practice contexts. To illustrate this, we used the introductory slides, contextual sections of the study guide, and

additional drawn examples that I had produced, or that lecturers had produced in their training in 2018. The examples were aimed at showing that CAD could be used for illustrating any subject and work as a design tool for technology subjects.

To demonstrate their use of CAD, the students developed their own resources for teaching in primary schools during CAD tutorials at campus and teaching practice. Students were provided choice in how they learned CAD. Initially, students produced an analogue clock drawing using Techsoft *2D Design* CAD software following step-by-step instruction provided in tutorial sessions (Appendix 17), or via a study guide and videos provided on the LMS. Students could opt to study off campus online, or on campus. As an extension activity, the students were encouraged to draw original designs using the same CAD drawing tools. As part of their assessment, students availed themselves of an online *Moodle* peer assessment tool known as *Workshop* (Appendix 20: ICTE200-Assessment-Results-By-Module- Campus-1), which Lecturer-1 suggested students use to critique one another's drawings, alongside traditional portfolio submissions marked by lecturers. This activity reinforced theory learning and enabled students to see one another's work online, thus comparing the quality and originality of their outcomes with peers' and lecturers' assessments.

In Cycle One (2019), each campus had a contact learning ICT lecturer allocated to teach CAD as part of the ICTE200 computing modules. Each lecturer used the same written or video guides we had developed, to teach students in live tutorials using a laptop, data projector, and screen. I was not the lead lecturer. Instead, I first co-taught with Lecturer-5 in live tutorials as

he had not attended initial training in 2018. Because students responded well to this, I offered to assist the other more experienced ICT lecturer, Lecturer-1, in his CAD sessions, seeing that he admitted to a lack of confidence in his CAD skills.

This team-teaching activity led to the development of additional resources for use in the module in 2020, in that I was able to introduce new examples which were not in the guide. Following our teaching of CAD in Semester 1, Semester 2 involved learning Microsoft Office skills, and developing an assessment portfolio which included contextualised CAD drawing activities. The students were asked to use CAD to draw a resource which included an illustration of school activities, in a *PowerPoint* presentation for their portfolio. Because the CAD guide provided suggestions for alternative ways of designing clocks using different methods, some students produced two different versions.

Obtaining data in the action phase from online and offline sources matched the multimodal blended online learning which students experienced, in that they were able both to attend contact lectures and tutorials and to study online, using resources and instructional videos on the LMS. The variety of data sources included formal documentation of lessons taught and reports from participants via emails, *WhatsApp*, online surveys, and interview comments (Appendix 30: Framework Matrix-Multiple sources-Sortable by Theme-Category-Item). These aided with triangulation (Gerber *et al.*, 2016, pp. 85-86) and exposed the entangled nature of blended online study experiences in offline and online spaces using a variety of technologies (Fawns, 2022).

To assess whether the student teachers had learned to apply what we had taught them on campus, I had encouraged participating lecturers to monitor their use of CAD resources during teaching practice in Semester 2 (Appendix 14 and 19). In turn, the students were asked in surveys and interviews to document and report their own use of CAD (Appendix 30). Because the participants in the CPAR project self-selected into the research project, teaching practice observations could not be set up in advance with the teaching practice department to observe specific students' CAD use in schools. Formal teaching practice observations only take place once a term; it was not possible to fit these assessments around the weeks when students were learning CAD. Instead, participating lecturers and students were asked to observe and report on the use of CAD resources as part of the action and observation stages.

In their interviews, I asked the lecturers to comment on their observations of CAD use on their school visits during teaching practice. Because they were allocated teaching practice students across all year groups, including those who were not participating in the project but were nevertheless learning CAD, lecturers could only expect to see three or four second-year students conducting the ICTE200 module each year. This limited the number of students lecturers could observe from the taught group to one or two.

During the first cycle in 2019, students followed a week-in-week-out blended contact and practical school-based teaching-practice model. The participating students reported on their experience in *WhatsApp* communications and an online survey. This allowed us to encourage the student teachers to test the CAD skills taught in lectures on campus in their teaching practice classrooms the following week. In Cycle 1, students' learning was augmented

by resources provided online via the LMS. As discussed above, the participants critiqued their experiences and practice of learning and applying CAD in post-course interviews. A smaller group assisted me in the analysis of Cycle 1 data (This is discussed later in the chapter).

Stage 3: Observing

The observation phase in Cycle 1 involved face-to-face sessions with students, together with online observation as students engaged in live campus tutorials, online learning, and teaching practice. Observation of lecturers' teaching and student learning in face-to-face sessions was achieved using an observation protocol (Appendix 9d) with researcher notes and sketches recorded in a research journal. A record was kept to track attendance of the research group against the total group (Appendix 17). Lecturers also gave feedback from their observations in direct conversations and email communications (Appendix 19). Students recorded their observations on the tutorials on the *WhatsApp* group (Appendix 19). Sketches were used to note room set-up, lecturer positioning in venue, student distribution in the room, and other technical features which might influence the teaching of CAD. These sketches were later refined using CAD to support findings with visual depictions of teaching and learning modes (Appendix 34).

As the main researcher in this CPAR, I first observed the lecturers and students teaching and learning in face-to-face tutorials. I was able to assist with initial introduction and demonstration of CAD co-teaching with groups managed by both Lecturer-1 and Lecturer-2; and was then able to observe these lecturers repeating this in the second session as revision. I

also observed students' online activity on the learning management system (LMS) using participation data to assess which pedagogical approaches were most effective for learning CAD.

The observations in CAD tutorials took place offline through co-teaching with lecturers on campus. Specifically, I observed what students were doing during the tutorial sessions at different stages of the sessions. I observed: 1) whether students were attentive during introduction and demonstration; 2) whether students were able to complete the drawing using the demonstrated method; 3) whether students relied on the lecturer demonstration only, or used the online guide; and, finally, 4) whether students sought additional assistance during the sessions.

In sessions when Lecturer-1 and Lecturer-2 were demonstrating, I also toured the room and looked at the students' personal devices, observing whether and how they used their devices for developing CAD resources, In addition, I scrutinised the co-teaching lecturers' reports to gauge whether they believed that students in their classes were able to follow the taught examples and to develop and draw their own resources. In sessions in which I was leading the tutorials, I asked the lecturer to walk around the classroom and to provide me with feedback on what he or she observed (Appendix 19). Students were asked to report on their own observations of additional tutorial sessions via the *WhatsApp* group.

Furthermore, CAD drawings completed on the course, which were submitted on the LMS for peer and lecturer assessment, were downloaded and viewed. Our aim was to assess students' ability to create resources using CAD, and to track the performance of those

participating in the CPAR against the whole ICTE200 year cohort. In the *WhatsApp* communications, students were asked to report on what they had drawn as resources, and for what type of lesson. They were asked how they planned to use their learning in their own classrooms during teaching practice and when they become practising teachers after graduation. Observations were followed up with questions about students' experience of learning in the post-course survey and face-to-face interviews discussed in the reflection stage.

Research journal entries were used to record observation notes, and sketch diagrams to record technical set-up of classrooms, and modes of teaching employed. These enabled reflection on the participants' (and my own) experiences in implementing CAD; recording of my observations of their learning; and understanding how technical set-up of spaces for teaching CAD might influence pedagogy (Petrina, 2003). The CAD course was taught every second week over three weeks during May 2019. Students had the opportunity of applying their skills at fortnightly teaching practice school placements after learning CAD on campus, if they were motivated to do so and if schools permitted this.

Secondly, the participating lecturers on all campuses reported their observations of their own teaching and their students' learning, via *WhatsApp* and email reports (Appendix 19). Additionally, the lecturers observed students from the ICTE200 module during their allocated teaching practice visits and reported this in emails and interviews. Lecturers reported their observations in emails and were later questioned in more detail about their experience in schools during interviews at the end of the CAD unit teaching period.

Thirdly, I asked the student participants to document and report their use of CAD during teaching practice via *WhatsApp* if they did not have scheduled lecturer assessments. In addition, survey responses collected immediately after the CAD unit was taught in May 2019, also gave me early indication of students' application of their skills (Appendix 26: *2D Design* CAD Survey – ICTE200 Students – 2019 (Research group sample) and Appendix 27: *2D Design* Computer-aided design Survey - ICT Staff - 2019 (Five staff responses)). These responses triangulated reported observations and helped me to refine questions about teaching practice which I later used in face-to-face interviews. The surveys were open for lecturers and students to complete from the beginning of the module until the end of the CAD unit, to gather feedback in 'real time'. Participants responded to slightly different questionnaires to account for their differing roles (Appendices 26 and 27).

Stage 4: Reflection

In Stage 4, we, the participants in the project: *Learning to Apply and Teach CAD*, reflected on the CPAR research design and the intervention in general, what worked and what did not work, what we learned from it, and how we might adapt the design for a possible second cycle. As discussed earlier, throughout the implementation stage, we had exchanged *WhatsApp* and email messages in which people could raise issues of concern and provide feedback. In addition, I emailed an online survey which I sent to all participants to complete (Appendices 26 and 27). Using these, we reflected on the successes and pitfalls relating to the multimodal CAD teaching pedagogy; and the students' attempts to implement their learning in teaching practice. I

conducted semi-structured interviews with students and lecturers after the CAD unit teaching had been completed. I interviewed lecturers in the first weeks of June after completion of the first semester and students after their semester break at the end of July 2019. I worded interview schedules slightly differently for lecturers and students to account for their differing roles in the action (Appendix 10: Interview Schedules), building on questions asked in the surveys and issues raised in *WhatsApp* and email dialogues during the implementation stage. The interviews were recorded transcribed verbatim, and the transcripts were shared with interviewees by email for member checking (Appendix 23: Member Checking). I realised that sharing the freshly processed data was essential in acknowledging and valuing participants as "maximal participant recognition" (Kemmis, 2014, p113).

As soon as CAD teaching started on campus, I asked students to reflect on their learning by means of the *WhatsApp* groups and emails. Students' and lecturers' reflections on the course, and application of CAD skills in schools, came from their critical appraisal of their teaching and learning journey in lectures and tutorials and on *WhatsApp* groups (Appendix 30: Framework Matrix-Multiple Sources-Sortable by Theme-Category-Item). The participants also critiqued their experiences of learning and using CAD per online tools provided on *Moodle* LMS in an online peer assessment activity. Participants suggested improvements to the course via *WhatsApp,* online surveys, and face-to-face interviews, after learning CAD. As an HOD, I was also able to view the module results to reflect on student outcomes; and as a researcher, I analysed the CAD resources they had developed and their portfolio work, using their participation and mark-book analytics alongside qualitative report data shared by the module

coordinator (Appendix 24: Student Usage Statistics for ICTE200 LMS Page used at MC Meeting – 18/10/2019). This enabled me to check students' engagement with CAD alongside the other content in the module.

From student and lecturer feedback in surveys and interviews, as a group of lecturers and student teachers participating in the intervention, following Cycle 1 of the project, we realised that teaching with a wider range of CAD examples, adding to those already developed, would improve students' learning in 2020. In addition, the end of semester ICT meeting revealed that the use of the *Moodle* 'Workshop' peer-assessment tool had proved to be valuable; however, the number of students allocated to each peer needed to be better managed. Finally, Lecturer-5 suggested that CAD questions be developed to allow summative testing of CAD theory in the module's theory quizzes. As the pedagogy was not finalised in 2019, I drafted a CAD quiz for the second cycle which Lecturer-5 and Lecturer-2 reviewed (Appendix 36: CAD Quiz Question bank for online course).

Our preliminary analysis of the data from Cycle 1 suggested that some students had applied their CAD knowledge in developing classroom resources, while others had not. Because I wanted to see how students would use their new knowledge with more fluency, we had not requested that students use their CAD skills for specific lessons in school. Viewing the students' results achieved in Cycle 1, and the feedback from surveys and interviews, we agreed that the first cycle had been mostly successful. Our addition of in-house videos and drawing guides enabled more student choice in learning to use CAD. However, there were still

improvements to be made in assessing students' application of CAD for various teaching contexts. For example, if students were eventually going to teach CAD in primary schools, they needed to develop resources which related to teaching practice lesson timetables. Ideally, we wanted to see students designing CAD to illustrate lessons in all subjects taught during teaching practice, thus demonstrating its versatility as a multidisciplinary tool.

The results from Cycle 1 also showed that the addition of extra contextualised CAD teaching examples: better measures for controlling peer assessment allocations, and the inclusion of CAD theory quiz material in lectures and online tests, may have helped to improve student understanding and application of CAD content. An improved system for monitoring students' actual application of CAD in teaching practice weeks was proposed for Cycle 2 which required participating lecturers to instruct students to draw a CAD resource for assessed lessons observed during school visits in the teaching practice programme. The former suggestions relating to improvements to teaching materials and assessment were implemented, while changes to observation in schools were not possible due to Covid-19 lockdown. This is further elaborated on in the next section.

4.7.2 Cycle 2: Learning to use CAD through online mode

In 2020, due to the COVID-19 pandemic, in line with all higher-education institutions in South Africa, the institution moved all second-year modules to blended online teaching and learning platforms; and replaced campus lectures with online webinars. Lecturers from

different campuses co-taught CAD via online live webinars. Similarly, teaching practice was curtailed during this period due to government lockdown of schools. While other modules struggled to quickly develop online resources for transitioning to this new mode, for ICTE200, this was not the case, because the resources we had were more advanced than other modules offered in the institution: we had deliberately initiated this a year earlier. Similarly, the second cycle of the CPAR intervention with the ICT module was taught at the same time in the academic calendar as in 2019; however, all CAD learning was delivered online through webinars, and improved resources provided via the online learning management system (LMS). Because we had collaborated in developing a more online course for the 2019 course design, we were better equipped than other departments for the emergency transition to fully online learning (Singh *et al*., 2020). We were not as well equipped for the transition to working from home, which disrupted workplace interactions, and forced a more formal online meeting approach using *Zoom* meeting technology. This reduced our work social life and affected staff energy and morale.

Furthermore, while the teaching of the ICTE100 course was noticeably different during 2020 because students did not attend campus for lectures or tutorials during the period CAD was scheduled, a positive development was that staff from the various campuses were scheduled to share webinars. This meant that my support of Campus-1 lecturers in 2019 could be modelled in a different manner online. Even though I did not teach the CAD course in 2020, Campus-1 lecturers now provided similar support to remote campus lecturers who were not able to work with me in the face-to-face tutorials in 2019.

Lecturing roles did not change on campuses except that Lecturer-5 took over from Lecturer-1 as module coordinator. This enabled us to implement some of the changes we had developed through co-teaching in 2019, for example, the addition of the online CAD quiz on the LMS, and the additional drawing examples to complement the analogue clock. In an online meeting with ICT lecturers, I suggested that we use the student survey and qualitative feedback on the module delivery during Covid-19 lockdown to assess whether changes to 2019 CAD teaching had influenced the students' learning and application of CAD.

At the end of Cycle 1, we accessed additional resources in the form of examples and multiple-choice online assessment to broaden choice in pedagogical approach. These changes came from students' and lecturers' suggestions that more examples would assist in contextualising CAD in the primary-school setting. In addition, the peer assessment settings on the LMS were refined to restrict the numbers students had to peer assess. This emerged from student interview feedback on the limitations of the online *Workshop* peer assessment activity.

In 2019, students could opt out of campus tutorials and complete their CAD drawing unit remotely using the online resources and instructional videos. In 2020, online webinars were not compulsory, and students could still opt to learn CAD independently with improved resources. This meant that students still had choice in how they learned CAD albeit in an online space. The institution created YouTube recordings of webinars so that students who missed live webinars could watch recordings at their leisure. This was an innovation that resulted from the pandemic response. Although they had recordings, student attendance at the ICTE200

webinars was good (Appendix 25: ICTE200 Module Report 2020). Students reported that they enjoyed the good-humoured banter between the lecturers in the webinars; and they also enjoyed the novelty of *Zoom* meetings at which they could contribute live in the lecture and ask questions in the chat (Appendix 28: ICTE200- CL Student module feedback Post-Covid 2020). This could also be attributed to that some of the same group of student participants we had in 2019 were repeating the module in 2020. Because students did not attend campus in 2020, I did not recruit new students into the study.

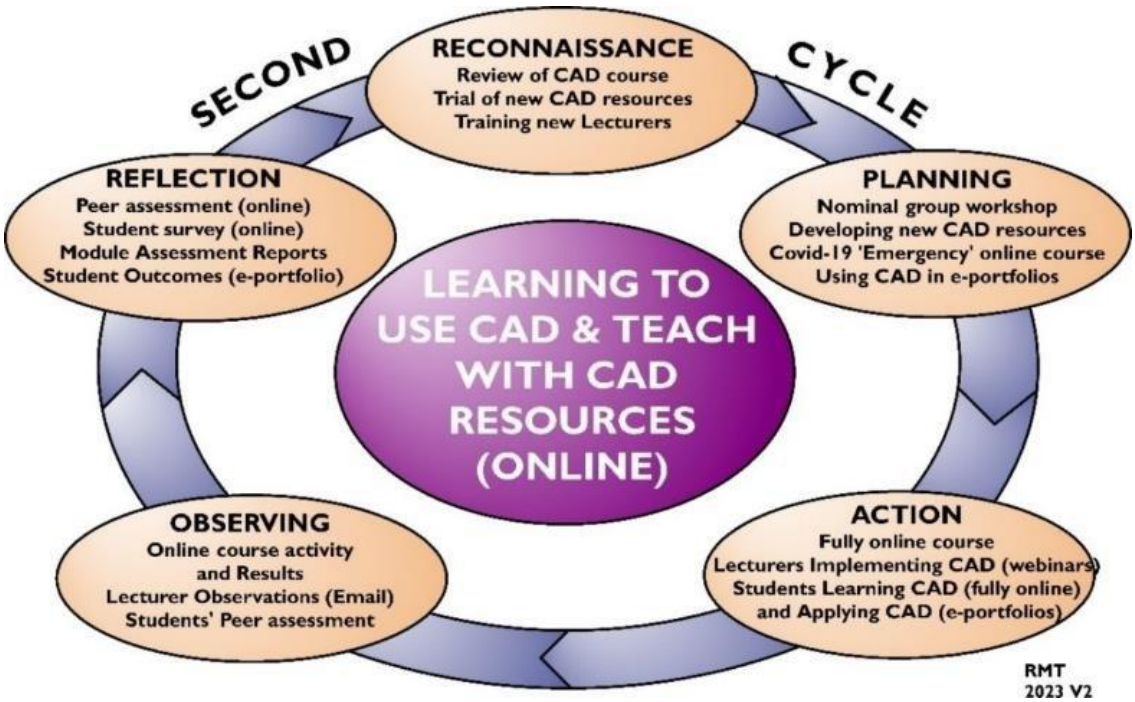
To address students' use of CAD resources in teaching practice, we encouraged direct use of practise-drawing examples taught at campus as resources to be used in teaching practice. This was achieved through more explicit mention of the purpose of the drawings in the revised teaching guides. Staff were also requested to stress this in their webinars. Because teaching practice was curtailed, we relied again on students' reporting the use of CAD in their survey. Evidence of drawing of CAD resources was presented by students in e-portfolios submitted at the end of the module in November 2020. These combined students' original CAD work combined with Microsoft Office activities produced throughout the year.

The second cycle of the critical participatory action research (CPAR) was planned to develop on the first cycle with improvements to CAD unit content and assessment agreed in 2019 meetings and interviews with participants after CAD was taught in the first cycle. These included: provision of more taught examples relevant for primary-school use; improved online peer assessment set-up on the LMS; and provision of theory quiz questions to assess

understanding of CAD contextually. We agreed to provide students with further choice in how they learn using a range of non-compulsory resources and drawing examples (Appendix 35: CAD Lesson Plan 4 - Dice activity). The unexpected disruption caused by the Covid-19 pandemic led to the second cycle being delivered in a different form with no face-to-face lectures or student teaching practice in schools. Figure 4.2 summarises the second CPAR cycle.

Figure 4.2

CPAR Cycle 2: Learning to Use CAD Through Online Mode



Stage 1: Planning:

Stage 1 of Cycle 2 involved revising our research and intervention plan. The pre-planning took place with the remaining 2019 participants (both lecturers and students). The second cycle planning and implementation of CAD involved analysis of student results (Appendix 20: ICTE200-Assessment-Results-By-Module- Campus-1); analysis of first-cycle findings in a nominal group workshop (Appendix: Nominal Group Workshop); re-planning using first-cycle themes; improving online resources for a new student cohort, and analysing 2019 student survey results for comparison with Cycle 1. The end of the first academic year of CAD implementation allowed time for reflection from Cycle 1 and planning of Cycle 2 (Appendix 29: Planning-Online Survey-Cycle 2-Dec 2019). The operational changes to peer assessment tools and addition of extra drawing and test resources were first suggested in the lecturers' meetings. The nominal group workshop drew on the positive aspects of the multimodal pedagogical approach in Cycle 1; however, participants stressed the need for CAD to be explained and justified further as a primary-school resource through better teaching of context.

Stage 2: Action:

Stage 2 of Cycle 2 of the CPAR involved *action*. During this cycle, the Covid-19 pandemic conditions disabled face-to-face collaboration opportunities during the action stage. Lecturers from the three campuses co-taught via *Zoom* online via live recorded webinars. In addition, the students in the module accessed the resources I had co-produced with lecturers in 2019,

including online guides and videos. As noted above, in 2020, I was not a lecturer in the CAD module, only occasionally guest-lecturing when requested by one of the lecturers. Evidence of the webinar interactions came from student surveys completed at the end of the module (Appendix 28). To document students' favoured modes of learning and the experiences of learning CAD remotely and online and living under Covid-19 lockdown, we relied on surveys completed by all participating students. We could thus assess the students' perceived ability to apply CAD to create resources for specific school subjects. Because students were unable to attend school teaching practice, they instead were asked to develop CAD resources in their ICTE200 e-portfolios introduced as an emergency measure by the teaching practice department to compensate for lost time in schools.

Stage 3: Observation:

Similarly, in Stage 3, *observation*, I relied on self-reported data from students, and on the lecturer's reports of performance in their courses, rather than observing students learning on campus or in schools in real time during teaching practice. As with everybody in the country, I was confined to working from home: it was not possible to observe students interacting with lecturers in CAD lessons on campus, or to engage in face-to-face interviews. Instead, I utilised lecturers' reports of their online co-teaching of CAD in webinars; observation of student results from the learning management system (LMS); student feedback via an online survey (Appendix 28: ICTE200-CL Student module feedback post-Covid 2020); and lecturer feedback in emails and module assessment reports (Appendix 25: ICTE200CL MC Report All Campuses

2020 Cycle 2). The student feedback from sixty-five anonymous students in the ICTE200 module online survey turned out to be invaluable. This data is presented in a framework in Appendix 30 and illustrated in Figure 4.3. The student participants, working from home during the 2020 lockdown period when CAD was taught, gave detailed feedback on their learning via the student survey at the end of the course.

Stage 4: Reflection

During Stage 4, reflection relied on interactions with the participants via email, *WhatsApp* groups, online surveys, and documented reporting from the learning management system. Because it was not possible to recruit a new group of students to collaborate with face-to-face in further redesign of the course, I utilised feedback from the 2020 student survey, e-portfolio outcomes, and lecturers' formal and informal reports to gain insight into 2020 students' learning and application of CAD in developing or improving the CAD teaching resources (Appendix 30). Reflections from Cycle 2 were based on survey questions such as those used in Cycle 1; the missing elements were campus interactions and lecturer and student interviews. Collaborating lecturers provided valuable reflections in emails and module reports. For example, Lecturer-5 produced additional details in his module assessment report (Appendix 25), as module coordinator for ICTE200, detailing his journey using live co-teaching webinars; and reflecting on the success of students studying remotely online using resources we redeveloped in Cycle 1. Some 2019 students repeated the module in 2020 due to failing it in

2019. Their reflections reveal how their repeating of the module was influenced by studying fully online with webinar support.

Student and lecturer feedback came through online surveys and module assessment reports. Students' applied CAD use was observed and assessed in second semester e-portfolios. In the second cycle an additional online test assessed theoretical and contextual understanding of CAD. In both cycles, students developed CAD resources (e.g., clock, dice net, geometric shapes) for teaching in primary schools; and used an online peer-assessment tool to critique one another's drawing work alongside portfolio marking by lecturers. This activity enabled students to see one another's work online; and to compare the quality and originality of their outcomes with peers. Aligned with the CPAR research design, the participants in this study were involved in planning and designing activities; learning and applying CAD; critique of resources, outcomes and chosen modes of learning; reflecting on their experiences and planning the activities to improve future iterations of the course. I acted as a co-researcher, facilitator, and participant observer in the action. Data was generated in initial reconnaissance, planning, action, observation, and reflection stages in Cycle 1. In Cycle 2, Cycle 1 reflection stages acted as the catalyst for planning the second cycle course activities; and assisted in refining data codebooks for analysis of the action research. Data on action, observation, and reflection stages of Cycle Two came from lecturers' email reports, student surveys, and module reports. The sources of data used are detailed further with reference to specific research questions in Appendix 3: Research Design Tables-Research Question and 2 Critical Questions.

The final stage of the study included both planned and unplanned action, caused by the Covid-19 pandemic, which spanned the end of 2019 and 2020. This was to be expected in CPAR, where humans coexist in the action (Zuber-Skerritt, 1992) and plans change according to realities on the ground. In 2019, development of CAD resources for the ICTE module lecturers and student participants' reports of CAD use on teacher-training practice in schools were planned. In 2019, my diversification of CAD resource development for PGCE modules and lecturer development of CAD resources for other ICT modules were unplanned. In 2020, while student feedback from ICTE200 module was conducted via an online survey and portfolio submissions, and lecturer feedback was given in module outcomes reports, co-teaching in online webinars was unplanned. Thus, the COVID-19 restrictions forced us to transition to understanding of the teaching and learning of CAD as a planned blended online course; and, subsequently, as a fully online course (U. Singh *et al*., 2020a).

4.8 Data Analysis

Action research does not generally start with a prescriptive theory, or clear scientific hypothesis (Kemmis *et al*., 2014). Rather, due to its unpredictability, action research maps a journey of learning and discovery, and often lends itself to a grounded approach to data analysis (Mertler, 2016). As discussed in Chapter One and above, this study addressed two critical questions:

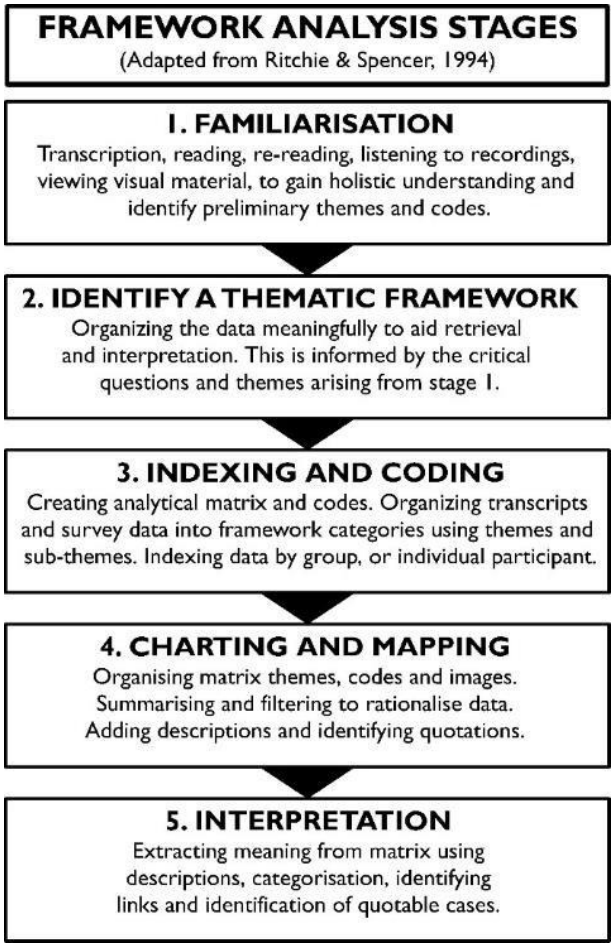
1. Which pedagogical approaches can best provide contextualized computer-aided design (CAD) education for enhancing intermediate-phase student-teachers' learning?

2. How might the use of CAD help intermediate-phase student teachers to effectively integrate ICT into developing teaching and learning support materials for their teaching practice?

To analyse data generated to address these questions in the CPAR project, *Learning to Teach CAD*, I used the *framework analysis approach* originally advanced by Jane Ritchie and Liz Spencer (Ritchie & Spencer, 1994) as an inductive form of content analysis. The approach follows five systematic steps: 1) familiarisation; 2) identification of a thematic framework; 3) indexing (or coding); 4) charting, and mapping; and 5) interpretation. These stages are illustrated in the diagram below adapted from the stages of framework analysis set out by Ritchie and Spencer (1994) in Figure 4.3.

Figure 4.3

Framework Analysis Stages (Adapted from Ritchie and Spencer, 1994)



4.8.1 Familiarisation

Step 1 involved familarisation with the data co-generated with participants. This involved organising and uploading *WhatsApp* transcripts, emails, interview recordings, student CAD drawings, reports and related journal texts into folders in NVivo 12 to sort data by its source. Familiarisation involved reading all survey response texts line-by-line, transcribed interview recordings verbatim. Identity coding was applied to protect participants' anonymity (Saldaña, 2013), and label coding to identify source, time, and location (if necessary). I added supporting descriptions (De Lange *et al*., 2012) to identify datasets by initial themes related to research questions. Initial *NVivo 12* qualitative data management software coding of data was applied to group data from multiple sources under the two research questions and sub-questions. Students' visual CAD examples were organised by student identity code. Additional reports and results documents were coded by title, content, source, date and author.

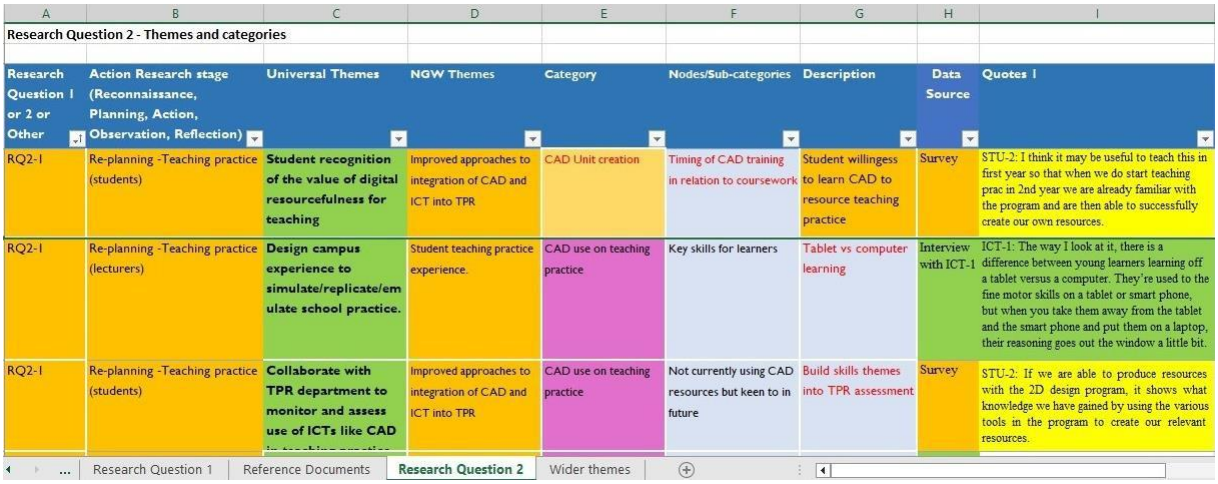
4.8.2 Identification of a thematic framework

In the Step 2, a thematic framework for analysis based on the main research questions and initial themes was identified, which emerged from *WhatsApp* communications and survey responses from participants. This started with reimmersion in the data to assist with descriptive and semantic coding of nodes of data filed in *NVivo 12*. This enabled organisation, mapping, and filtering the data to assist with interpretation. This systematic data management provided me with a transparent audit trail for member checking at the time and enabled me to re-engage with the data in subsequent data-analysis activities. I initially built a matrix in *NVivo 12* using

data links and nodes to categorise transcript quotations under research questions, survey, and interview questions, along with socio-technical systems themes which emerged from these tools. This process generated codebooks which created the structure for the main framework analysis matrix (Appendix 30: Framework Matrix-Multiple Sources). Figure 4.4 shows samples from the framework analysis matrix I developed from NVivo 12 codebooks and transferred into Excel spreadsheet format for ease of editing and dissemination. The main matrix (partially illustrated in Figure 4.4) was derived from multiple sources and is filterable by data source as well as by research question, theme, and sub-theme. The sortable columns enabled further linking of themes and cases, assisted with triangulation, and aided interpretation.

Figure 4.4

Extract from Framework Matrix showing a Sample of Themes relating to Research Question 2, Sub-theme 1.



A	B	C	D	E	F	G	H	I
Research Question 2 - Themes and categories								
Research Question 1 or 2 or Other	Action Research stage (Reconnaissance, Planning, Action, Observation, Reflection)	Universal Themes	NGW Themes	Category	Nodes/Sub-categories	Description	Data Source	Quotes 1
RQ2-1	Re-planning -Teaching practice (students)	Student recognition of the value of digital resourcefulness for teaching	Improved approaches to integration of CAD and ICT into TPR	CAD Unit creation	Timing of CAD training in relation to coursework	Student willingess to learn CAD to resource teaching practice	Survey	STU-2: I think it may be useful to teach this in first year so that when we do start teaching prac in 2nd year we are already familiar with the program and are then able to successfully create our own resources.
RQ2-1	Re-planning -Teaching practice (lecturers)	Design campus experience to simulate/replicate/emulate school practice.	Student teaching practice experience.	CAD use on teaching practice	Key skills for learners	Tablet vs computer learning	Interview with ICT-1	ICT-1: The way I look at it, there is a difference between young learners learning off a tablet versus a computer. They're used to the fine motor skills on a tablet or smart phone, but when you take them away from the tablet and the smart phone and put them on a laptop, their reasoning goes out the window a little bit.
RQ2-1	Re-planning -Teaching practice (students)	Collaborate with TPR department to monitor and assess use of ICTs like CAD	Improved approaches to integration of CAD and ICT into TPR	CAD use on teaching practice	Not currently using CAD resources but keen to in future	Build skills themes into TPR assessment	Survey	STU-2: If we are able to produce resources with the 2D design program, it shows what knowledge we have gained by using the various tools in the program to create our relevant resources.

4.8.3 Indexing and coding

In Step 3, I used indexing and coding to structure the analytical matrix and organise cases and quotations from transcripts to address key research questions. I undertook additional coding and indexing of the data by group, source, or research activity. This enabled me to refine the data down to the most relevant content. Key stages of coding, for the purposes of analysis, followed Johnny Saldaña's qualitative approach (Saldaña, 2013). The survey and semi-structured interviews questions gave the framework prior order based on the research questions. Following Saldaña's exploratory approach enabled me to generate themes based on systematic organisation of data using manual and computerised analysis (Gerber *et al*., 2016, p. 112) which can lead over time to theorizing. I initially used identity coding to anonymise participants, and to differentiate them as ICT lecturers, students, SRC members, non-ICT lecturers, and technical advisors. To enable sorting in NVivo12 and the Excel matrix, I first coded the participants by role, and gave them a numeric suffix to enable automatic sorting, e.g., Lecturer-1. Finally, I gave them first name pseudonyms to retain anonymity while enabling a more natural narrative for reporting in this thesis. (Appendix 31: Participants' Identity Coding Table). The School of Education in Durban is a small but well-known teacher-training institution in the province. It is possible that some of the participants may be recognisable by the roles they played and/or continue to play in the institution. As such, total anonymity cannot be guaranteed. This was discussed and negotiated with the participants, who gave their consent.

For student participants, because the numbers were slightly bigger, including those who participated in the CPAR and in the surveys, I used a different approach to identity coding. Because surveys and interviews had been structured using preset questions, I first coded data from these by question number and research question, and then grouped similar answers, or themes emerging from answers, in rows in the matrix. This meant that similar responses from different participants were grouped together for triangulation. Additional colour coding and thematic coding was conducted to identify and locate data in sub-themes grouped under Research Questions 1 and 2. I undertook this sorting firstly in NVivo 12; and then refined it further in the Excel framework analysis matrix, illustrating this in the mapping stages. For student participants, final participant identity coding was applied in the second cycle of the process when anonymous student surveys were analysed. The "STU…" code, number, and additional suffix "-2" were used to differentiate between First Cycle participant students and anonymous students from the Second Cycle cohort (Appendix 25).

4.8.4 Charting and mapping

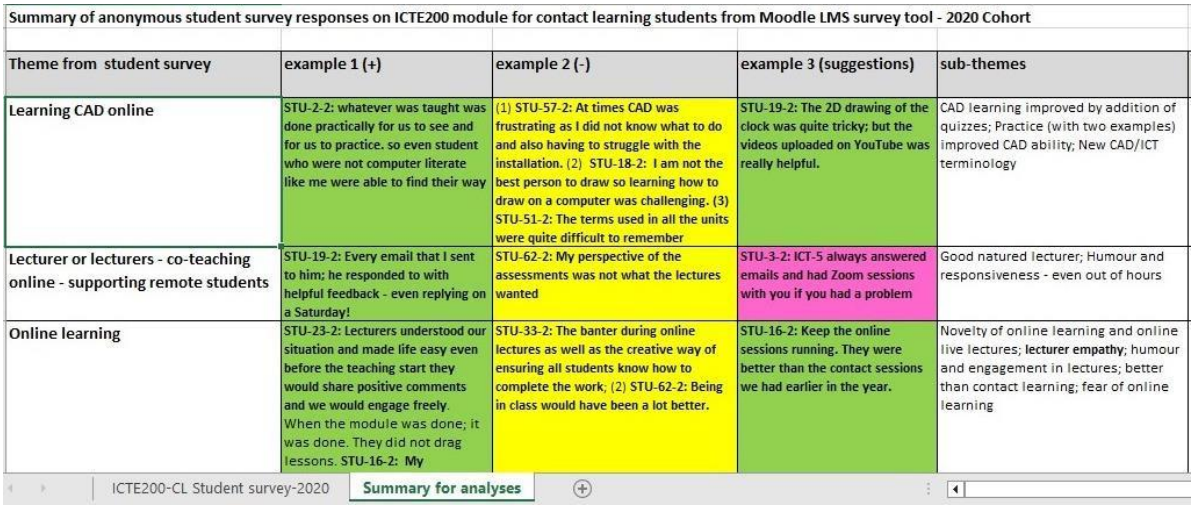
|In Step 4 of my framework analysis process, I employed charting and mapping to further organise the coded data into a large sortable Excel matrix under themes and sub-themes relating to research questions. This made the matrix an active adjustable tool for viewing content under various themes and filters. Charting and mapping allowed me to undertake rapid summarising, description, and writing up. During this phase I applied additional filtering columns to the matrix, with descriptions and summaries in which multiple participants

provided answers to questions. Following the nominal group workshop (Appendix 32: Refinement of Coding Framework from Nominal Group Technique Workshop), I introduced refined themes into the matrix which were developed by participants in the collaborative event.

The mapping involved the creation of summaries and summary blocks on separate tabs of the Excel matrix. These allowed me to group data separately, and to create links and cases to report in the findings. Figure 4.5 shows an exemplar summary block from Cycle 2 survey data which separates student answers under positive and negative responses and suggestions for improvement.

Figure 4.5

Extract from Framework Matrix from Cycle 2 Summary Block showing Themes and Sub-Themes and Colour-coded Participant Quotations.



Summary of anonymous student survey responses on ICTE200 module for contact learning students from Moodle LMS survey tool - 2020 Cohort

Theme from student survey	example 1 (+)	example 2 (-)	example 3 (suggestions)	sub-themes
Learning CAD online	STU-2-2: whatever was taught was done practically for us to see and for us to practice. so even student who were not computer literate like me were able to find their way	(1) STU-57-2: At times CAD was frustrating as I did not know what to do and also having to struggle with the installation. (2) STU-18-2: I am not the best person to draw so learning how to draw on a computer was challenging. (3) STU-51-2: The terms used in all the units were quite difficult to remember	STU-19-2: The 2D drawing of the clock was quite tricky; but the videos uploaded on YouTube was really helpful.	CAD learning improved by addition of quizzes; Practice (with two examples) improved CAD ability; New CAD/ICT terminology
Lecturer or lecturers - co-teaching online - supporting remote students	STU-19-2: Every email that I sent to him; he responded to with helpful feedback - even replying on a Saturday!	STU-62-2: My perspective of the assessments was not what the lectures wanted	STU-3-2: ICT-5 always answered emails and had Zoom sessions with you if you had a problem	Good natured lecturer; Humour and responsiveness - even out of hours
Online learning	STU-23-2: Lecturers understood our situation and made life easy even before the teaching start they would share positive comments and we would engage freely. When the module was done; it was done. They did not drag lessons. STU-16-2: My	STU-33-2: The banter during online lectures as well as the creative way of ensuring all students know how to complete the work; (2) STU-62-2: Being in class would have been a lot better.	STU-16-2: Keep the online sessions running. They were better than the contact sessions we had earlier in the year.	Novelty of online learning and online live lectures; lecturer empathy; humour and engagement in lectures; better than contact learning; fear of online learning

ICTE200-CL Student survey-2020 | Summary for analyses

Finally, diagramming was employed using spider diagrams and graphic illustrations of pedagogical workspaces. This enabled creation of visual summaries of related themes and observed socio-technical systems. For example, I developed illustrations of each ICT classroom room layout used between 2018 and 2020, in terms of furniture, devices used by staff and students, and educational technology provided. These visual records of room layouts and educational technology facilities helped illustrate graphically ways in which changing pedagogical approaches were influenced by changing physical spaces and technology provided for student tutorials. These diagrams were filed in a cloud folder using logical filenames and identity codes and number suffixes to organise screenshots of these chronologically in the main matrix under a separate tab. These infographic diagrams are presented in findings chapters (Chapter Five and Six). The full collection of images is viewable in Appendix 34: Illustrated practice architectures at the institution's campuses and schools-2018-2020.

4.8.5 Interpretation

In Step 5 of the framework analysis, the interpretation stage, I pursued an intensive process of immersion in meaning-making that is core to qualitative research (Miles *et al*., 2014). As the researcher, experienced CAD user, and teacher, my aim was to bring deductive reasoning into the organisation of and the assumptions of the course (Petrina, 2003; Ritchie & Spencer, 1994). To aid my interpretation of the data, I first used the framework analysis matrix

(illustrated partially in Figures 4.4. and 4.5) and *2D Design* graphic tools to re-organise and cross-link themes and categories visually. Secondly, I interrogated recurring content from different sources to add descriptive interpretation and to triangulate findings. Two graphic frameworks are shown in Appendix 33: Analysis - Mapping of Sub-themes, one from Research Question 1, and one theme from Research Question 2, which illustrate the mapping of themes relating to the two main research questions. These enabled summary visualisation of the matrix for interpretation of data first coded in *NVivo12.*

I organised and sorted data by identifying CPAR "practices and practice architectures" amongst participants in relation to the research questions (Kemmis, McTaggart, *et al*., 2014, pp. 59-63). Specifically, to understand practice, I used journal memos, survey responses, and transcripts, to cross-reference data under categories relating to participants' activity, what they said, interactions, skills demonstrated/recorded online, and values communicated. To understand practice architectures, I surveyed, illustrated, and described the changing learning environment reported in surveys and interviews (assisted by diagramming). I tabulated the practices and practice architectures in the matrix (Appendix 34); and used these to identify common links and cases relating to participants' experiences, highlighting quotable material for the findings.

Framework analysis is valuable in developing recommendations within a given timescale (Lacey, 2007) and is a suitable analysis for a time-limited PhD study. Framework analysis is not tied to a specific epistemological position, thus enables researcher flexibility (Gale, *et al.*, 2013). This flexibility assists when dealing with unpredictable outcomes from

multiple data sources. Framework analysis also supports extraction of meaning from qualitative data and acknowledges use of quantitative data to add value to the understanding. Framework analysis embraces the use of computer-assisted qualitative data analysis (CAQDAS) technology (Odena, 2013) used in this study, such as: *NVivo12* (Bazeley & Jackson, 2013), *Excel* (Swallow, *et al.*, 2003) and *Google/MS Forms*.

The study reported in this thesis produced data in the form of qualitative transcripts of meeting minutes and email communications, journal notes, online survey responses, and face-to-face interview transcripts. These were supplemented by students' CAD drawings and portfolio submissions, quantitative module marks summaries, and module outcomes reports extracted from the learning management system (LMS) and student information management system (SIMS) over the course of two cycles of implementation. Organisation and securing of data took place immediately as data was produced in 2019 and 2020 using computer hard drives and my personal internet-based secure cloud file storage.

Using a framework analysis approach assisted me in the transcription, sorting, reduction, and grouping of data; application of codes; grouping of codes under concepts linked to the research question or sub-questions; reorganisation of data under sub-groups or categories; and finally, organisation of data into themes for interpretation. I undertook the first three stages independently, albeit guided by participants' dialogues. In Cycle 1, the final stages were assisted by a collaborative nominal group workshop organised with Campus-1 research participants. In Cycle 2, I was unable to meet participants due to the Covid-19 lockdown; I

relied on email and telephone discussions to discuss additional data with the participating lecturers.

The thematic framework, described in this section, assisted me with organisation, interpretation, and presentation of findings from reconnaissance, planning, action, observation, and reflection sources in two cycles of action (Mertler, 2016, p. 131). This cross-linking of references from different human sources in different "communicative spaces" (Kemmis, *et al*, 2014, p. 70) gave me an adaptable interpretive framework (Ritchie & Spencer, 1994) to address themes in which participants engaged and reflected critically in different online and offline settings (Gerber *et al*., 2016, p. 93). This framework helped to map and interpret critical discourse from our collective social co-existence in the action-research cycles, ensuring that our encounters were recognised as "opportunities for learning and growth" (McNiff, 2013, p. 19). Such was manifested in the development of participants' understanding of student-teachers' appropriate modes of learning and subsequent application of CAD as they adapted to changes in the institution and wider environment.

4.9 Ethical Considerations

As a methodological approach, CPAR should not expose participants to physical or emotional harm, or present significant ethical challenges (Banks *et al*., 2013). The study did not pose great risk to participants. However, participants' collaboration in co-creating and co-critiquing CAD learning and teaching raised questions around how learning material can be pre-tested with students to ensure relevance of content and mode of delivery, without

interrupting their learning. As a collaborating researcher, I was conscious that there is a trade-off in action research between participants doing extra work for the benefit of advancing learning for all, and personal collaboration which requires an investment of time and effort.

The study was initially designed to include the teaching of CAD in face-to-face settings. However, in 2020, after the first cycle of the CPAR, the institution had moved to teaching all its teacher-education programmes online in the face of the Covid-19 pandemic. This denied the students the opportunity to pilot the CAD resources they had developed on campus during their teaching practice. Because the online teaching resources used in the CAD course were successful, they were used to justify a blended online approach for teaching all modules in the department. As an advocate of practical face-to-face technological education (Gumbo *et al*., 2019), I found that this clashed with my ideology. I concluded that institutional research in private higher-education spaces is vital in challenging commercially driven priorities which can disagree with academic integrity and human agency.

By creating a democratic collaborative course design process, involving students and lecturers, participants were positioned so that their contributions were treated with equal value. Managing myself, as a driver of the study and departmental head, was a challenge. As researcher, co-teacher, and content designer, I was a constant presence in the study. I had to be careful that my opinions and enthusiasm for CAD did not consume all my personal and professional time. During the isolation of Covid-19 lockdown, this created a genuine risk to personal health and well-being.

As an HOD, I also had to be aware that my managerial status should not inhibit participants from acting and speaking out freely. My access to the learning management system as a line manager enabled online observation of student activity and extraction of qualitative (surveys) and statistical data (CAD outcomes). I encouraged the lecturers, as co-researchers, to observe student activity, and to extract data for analysis. Sharing data freely with both lecturers and students in member checking and nominal group workshop activities was designed to give all participants access to data, and to provide a chance to contribute meaningfully and equally to the enquiry (Guba, 1981).

4.10 Trustworthiness and Rigour

To ensure trustworthiness and rigour in this CPAR study, first, I used methods which I felt adequately addressed the research questions I posed in the study. Specifically, I used multiple sources of data which enabled triangulation of action and reaction in both cycles of the CPAR. This included observations, interviews, fieldnotes, document analysis, and students' portfolios.

Second, collaborating with my co-researcher participants also ensured a level of rigour in the study. For example, our *WhatsApp* dialogues enabled rapid feedback on action as it transpired (Gerber *et al*., 2016). This enabled building of a sense of community online which corroborated face-to-face action at campus (Cronje & Van Zyl, 2022), as students reported on action in tutorials and from remote learning. In Cycle 2, lecturers' reporting via *WhatsApp* also kept me connected to events I could not attend in person.

Third, analysing the data using framework analysis provided a transparent archiving process to ensure authenticity and a systematic way of presenting data (Gerber *et al*., 2016, p. 85). This enabled easier verification of my interpretation of findings with participants in a nominal group workshop through generation of accurate data codebooks discussed in group validation. Reliability and repeatability were ascertained using standardized data-collection forms, online survey questionnaires, and interview schedules, ensuring that the sample group did not experience bias or variation in their treatment. These were checked by my critical friends, or validation groups, drawn from the participant group.

I followed reflexive processes to ensure the trustworthiness of the data generated. Such processes involved maintaining close and regular online and face-to-face dialogue with participants, as well as discussions via *WhatsApp* groups and email. Specifically, some triangulation of data was conducted by repeating similar questions in surveys and interviews, and subsequently sharing transcripts via email for confirmation of content. This process of "member checking" (Mertler, 2016, p. 131) enabled verification of data sources and correction by participants where needed (Appendix: 23). Archiving of research logbooks, transcripts, and framework analysis matrix was achieved systematically, manually, and electronically, ensuring ease of cross-checking by my critical friends, and possibly, stakeholders and auditors later, if necessary. Recordings and transcripts of interviews, emails and dialogues were backed up using password-protected online cloud storage.

In summary, following human sciences guidelines with clear research project briefings, consent letters and forms, and options to leave at any time, guaranteed that participants received

fair treatment and were given equal opportunity. My recording and archiving of this process using systematic data storage, management, and accessibility procedures saw to it that the participants' contributions were safeguarded and created a historic record for future research and dissemination purposes.

4.11 Limitations of the Design

To evaluate CPAR is necessary in critiquing the methodology. considering my lived experience as a researcher and observations from co-researchers and critical friends. The study's limitations are fourfold: the scale of the implementation was limited; the main action took place on one campus with a small sample group; my HOD status could potentially distort the findings due to power imbalances in the group; the CPAR methodology required participant engagement to be managed simultaneously with normal running of a commercial module; and limited human resources made it difficult to observe a large sample of students applying CAD skills in schools.

Firstly, resources dictated that it was better to observe integration intensively, on one campus, instead of as a detached online multi-campus research project. Reconnaissance exposed a need for better inter-departmental and institutional training to enable collaborative research. Observation of teaching and student work from all three contact learning campuses could have engaged a wider diversity of students and provided richer demographic and geographic data for comparison. Ironically, the Covid-19 pandemic forced us into a more

collaborative online form of multi-campus webinar teaching in Cycle 2 which helped to bring staff together online during a period when we all were compelled to work from home.

Secondly, the CPAR methodology enabled simultaneous action, and monitoring of action, but raised questions about whether the researched action was the same as 'normal' unresearched action. The positive staff-lecturer cooperation, in public spheres, may have fuelled optimism that future development would follow the same route (Kemmis, *et al*., 2014, p. 87). The Covid-19 pandemic disrupted the second cycle plans. It did not dampen the group's enthusiasm to continue researching; however, it did force others out of the project.

Thirdly, potential fears that my status as HOD, with prior experience as the LMS administrator, might create tensions in the group, turned out to be groundless. It did not appear that my experience inhibited others when I occupied the dual roles of co-researcher and HOD (Postholm & Skrovset, 2013). This may have been due to my working collaboratively with students and lecturers in multiple roles as a lecturer, administrator, and departmental manager. Institutionally, my departmental title did not hold great power over the lecturers, HODs acting more as informants to lecturers rather than overseers. Additionally, the rapport developed with students previously as their science lecturer in the first year of studies meant that students knew me as an individual prior to signing up to participate.

Fourthly, the decision to research in action, as new CAD changes were implemented for the first time, turned out to be a positive choice: the action unraveled naturally, and exposed various co-researchers' views and experiences relating to digital literacy (Rowsell, 2013) which could not be predicted.

Finally, difficulty in scheduling follow-up observation of students' action on teaching practice exposed limitations in researching student-teachers' action in schools. An impediment to planning is the uncertainty of students' school placement before the term of study. This makes it difficult to seek early research consent from targeted schools for participating students. Tracking students outside the institution's contact learning sites is hampered by limited administrative resources. The school observation is effectively another research site which requires a different form of ethical clearance and gateway permission from schools. A preselected "purposeful sample" (Merriam, 2009, p. 77) may enable more proactive students to influence their teaching observation in schools. Researching student-teachers' CAD learning, and the application of this learning in teaching practice formally, requires a multidisciplinary collaboration between the ICT department, students, teaching practice departments and placement schools.

In this case, observations, interviews, and *WhatsApp* dialogues elicited feedback from lecturers and students on their school experience. In a longitudinal study, it may be possible to formalise observation of a CAD or ICT lesson as part of a scheduled termly assessed teaching practice visit by teachers or researchers. Given the current resources available, observation tends to form part of a single scheduled teaching practice lesson observation. To assist in enabling student teachers to participate in sharing experience of their use of CAD in schools, without necessarily observing them, Kemmis *et al*. suggest that all participants keep research journals throughout CPAR (Kemmis, *et al.*, 2014, p. 177). In this study, unobserved students reported their experience in *WhatsApp* posts, online surveys, and interviews as a form of

electronic journalling. Additionally, those who attended the nominal group workshop contributed to interpretation of findings as part of the research group. Replacing hard-copy logbooks with online discussion forums, on the LMS, may ensure better continuity of dialogue on a yearlong research project.

4.12 Chapter Synthesis

This chapter has presented the research design and methodology used to address the research questions posed in the implementation of computer-aided design in a primary-school student-teachers' ICT course. Specifically, I provided a discussion of CPAR to study the teaching and application of CAD in primary-school teacher education using a socio-technical systems theoretical viewpoint. Additionally, I also provided a discussion of the private higher-education context, participant recruitment, data generation and framework analysis approach used to organise and interpret data from online and offline sources. Finally, I presented the ways in which I ensured validity, considered ethical issues, and identified limitations of the study.

The next chapter, Chapter Five, presents the qualitative findings responding to the main research question in the first cycle of implementation. Chapter Six shares the findings of the post-implementation and second cycle stages which triangulate with and contradict some of the findings from Cycle One. These chapters show how the action-research process enabled development and improvement of resources, explored modes of course delivery, and revealed

the various student and institutional approaches to application of CAD resources and skills in teaching practice.

END OF CHAPTER

Chapter 5. Implementing a Computer-aided Design Course in an Intermediate Phase Teacher Education ICT Module: Findings from the First Action Research Cycle

5.1 Introduction

The following chapter presents the findings of the first cycle of action research. Following the critical participatory action research (CPAR) methodology (Kemmis, McTaggart, & Nixon, 2014), I present the findings from the reconnaissance, planning, action/implementation, observation, and reflection stages of the first action research cycle in the project. I present multiple perspectives incorporating personal views and "second and third person" views (Zuber-Skerritt & Fletcher, 2007, p. 413) obtained from staff and student *WhatsApp* groups, staff and student surveys, interviews, and email conversations. The findings are presented in a chronological order, mapping the stages of the first action research cycle. Chapter 6 continues from this chapter and presents the second cycle findings supported by results from Cycle One.

The previous chapter presented the methodology used to address the research questions in this study: 1) Which pedagogical approaches can best provide contextualized computer-aided design (CAD) education for enhancing intermediate phase student teachers' learning? and 2) How might the use of CAD help intermediate phase student teachers to effectively integrate ICT in developing teaching and learning support materials for their teaching practice? The methodology chapter described how the study used critical participatory

action research (CPAR) to address these questions. It explained how socio-technical systems theory, described in Chapter Three, operating within the critical paradigm, aided my organisation and analysis of findings presented in this and subsequent chapters. The benefits and limitations of the CPAR methodology, in the context of this study, are revealed as this chapter traces the first action research cycle.

The project used CPAR to engage the participants, intermediate phase lecturers and student teachers, in an authentic "continuing professional development" process (Zuber-Skerritt, 2007, p. 416). The aim was to enable critical and collaborative engagement between the participants and me. To achieve this, I attempted to create a "collaborative, democratic" environment that enabled the participants to work together in "cogeneration of knowledge" (Brydon-Miller & Greenwood, 2006, p. 120). The aim was to identify the most appropriate pedagogical approach for teaching CAD as the course adapted to various environmental, institutional, technical, and organisational influences.

To explore the best pedagogical approaches to learning CAD (RQ1), we set out to provide students with choice in mode of learning by providing alternative ways of learning in face-to-face and online spaces. In facilitating and mapping students' use of CAD for teaching practice (RQ2), we asked the students unobtrusively to conduct this process per the various resources used for teaching CAD. I followed up on their application of CAD in three different forums. The collaboration between students and lecturers in the design, implementation, and critique of the course revealed varying practice and practice architectures (Kemmis, Wilkinson, *et al*., 2014) which resulted from activities in physical and online spaces.

The following chapter presents stages of the CPAR process summarised in Chapter 4, Figure 4.1: CPAR Cycle 1: Learning to Use Computer-aided Design. The Figure illustrates where and how participants, including myself, interacted and co-created the CAD course for teaching both on campus and online using a learning management system. This chapter considers the findings from the sub-sections of action from each CPAR stage of reconnaissance, planning, action, observation, and reflection. In CPAR, these discreet actions are described as small "spirals of action contributing to the main compound study" (Kemmis *et al*., 2014, p. 19). Action also involved my documentation of the process, as a researcher, through journal notes and illustrations. These support the findings and assist with describing the socio-technical context during the period of the study.

The reconnaissance stage includes the background research and preparatory work I shared with lecturers prior to the module implementation, which culminated in institutional gatekeeper permissions. The planning, action, observing, and reflection subsections demonstrate the core activities in the process of which all research participants collaborated. The chapter begins with "reconnaissance" to develop understanding of the context prior to planning and action (Kemmis, 2014, p.89). This aligns with Petrina's view of socio-technical theory's prioritising of appreciation of the wider context to design better pedagogies for teaching CAD (Petrina, 2003, p. 54). Chapter sections are structured to show how the CPAR stages unfolded. These sections incorporate sub-headings which illustrate the "internal cyclical processes" (Zuber-Skerritt, 2002, p. 177) which took place in both offline and online spaces.

The first cycle of the CPAR process involved interrelated activities in both in-person and online locations. The stages involved working with ICT lecturers and student teachers in co-creating, implementing, and critiquing a new CAD course as part of an existing ICT module. The CAD course was implemented with second-year student teachers (Appendix 3). In the sections that follow, I present the first cycle stages. Following this chapter, Chapter 6 presents findings which resulted from first cycle post-implementation reflection (Schön, 1995); and the second cycle of action which draws on findings from students' course outcomes, dialogue with lecturers and students, a nominal group workshop, and a follow-up survey to describe the action which unfolded during the global Covid-19 pandemic.

5.2 Reconnaissance

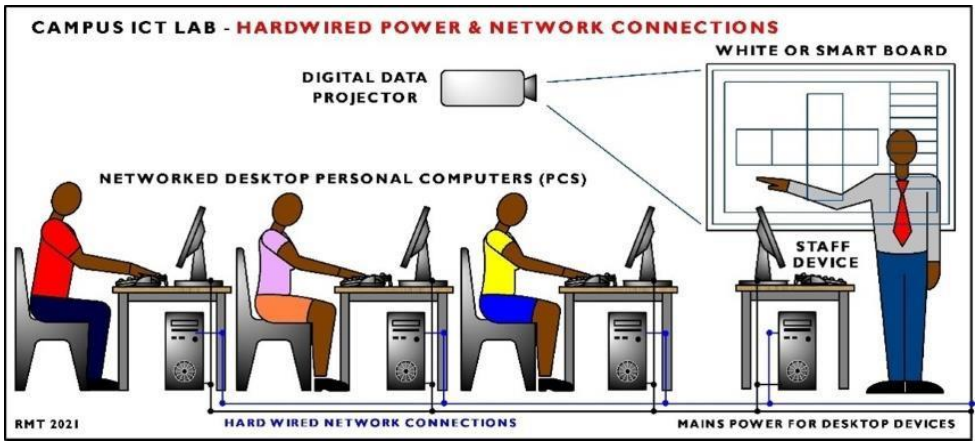
Findings from the key first-cycle reconnaissance, or pre-planning stages of the CPAR process are contained in this section. Prior to implementing CAD in the ICTE200 module 2019, I undertook a period of reconnaissance in achieving institutional research permissions, establishing whether facilities were suitable for teaching CAD; reviewing the ITCTE course, trialling CAD software with lecturers, and introducing lecturers to the research project. The findings report ways in which the reconnaissance informed and resourced my planning of the implementation.

5.2.1 Review of facilities

In 2018, I undertook in-person inspections of Campus-1, Campus-2, and Campus-3 to review facilities with ICT lecturers. The purpose of these inspections was to assess whether facilities were suitable for teaching CAD. Observations were recorded as sketches and notes in research journals. At the end of 2017, the school of education campus moved from its previous location in Durban to its current location. The original campus had operated with a fully wired ICT lab comprising 25 desktop computers, digital projector, and a staff desktop computer (Figure 5.1). The desktop computers from the ICT lab were relocated to the new campus's library as general-purpose student computers.

Figure 5.1

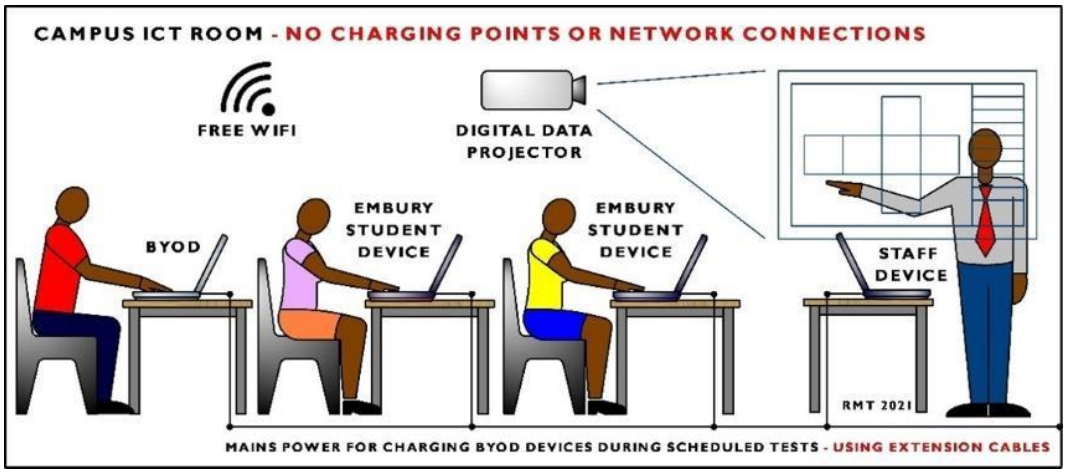
Original Campus ICT Laboratory Set-Up in 2017



The Durban campus did not have ICT labs and instead used multipurpose classrooms, with students expected to work on their own devices Figure 5.2:

Figure 5.2

Campus-1 Campus ICT Laboratory Set-Up in 2018 with BYOD Policy in place



During my scheduled visits to Campus-2, and Campus-3 in 2018, as head of mathematics, science, technology, and ICT subjects, I established that these two campuses were moving to a bring-your-own-device policy following the Durban campus's lead. However, both still offered students the opportunity of learning on desktop devices in purpose-built ICT labs.

The above technical systems reconnaissance informed my decision to use *2D Design* CAD software for introducing CAD, as this could be installed on both desktop and staff and student laptop devices using educational site licences which did not limit the number of users

of the software. Although I was reassured that students would be able to access the software to learn CAD, I was concerned that campus students without their own devices would be restricted to trying to learn CAD in the library after lectures.

5.2.2 Review of the ICTE200 computing course

In November 2018, I engaged critically with ICT lecturers in a departmental meeting to review the content of the ICTE200 course taught in 2018; and outlined the integration of the CAD content in an online departmental meeting. This involved: 1) reviewing the successful units of the module, 2) identifying redundant/out-of-date material, 3) considering addition of alternative content, and 4) exploring various ways of delivering and assessing content. Stage 4 was required because ICTE200 was identified as a module to be taught using a blended online mode of delivery as an institutional 'digitalisation' project. Following this process, the institution resolved to phase out electronic whiteboard teaching, new campuses not including this classroom technology as standard equipment. This created the gap for CAD to be taught as a replacement unit in the module and included in formal assessment (Appendix 7: Info Comm Tech for Education ICTE 200 Study Letter-2018-2019-E1). At this meeting, I suggested that CAD would be a good unit to pursue in 2019. I wanted to study its implementation in the intermediate-phase programme to prepare teachers for teaching coding and robotics. Durban campus ICT staff supported this, because we (Lecturer-1, Lecturer-2, Lecturer-3 and I) had attended a Department of Education coding and robotics teachers' professional development

course in Durban earlier in the year. At this meeting, I also informed lecturers that I was planning to research the CAD implementation as a PhD study. Staff were supportive.

5.2.3 Training staff and final-year students as a pre-trial

In Semester One of 2018, ICT lecturers Lecturer-1 and Lecturer-3, and a mathematics lecturer, Lecturer-6 attended the two staff development classes I ran with invited senior students. The students' council representative SRC-Student-1 assisted with inviting students from 3rd and 4th year degree programmes. At these sessions I demonstrated the step-by-step process for drawing CAD resources. The process involved (1) introducing students to the CAD tools, (2) drawing a given example following step-by-step instructions and screen-shot images, and (3) comparing results with a finished exemplar or colleague's work. These stages follow a similar introductory pedagogical approach reported in the Swedish study by Brink, Kilbrink, and Gericke (Brink *et al*., 2022).

Trials of CAD lessons and resources were conducted on consecutive Monday afternoons, when no student lectures were timetabled. Figure 5.3 illustrates an example of a CAD clock drawn during the trial course. I used this example because it combined drawing of line types, radii, text, repeating details and 'parts' (clock hands), as well as decorative fills, to represent materials. The final drawing was an assembly of four parts: clock face, hour hand, minute hand, and second hand. Contextually, treating drawings as assemblies relates to mechanical drawing and product design taught in high-school design-technology and engineering-graphic design courses. Drawing assemblies of parts also requires students to learn

digital file management which is used in professional design and engineering collaborations (Ham & Dawson, 2004). The positive response to the use of the clock example stimulated its development as the main example for the 2019 guide and videos used in the ICTE200 course described in the planning stage.

Firstly, the clock (Figure 5.3), dice net, and a three-dimensional revolved wireframe product were used to demonstrate beginner-to-advanced CAD drawing tools. These provided lecturers with more practice and a choice of contexts to teach in the ICTE200 CAD course. My departmental training initiative enabled development of student resources which were adapted and improved with feedback from the participating ICT lecturers and students in the study.

Secondly, the trial activities enabled presentation of examples encouraging lecturers to create their own resources and appreciate the difference between CAD and basic graphic tools provided on Office software. Some lecturers used the experience to assist their teaching in 2019, and to revise the course in 2020. Lecturer-3 was initially the most enthusiastic lecturer/student of CAD in 2018. In 2019, she moved to Gauteng and taught the module from Campus-2.

Figure 5.3

Clock drawing example used for staff training and IP student CAD unit



Finally, learning CAD from the viewpoint of a student enabled lecturers' appreciation of teaching pedagogy and the issues that students face while learning. For example, in the staff survey in 2019, Lecturer-1 recalled: "You showed us how to draw like half a cup and rotate it 360 degrees to create that 3D effect. I think it would be something nice for the students to learn." This example affirmed his retention of knowledge of the preparatory training and the differentiation of drawing complexity used to extend learners.

5.2.4 Institutional gatekeeper permission and site reconnaissance

Institutional permission to research CAD in the ICTE200 module was given in November 2018. I consulted my institution's dean of research and the campus manager. Both advised me to develop achievable objectives and to submit a proposal for gatekeeper permission (Appendix 4: Gatekeeper Permission Letter). In January 2019, full ethical clearance

was given by the UKZN Ethics Committee (Appendix 1: Ethical Approval Letter-– Ref: HSS/0011/019D).

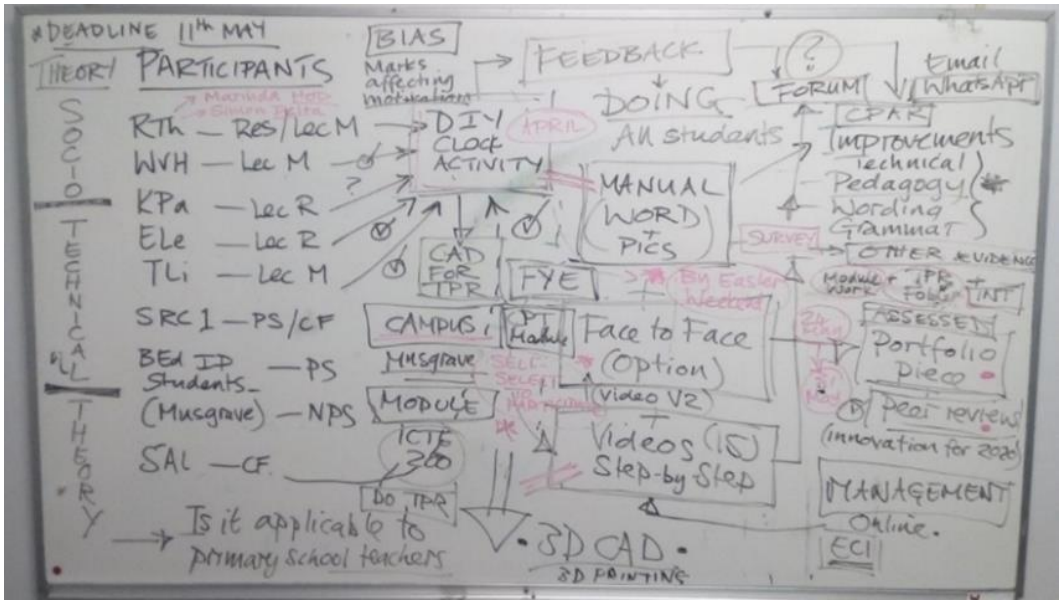
I planned to work collaboratively using action research. Research involved interactions in departmental offices, ICT lecture rooms, and, virtually, in *WhatsApp* groups and via the learning management system. Because I worked at the research site, and had good relations with lecturers in my department, it was possible to visualise some "barriers and enablers" (Hramiak & Boulton, 2013, p. 91) from the outset. I used this as background preparation for the ICTE200 course review, lecturers' briefing meeting, and recruitment workshop. This background knowledge also assisted in refinement of tools used later in the study.

5.2.5 Recruiting and training lecturers both informally and formally

In April 2019, I met ICT lecturers on campus in a focus-group meeting in our department office. We discussed the proposed CAD course design, integration of the research project in the calendar, software access for students, and recruitment of students using a campus workshop. Ideas from the brainstorming session (Osborn, 1963) were recorded on a whiteboard as an unstructured mind-map with notes (Figure 5.4).

Figure 5.4

Brainstorming Notes from Focus-Group Meeting with Lecturer-1, Lecturer-2, And Lecturer-5 (April 9th, 2019)



Following campus facilities reconnaissance, I reported that I had reservations about the BYOD device policy impacting lecturers' technical support of students learning ICT should students be using "low-spec devices". Lecturer-5 queried whether students would be able to use Apple Mac devices. I reported that students had been informed in induction that they should be using Windows-compatible laptops; the minimum specifications for these provided ample capacity to run the *2D Design* software.

Lecturer-1 and Lecturer-2 supported the course design elements of the research project and agreed that researching CAD in the ICT course was timely to support the institution's blended online format. I reported that I intended to involve students in planning by requiring them to critique lesson plans and resources both prior to and during the course; and that students would be asked to upload examples of CAD drawings for peer critique and lecturer marking on the LMS. Lecturer-1 proposed installing a *Moodle* online peer review activity named "Workshop", on the LMS course, for students to critique peers' clock designs online. Lecturer-1 also suggested that a CAD drawing be included in the end of year portfolio to ensure that students received summative marks for their drawings.

Lecturer-5, as a new member of staff, expressed both interest in the CPAR research process and some reservations about the impact of the project on workload. A key reflection point was Lecturer-5's observation: "Is it [CAD] applicable to primary school teachers?" I reflected that this initial critical question from a new member of staff with no prior experience in a research project showed that he was interested. This stimulated further discussion on the relevance of teaching CAD to primary school teachers. I reiterated my assertion in our 2018 meeting that inclusion of CAD in the ICT modules would prepare students for teaching technological subjects such as coding and robotics. This seemed to reassure Lecturer-5. He later became a promoter of CAD and blended online teaching, after co-teaching with me during face-to-face CAD sessions. I offered to run these because he had missed the previous year's staff training.

Lecturer-3 and Lecturer-4 were not present at the meeting. As they were experienced ICTE200 lecturers from Campus-2 and Campus-3, I recruited them in individual online meetings. I sent them copies of the 2018 workshop presentation and they completed consent forms via email. I reassured these lecturers that the aim was to integrate the research into normal teaching activities using the learning management system, online *WhatsApp* groups, and surveys, to manage communication and observe action. I emphasised that lecturers were not expected to change behaviour when teaching CAD, but simply to "do their job naturally".

5.3 Planning

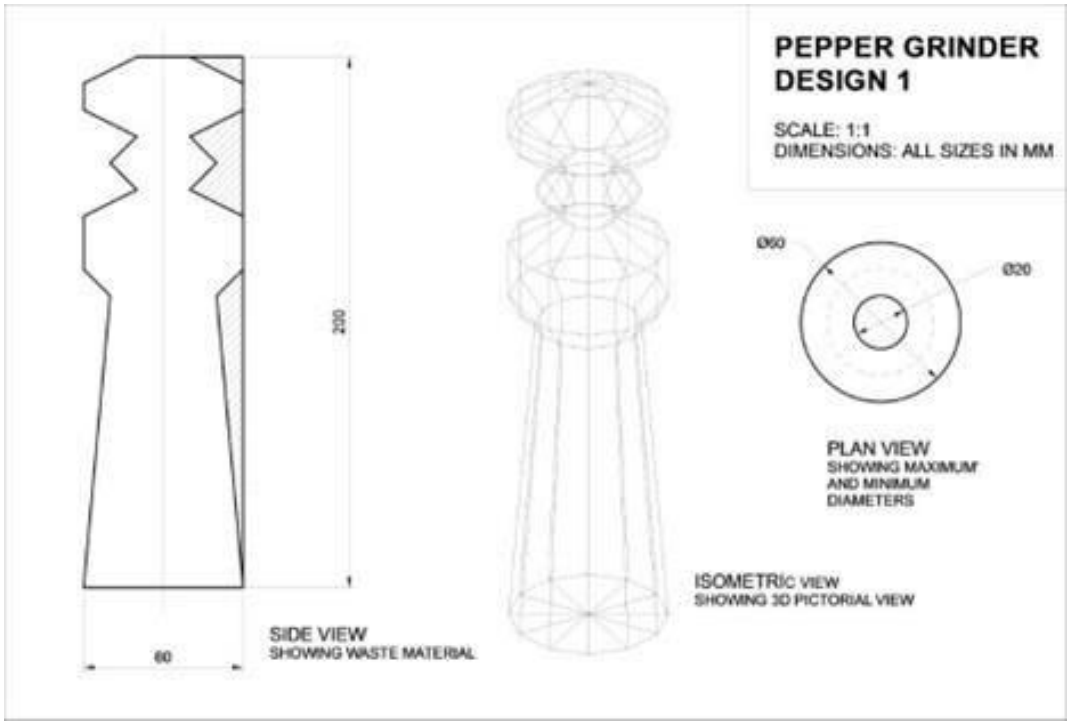
Findings which emerged from the first cycle CPAR planning stages are presented in this section. Planning is evident in the recruitment of participants to the projects; collaborative development of CAD resources; development of the blended online course and encouraging students' use of CAD in teaching practice. I used campus and online 'spaces' to bring participants together both in-person and online to design the best pedagogy for student teachers to develop skills to use CAD, and to resource their primary school teaching. The design of the course involved my sharing of draft CAD lesson plans and content online via email and the learning management system (LMS), thus eliciting constructive critique from participants. Critique of our course content spanned all stages as it was invited before, during and after the course, respectively, in *WhatsApp* and email dialogue, survey responses, and interviews.

5.3.1 Recruiting student participants

The face-to-face student recruitment workshop (Appendix 6: Recruitment workshop − Outline) promoted CAD action research and formalised participant recruitment through issuing of research consent forms (Appendix 2: Informed consent letter). Two permanent ICT lecturing staff and forty students attended. During the session, I shared examples of my own work (Appendix 5: 2D-Design Tools-Slide Presentation -Sample) to inspire students to appreciate CAD as a learning tool; and to develop resources (Figure 5.5) using applied design and technology contexts. I also explained the ways in which I would like students to be involved as "co-researchers" in planning, action, observation, and reflection stages of the CAD implementation project. I suggested that we communicate via a *WhatsApp* group to share ideas and give feedback during all stages. I also invited participants to email me on my institutional email should they wish to contact me outside the group. After an informal question-and-answer session, I read and summarised the informed consent form and reiterated participants' personal autonomy during the research process. Complete informed consent and applications forms were collated, and participants' demographic data recorded for reference (Appendix 18: Participant Demographics (anonymised).

Figure 5.5

CAD Wireframe 3D Example used in Student-Recruitment Workshop



Students and lecturers questioned the timing and duration of the research, commitment required, and whether participation would be extra work. Student-6, who later joined the research group, asked: “Do we have to do this separately, as extra work, or does it fit around the module?” Another student, who did not join, asked: “Does the CAD research count for marks?” I reiterated that there were no marks for the research; however, the CAD activity

counted for some marks in the module, and participating might assist their understanding of course design.

I reassured participants that the aim was to collaborate in designing the CAD course by following the teaching and learning process critically and, if necessary, re-designing the course. I said that participants' contributions would be acknowledged in research outputs and'a thesis. I informed attendees that use of *WhatsApp* and email would enable us to maintain regular online dialogue, and lectures, meetings, and interviews would enable face-to-face contact.

A total of 17 (n =17) participants (including me) consented to participate in the implementation (Appendix 18). This comprised 11 students (n =11) and five ICT lecturing staff (n = 5). All 11 students attended the recruitment workshop. I was pleased with the range of students who signed up; and was heartened that all the existing ICT lecturers had consented. The workshop promised no incentives. However, I produced participation certificates, signed by the dean, and t-shirts with the clock logo "I MADE TIME FOR ACTION RESEARCH" as a sign of gratitude for participants that persevered until the end of the first cycle (Appendix 39: Incentives – Certificates and T-shirts).

In addition to the core research group, Lecturer-6 was asked to share his experience of using CAD in mathematics modules: he had attended the 2018 CAD training and was using it in a geometry assignment for his IP fundamental mathematics module. Student representatives Helen and Josh also consented to participate, thus providing additional communication avenues with students; and trialling new resources with senior students if required, as they had done in 2018.

Students' interest in the project's purpose and goals was evident in their direct questions and affirmative action in signing up as participant co-researchers. These early interactions encouraged me by signaling the beginning of the social relationships necessary in developing collaborative reciprocity in the action research (Maiter *et al*., 2008, p. 307).

5.3.2 Developing CAD resources

Participants' input on resource development came through reading and editing of illustrated guides and lesson plans and providing feedback via emails and *WhatsApp* groups. This enabled further refinement of resources. For example: Lecturer-1 suggested adding "screen shots of the stages of drawing the clock used in training presentations" to enhance the study guide. Also, Lecturer-2 offered to review and user-trial the study guide to teach himself CAD remotely. Lecturer-2 acted as a critical friend providing additional editorial input on the guide as he used it (Appendix 13: Online 2D CAD Guide Document V2 - Lecturer-2 edits).
CAD was introduced as a formal unit in the 2019 ICTE200 course, following an academic board (ACBO) approval process completed at the beginning of the second semester of 2018. (Appendix 7: ICTE 200 Study Letter-2018-19-E1). We developed CAD online teaching content between October 2018 and May 2019. This included setting up the *Moodle* learning management system (LMS) with the new online version of ICTE200, developing draft lecturer lesson plans, and creating illustrated study materials. LMS content was developed for on-campus and remote learning students to view exemplar resources and CAD drawing guides (Appendix 21: CAD Course-Online Guide-*2D Design*). Three CAD lesson plans were drafted

in December 2018 for use as online resources for lecturers teaching CAD (Appendix 15: CAD Lesson Plans 1-3). I shared these as templates for lecturers and students to plan their own CAD lessons. Lecturer-5 and Lecturer-2 gave editorial feedback on these. The lesson plans were shared with the student participants via the LMS and email. They did not provide feedback on these until they were mentioned in interviews.

Following the project briefing in April 2019, additional suggestions were made in email communications. Lecturer-1 suggested development of video content to mirror the study guide:
Lecturer-1: "Looking at the CAD guide, I was thinking you could make short videos like I did for the Office apps. You could use the recording studio I set up in the office with the Camtasia [editing] software".

Additionally, Lecturer-2 highlighted the challenge of teaching CAD on a single laptop screen should students be going simultaneously to learn with an on-screen guide (or videos):
Lecturer-2: "I find it very hard to work on a single screen now […] This creates an issue when we come to teach it to students because we can't give them all an extra screen".

The addition of video supporting the study guide, was an innovative suggestion by Lecturer-1. Our collaborative production of these enabled greater choice in mode of learning for students. The instructional videos became essential in the second cycle when students were obliged to study remotely during the 2020 Covid-19 lockdown. Sadly, there was no institutional budget to provide second screens for students to use at campus. However, Campus-2 and Campus-3 retained their ICT labs with monitor screens, which could be used for this purpose, until 2022.

The period of reconnaissance and subsequent planning was important to instigate a common purpose in the study or to develop "mutual understanding" and "unforced consensus about what to do" (Kemmis, 2014, p. 68). The inclusion of instructional videos as a mode of instruction was not part of the original plan; however, Lecturer-1's enthusiasm provided motivation to include them as a co-researcher's design initiative.

5.3.3 Planning implementation of CAD in a blended online course

Implementation of CAD in the ICTE200 course required: 1) updating of module documentation; 2) addition of CAD activities to the lecture programme and LMS course; and 3) creation of lecturing resources. To enable Lecturer-1 to manage these stages, Lecturer-5 and I assisted with this process. In 2018, my role shifted away from the learning management system (LMS) administration, giving me greater freedom to use my technical experience to resource the CAD unit online. As a department, we implemented CAD as a unit in two blended online ICT modules in the higher certificate programme (CPT101, semester module), and the BEd IP programme (ICTE200, a year-long module). The online CAD unit content was designed to be interchangeable and usable on both modules.

5.3.3.1 Refining the CAD course using videos and additional Techsoft resources to learn in an online classroom

Following Lecturer-1's recommendation that we create video resources to augment the step-by-step manual guide, I created fifteen instructional videos for the CAD course (Appendix

16: *2D Design* Instructional Video Planning and Play List). I was a novice in creating instructional videos for teaching CAD. Lecturer-1 was skilled in video production and editing after spending his vacation creating video clips for teaching MSOffice skills. Using his recording equipment, in our department's meeting room converted into a temporary recording studio, I recorded the videos quickly over one day with his assistance as recording producer and editor. A laptop with extended screen enabled live screen capture of my CAD drawing on one screen, and written study guide script scrolling on the other. This use of two screens enabled me to provide more detailed supporting dialogue which matched the written guide while producing drawings live. Additionally, Lecturer-2 tested the resources as a critical friend by teaching himself CAD using the guide and videos. Lecturer-2 reiterated that it was straightforward should the user have two screens to view the guide or video while drawing on the CAD software.

The videos were created to explain the steps to drawing a clock with CAD using standard drawing tools. I demonstrated how to use the guide by narrating what I was doing while drawing the CAD image myself. Use of the manual as the script for the video meant that resources were aligned with taught practical CAD exercises conducted in face-to-face sessions. This acted as a personal trial of resources or "user trip" (Lebbon, Davies, & Shippen, 2009). I put myself in the place of the student for the sake of experiencing what they had to do when drawing the example.

Lecturer-1 edited the videos to remove repetitive sections and to create logical breaks. Because the institution had no formal video repository, he created his own YouTube video

channel to upload to the LMS (Appendix 16). Use of YouTube channels to distribute the institution's video content recorded for blended online learning became standard practice in Cycle Two under the Covid-19 pandemic (Chapter 6). With videos added to the LMS, students had three methods of teaching themselves the CAD software online. This enabled participants to compare different approaches to teaching and learning CAD with in-house and commercial resources provided by Techsoft.

5.3.4 Planning CAD use in teaching practice

The examples used to teach students CAD either on campus or online were planned to be applied directly as resources in teaching practice: 1) The clock example to teach analogue time, 2) The dice example to teach shape, form, perimeter, and volume, and 3) The revolved three-dimensional shapes to teach applied design and complex 3D solids in mathematics. Students were advised in CAD lessons, and in the study guide, to use these to illustrate CAD in schools (Appendix 14: CAD Course-Online Guide-*2D Design* V3: Appendix 21: Preamble: "Before you can teach learners to use CAD, you need to be able to use it yourself. In this exercise, you are asked to design a clock which could be used for teaching analogue time in schools. Try to use your teaching practice to demonstrate your CAD skills by creating your own teaching resources."

The initial version of the step-by-step guide was a live working document onto which staff and student examples of good practice could be attached. Because most of the team were novice users, they reserved feedback on the drawing examples and method until the end of the

implementation. The draft lesson plans which accompanied the guide and videos went through three iterations (Appendix 15). During lectures and tutorials, we encouraged students to apply their CAD schools in school teaching practice between the consecutive weeks when CAD was taught. I also reminded students to use CAD on teaching practice in our *WhatsApp* communications. Lecturer-1, Lecturer-3, Lecturer-5, and Lecturer-6 later reported on students' use of CAD observed in their teaching practice assessment visits. I requested feedback from students in the *WhatsApp* group, online survey, and interviews which is presented in the reflection section.

5.4 Action

Findings which emerged from the first cycle collaborative action in the CPAR process are presented in this section. The action stages of this study involved implementing the blended online course; teaching of CAD from the lecturers' point of view; learning of CAD by students; and gaining feedback on students' use of CAD on teaching practice. The implementation of computer-aided design (CAD), as a blended online unit of work in the ICTE200 module, was managed using collaboratively designed resources. The additional online instructional video and tutorial examples enabled a multimodal form of study allowing students the flexibility to attend campus and study at home if they wished.

5.4.1 Blended online course with choice of mode of study

The CAD unit was taught over three weeks during May 2019. Students were afforded four double periods and two single periods, in two lecture weeks, amounting to seven-and-a-half hours' contact time. Specific face-to-face sessions were timetabled on the institution's lecture calendar and communicated using learning management system (LMS) announcements. I promoted these via *WhatsApp*: Researcher: "Please note that I am doing a practical *2D Design* CAD session in Pongola, with Lecturer-5, on Friday from 12:40 - 14:00. Please have a look at the resources on *ECI* [LMS]."

Theory contact sessions were used to combine teaching the background to CAD (Appendix 5: *2D Design* Tools - Presentation) with practical sessions that demonstrated drawing with CAD according to the lesson plans. Simultaneously, online resources were provided on the LMS to augment the contact learning teaching using the step-by-step guide and videos. Figure 5.6 illustrates how the CAD Study Unit 5 was presented to students on the LMS.

Figure 5.6

Screen Capture Image of ICTE200 Study Unit 5: Drawing Tools (CAD) from Moodle Learning Management System

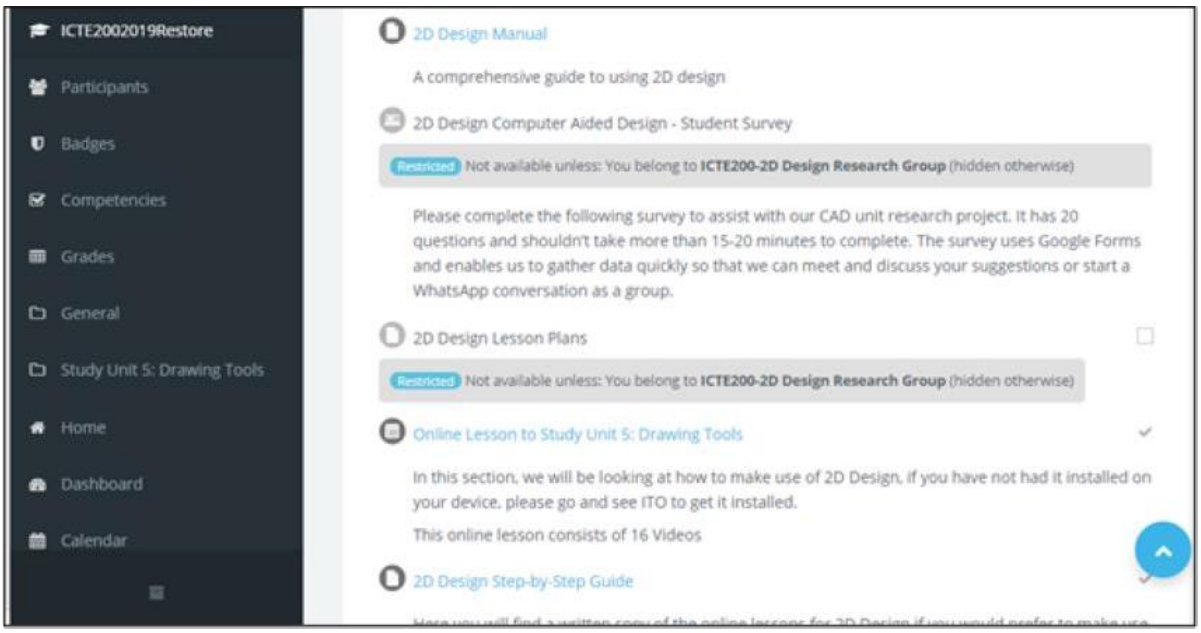


Figure 5.6 shows a screenshot of the LMS online resources: '*2D Design* Manual' (Techsoft tutorials), 'Online Lesson to Study Unit 5: Drawing Tools' (16 video lessons) and '*2D Design* Step-by-Step Guide' (PDF guide to drawing the clock). Students were offered a variety of approaches to learning CAD both online and offline, as a form of multimodal digital pedagogy (Rowsell, 2013). Because students were not obliged to attend lectures, with the option provided to study online, LMS analytics settings were enabled to automatically track students' online

participation on the course. Viewing of resources or completion of activities was not compulsory (Appendix 24: Student Usage Statistics for ICTE200 LMS Page used at MC Meeting – 18/10/2019). Students' observations on their contact and online learning experiences are shared in Section 5.6.

Lecturers were also invited to give feedback on course pedagogy during teaching (Appendix 27: *2D Design* Computer Aided Design Survey - ICT Staff - 2019 (Five staff responses)). Lecturer-5's survey response reflected closely the approach that was used.

Lecturer-5: "The best way is to take students through a guided exercise with resources (e.g. video) to assist them in their activity, then, introduce a more challenging design project which incorporates the same skillset."

Using collaboratively designed customised guides aligned with instructional video enabled online teaching and self-guided study for many students. Many opted for this option which meant that campus attendance diminished. However, discussion of modes of delivery revealed that not all wished to learn completely online. Some preferred a combination of face-to-face and online, or face-to-face only: For example: Student-1 [*WhatsApp*]: "Face to face method worked well for me." This did not surprise me because some of the second-year students displayed weak ICT skills and responded better to direct support from lecturers.

5.4.2 Implementing CAD (lecturer practice)

Lecturers were briefed on the location of online resources face to face and via email. Because all were active ICT lecturers, and most had attended training in 2018, no additional

group training was organised immediately prior to the course roll-out. I assisted Lecturer-5 in his first sessions as a form of mentorship. No significant pedagogical issues were reported during the teaching of CAD: all lecturers used the same resources shared on the LMS.

As module coordinator, Lecturer-1 set up online resources on the LMS page, including assessed CAD content. *Moodle* reports allowed tracking of lecturer use of the LMS; and showed that the CAD lesson plan and resources had been reviewed by all ICT lecturers and one student at the planning stage. Most followed the step-by-step routines presented in the lesson plans. Lecturer-4's survey comment reflected the consensus that the practical approach was effective: Lecturer-4: "Teach this kind of software using a project. Where a person gets a hands-on experience."

My team-teaching face-to-face practical sessions with Lecturer-5 took place over two consecutive weeks as two-hour long Friday afternoon practical lectures. While I presented the drawing method, Lecturer-5 toured the room giving one-to-one technical assistance. Initially, I was concerned that non-attending participants (Appendix 17: Student Attendance - Five Face to Face Sessions) might be struggling. I discovered later, using the LMS analytics data, that some had completed the CAD activities online without assistance on campus. Lecturer-5 relied on me for the first session, then taught solo sessions to complete the drawing.

After running the first shared session with Lecturer-5, Lecturer-1 requested that I assist him in the same way, citing that he was not yet sufficiently confident to teach CAD on his own. We followed the same co-teaching approach. His experience in setting up student devices complemented my experience as a CAD teacher. I reflected that the remote campus ICT

lecturers might also struggle on their own; and asked Durban campus staff to support Lecturer-3 and Lecturer-4 should I not be available.

5.4.3 Learning CAD (student practice)

Students learned CAD using a variety of modes of learning. Evidence of blended learning of CAD, using a variety of offline and online options, is available from contact-learning class registers (Appendix 17) and LMS student participation activity logs (Appendix: 24). However, some students reported their blending learning experience live via the *WhatsApp* group:

Student-7: “The videos are really good. I am a visual learner, that's probably the reason why I find them more suited to me. I have also found that the tutorial sessions with Lecturer-5 are quite helpful.”

Additional *WhatsApp* dialogues and survey responses show the ways in which students were actively learning in different modes both online and offline. As learning online was a novelty, a large proportion of the ICTE200 cohort opted to study from home. However, although attendance at the campus sessions was lowered, those who attended reported efficient task completion. Student-6 reported for her group after Lecturer-5’s first solo session: “The afternoon went very well. […] All of the students that were there submitted.”

5.4.4 Using CAD on teaching practice

Students were asked to implement their CAD learning in teaching practice during the weeks between learning CAD, either on campus or online, in course documentation (Appendix 14: CAD Course-Online Guide-*2D Design* V3). Students were also asked to apply their CAD skills to resource lessons during the year, and to save examples to upload in their ICTE200 portfolio at the conclusion of the year-long module (Appendix-19: Participant Dialogues Email and *WhatsApp*). Students reported on teaching practice during the CAD unit in the *WhatsApp* forum and student survey, and later in interviews. Evidence of original student drawings was visible in CAD portfolio submission. Their observations and reflections on this are shared in the following sections.

5.5 Observing the CPAR process

To observe the multimodal learning and application of CAD on teaching practice, in-person observations, blended online course activity, *WhatsApp* dialogues, emails, and online surveys were employed (Appendices 19, 26, 27 and 30). The general aims were to observe whether students were able to use CAD following instruction; and how they applied this learning to draw their own resources for teaching. Findings from the first cycle observation stages of the CPAR process are shown in the sections below.

5.5.1 Blended online course observation feedback

Real-time observations and student feedback on Cycle One brought specific critique and comments on advantages and challenges of teaching and learning CAD. I observed lecturers and students in sessions we shared and made notes and sketches. Lecturers and students shared observations on our co-teaching sessions at campus; and those who studied remotely shared their experience of learning online. Remote campus lecturers, Lecturer-3 and Lecturer-4 also provided some insight into their experiences via email.

The face-to-face tutorial sessions demonstrated the CAD activity in a traditional ICT demonstration format. Lecturer-5 and I introduced CAD live using the software on dual projector screens, with contextual examples presented simultaneously on a parallel *PowerPoint* slideshow (Appendix 5). Students used their own laptops to practise CAD and to complete drawings during the live session. While one of us demonstrated, the other toured the room assisting students. Students who were able to download the software to their personal devices made good progress. Those with Apple devices could not access the software easily. For example, in the session on 23rd May (Appendix 9f), it was observed that some students preferred to sit and watch the entire demonstration before completing the task (n = 4); while two others chose to use the online guide and to draw while the lecture proceeded (n = 2). Two students with one device arrived late and sat at the back of the room sharing their device. These two students did not complete the task in the session; however, later reported on the *WhatsApp* group that they had completed the work (Appendix 19).

All lecturers found themselves providing more support in setting up the software. In our co-teaching sessions this was not problematic in that one of us could tour the room while the other delivered the drawing instruction. When lecturers worked solo, they had to interrupt their teaching to deal with students' technical issues. I recorded positive observations from our shared sessions. I saw that all students were eventually able to access and use the software to draw in a single one-hour session. Providing up to three practical sessions over a fortnight enabled students to complete the guided drawing activities despite initial technical issues. I reflected that ICT labs with pre-installed software would enable more efficient teaching on campus.

At the time of delivery, lecturers gave suggestions for improvements to technical set-up and additional contexts which they considered for teaching CAD at IP level: Lecturer-3 advocated "creating resources"; Lecturer-4 advised "teaching of geometry, time, fractions, life skills, colouring-in"; and Lecturer-5 suggested: "designing characters for animation purposes." I assumed that they were taking a teaching-centred contextualised view highlighting CAD's value across multiple subjects.

5.5.2 Observing CAD implementation using *WhatsApp* and email dialogues

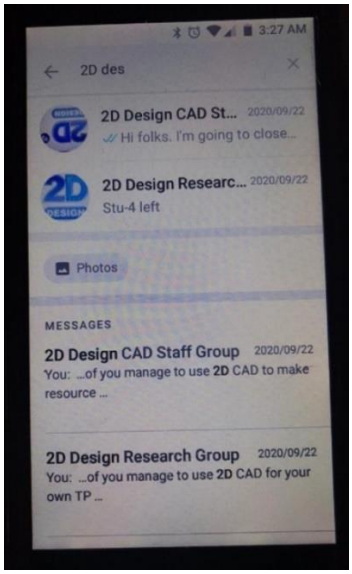
WhatsApp and email recorded spontaneous 'real time' communication between participants alongside face-to-face sessions. *WhatsApp* messenger data enabled a continuous form of on-and-off-campus conversation which aligned with participants' preferred form of

online social communication (Cansoy, 2017). Such data also enabled me to observe students who were working remotely through their real-time reports.

I identified the separate staff and student *WhatsApp* groups on my cellphone using various *2D Design* icons, as shown in Figure 5.7. Transcripts of the two group chats were used for analysis (Appendices 19 and 30). In addition, five students, (Student-1, Student-2, and Student-4, and SRC reps) opted to communicate with me directly via *WhatsApp*. Only Student-2 requested not to be part of any *WhatsApp* group. Student-2 communicated directly via text, email, or face to face. Student-2's stance indicated that there was no ideal form of communication for all.

Figure 5.7

WhatsApp staff and student groups (mobile phone screen shot)



WhatsApp reinforced my communications as a researcher and enabled me to request feedback in an informal manner, for example, in following up on the recruitment workshop and in inviting students' observations: Researcher: "Feel free to share your experiences of learning and using *2D Design* CAD as you progress through the course and when you use it in your own work. Decide whether you want to use quotation marks; use them consistently throughout."

I also used email to explain the research process. For example, students were asked to provide feedback using their choice of the various communication options provided: Researcher: "I would be very grateful to get some feedback on your CAD learning experience this week. […]

You can choose how much you wish to contribute. Please use *WhatsApp*, 20 question survey, email response, or a combination of these."

During implementation, I gave *WhatsApp* feedback to lecturers from face-to-face sessions I facilitated with Lecturer-1 and Lecturer-5: Researcher: "We had 18 students on Friday. We got through the two lessons plus extra content on the use of bitmaps - imported images." *WhatsApp* enabled students to give spontaneous and direct information on their various online and offline learning approaches. For example: Student-11 reported his intention to attend face-to-face sessions: Student-11: "I would like to attend the session on Friday."

In the research group, seven attended tutorial sessions (Appendix 17). Student-4, Student-6, Student-8, and Student-9 used the group to express gratitude for the support of lecturers: Student-9: "Lecturer-5's class was great help. A real eye opener. […] Was able to submit and quickly discovered how *2D Design* would be so useful for my coming assignments and lessons."

Reciprocating, I shared news and gave positive feedback to the student group. For example: Researcher: "Thanks to Student-8, Student-2 and Student-6 for your attendance this morning. If anyone needs help with the clock activity, please email me […] you can set up a time with me or Lecturer-5."

This stimulated similar constructive responses from remotely studying students, with some acting as CAD promoters in the team: Student-7: "I've completed my clock today. It wasn't super easy in the beginning. Once you get the hang of it, *2D Design* becomes super fun

to use. It has a lot of cool features." The *WhatsApp* groups enabled pre-emptive warning of future events through sharing of successes and 'extras' included in face-to-face sessions: Researcher: "I have set up extra *2D Design* sessions on Friday [date] […] I will show how to use *2D Design* like Photoshop to manipulate images."

Having completed the sessions, and their CAD drawings, participants seemed comfortable sharing their success through 'real-time' instantaneous feedback on the *WhatsApp* group. Participants who gave little feedback in other forums, provided direct feedback to me via *WhatsApp*: Student-3: "The face-to-face sessions helped, especially after watching the videos and exploring the software on my own." Student-8 shared gratitude for guidance on 'fills' for colouring her clock design: "Thank you for the fill brief. It's really helpful." They also shared functional issues with the software: Student-7: "The only thing I have a bit of a problem with, is the undo button. It only does it once."

One student, Student-4, attended two face-to-face sessions and arranged additional one-to-one support. She was concerned about drawing the clock hands as separate parts and about submitting the drawing activity on the LMS: Student-4: "Morning. Can I come see you, I need help with the clock." This was a successful meeting. She submitted her completed clock. Student-4: "Thank you and Lecturer-5 for helping us at campus." Student-4 passed the module without completing the workshop peer review activity.

I observed that students used *WhatsApp* to actively participate in dialogue and be part of "social planning" in what Werner Ulrich labelled "critical systems discourse" (Ulrich, 1996, pp. 6-7). The *WhatsApp* groups helped me to communicate proposed changes for discussion

and to gain feedback timeously (Christensen, Horn, Caldera, & Soares, 2011). The online group communications enabled participants studying at home or on campus to raise issues related to pedagogy, mode of learning in lectures or online, and teaching practice issues as they were learning.

5.5.3 Staff observations via *WhatsApp*

The staff *WhatsApp* group produced less data than the students' group. After I communicated student responses to initial set-up and use of the software, communications from staff were limited to operational issues relating to student access to software licences loaded to the LMS page. Lecturer-1 used the group to assist Lecturer-4 on Campus-3:

Lecturer-4: "Two students asked for assistance with installing the 2D software… No other queries at Campus-3 yet."

Lecturer-1: "Hi Lecturer-4, I'm making a how to install guide for the DL students, once complete, I'll send you a copy which you can email to them."

Lecturer-1 identified that an additional manual which explained software installation would help students who were unable to attend campus. By the end of 2019, this software installation manual was developed as a PDF document for use by all students. On remote campuses a distance-learning licence was adopted institutionally as the most economical software option for multiple campuses.

Staff discussed the new distance-learning licensed version of the software available at remote campuses: Lecturer-4: "They cannot save anything when working in Demo mode." The

software had limited features preventing students from copying software and restricting saving/exporting in drawing file format. Conversely, Durban campus-based students had access to a full licence which allowed exporting in common drawing file formats. CAD installation created operational issues for me in ensuring that students had equal access to the same resources, while budgets were devolved to each campus.

5.5.4 Survey responses collected during the CAD course implementation

Online surveys gathered feedback via the LMS for students or by email link for lecturers (Appendices, 27, 28 and 30). Questions drew on participants' observations of the teaching and learning of CAD in a blended online course, as well as its application in teaching practice. The sub-sections below summarise responses to Research Questions One and Two as well as to wider socio-technical issues.

5.5.4.1 Lecturers' responses to CAD resources and pedagogical approach

Survey responses related to general impressions of teaching and learning CAD were on the best pedagogical approaches to teach and use CAD in developing resources for teaching practice. Feedback on design of study guides and drawing resources initially came from the lecturers using the resources shared. I incorporated lecturers' suggestions into revised versions loaded onto the LMS for student use.

In his role as a remote "critical friend", Lecturer-2 gave general suggestions on the teaching of CAD and ICT after using the resources himself: Lecturer-2: "In teaching ICT, it

would be far more valuable to challenge learners to create artefacts of value rather than just simply being proficient in using certain software." Lecturer-2's editing and review of the videos, after his user trip, helped us to rationalise content for the student reader. Lecturer-2: "I think teaching a person the tools and the interface is key, before taking them forward […] as opposed to jumping in to create something."

Lecturer-5 continued where Lecturer-2 had left off, providing critical feedback on vague areas in the instructional material. Lecturer-5: "I would set up the space as a first step […] as a first-time user, you wouldn't appreciate the repercussions of making sure that your page was the right size or that the gridline spacing was important."

Lecturers gave positive feedback on the flexibility of the resources required for teaching both students and untrained colleagues. Lecturer-3: "I believe that learning different types of software in different ways can empower an individual."

Some lecturers made superficial use of the illustrated guide and attempted to teach themselves the software using YouTube videos. For example, Lecturer-1 was initially sceptical about teaching CAD. Lecturer-1: "It's time consuming and should be taught separately from the computer courses." Lecturer-1 was also dismissive of the 'home-grown' resources: Lecturer-1: "I would rather teach a brief introduction to Paint." This contradicted his willingness to help produce videos as technical experience. Lecturers' varied reactions to CAD encouraged me: this reflected their freedom of expression in the study and showed that they were engaging critically with the content.

5.5.5 Students' preferred modes of learning CAD (RQ1) revealed from survey

Student responses to the online survey gave insight into their perceptions of learning CAD; and its value to novice teachers for creating resources, for teaching technology, and other creative subjects. The limited number of responses (27% response rate compared with 100% response rate from staff) may reflect students' over-exposure to online surveys for every academic module completed in the institution.

Student-2 and Student-4 both expressed a preference for face-to-face learning in a traditional practical environment while Student-10 preferred to study CAD via the online videos. Student-4 justified succinctly the preference for face-to-face learning in response to Question 6:

Student-4: "I found the practical workshops more efficient. If you're not a computer person, and try to figure this out on your own, it's a bit difficult. The practical sessions mean you can ask for help whenever you are stuck..."

Student-2 and Student-4 recognised the value of viewing and contributing to the lesson plans prior to learning CAD. Student-2 summed this up in his response: "If we can produce resources with *2D Design*, it shows what knowledge we have gained by using the various tools in the program to create our relevant resources."

The student survey tool provided me with some direct insights into the varied experience of students with a background in ICT use (Student-2) compared with a student with less ICT experience (Student-4). One studied remotely online using the videos and guide, while the other relied directly on my expertise to explain what was explicit in the written guide and

videos. These two students emerged as consistent collaborators, contributing at all stages. Their alternative viewpoints exemplified students learning CAD in different ways through differentiated instruction (Boelens, Voet, & De Wever, 2018). This was required to successfully teach CAD to the diverse student-teacher group.

5.5.6 Observed use of CAD resources in teaching practice

The survey reported participants' use of CAD in teaching practice (TPR). Students provided feedback on their use of CAD resources in TPR in their survey responses: Student-10: "For an ICTE200 assignment, I designed a clock and classroom layout on *2D Design* which I found quite simple. For TP, I made some drawings of shapes to show my learners." Lecturers provided feedback from their TPR assessment visits to schools: Lecturer-3: "[…] I have seen a few examples of students creating images using CAD for their worksheets or posters."

Because some lecturers did not directly assess student participants in the research group on TPR, they reported more generally: Lecturer-5: "Students […] used it in NSTI101 lesson assignments." This revealed that students were using CAD as a multidisciplinary illustration tool and developing their own original resources. Use of CAD resources for teaching practice is revisited in interviews, below, which took place after the CAD course had been completed.

5.5.7 Interview transcripts

In interviews, participants reflected on the teaching and learning of CAD, as well as experience in applying CAD in teaching practice. As final marks for the module were collated

in November, I could not discuss their assessment in interviews. Students' module outcomes are discussed in Chapter 6 as comparative reflection and re-planning for the second cycle. The findings from interviews are organised under themes extracted from the framework analysis and the nominal group workshop's refinement of these.

5.5.8 Definition of CAD for primary teachers

A better definition of CAD, for primary education, was considered necessary to enable consistency in teaching it to student teachers. Various ways of defining CAD were suggested. Positioning CAD in the ICT module with a suite of other multimedia software tools was also considered important. Lecturer-3: "I believe that learning different types of software can empower an individual. CAD allows teachers to create their own resources, and this is extremely important." Choosing the right contextual primary school teaching example to train teachers with was an imperative. Lecturer-5: "You see a clock is a very good example."

I justified the pedagogical approach used in student training, including a contextual explanation of CAD and its value for schools, as a method which could be transferred into classroom delivery, when interviewing Student-2.

Researcher: "If you looked at the lesson that you followed, it's more than one lesson. It might be a week's worth of activities in a school. You have done much more in 45 minutes than a child would do. Once they can use CAD, you don't need the lesson plan."

Learning CAD to produce visual material, instead of traditional rote learning, was considered by Student -11 crucial to promoting CAD: "I think kids today are so involved with technology.

It's something that they are more comfortable with than with pen and paper. If you involved CAD in their learning, they might respond to it better than they do to schoolwork where they're mostly reading from a book and answering questions."

Staff's impressions of learning CAD themselves added to their appreciation of it as an educational tool to modify traditional teaching pedagogy by creating blended online multimodal lessons. MAT-1: "Putting stuff online works much better. As a lecturer, you video yourself designing stuff and then you put it there for students." Learning in the same way that students/learners do, following a design process (Nordlöf, Höst, & Hallström, 2022), was considered valuable for lecturers to trial resources, share experiences, and encourage reflection. Lecturer-2: "You have design criteria. You have a problem to solve. It forces you to think in a non-linear way to use your problem-solving skills as well as your creative side. So, for me, using it [CAD] is a key in making a person think."

The practical project-based approach assisted lecturers to understand CAD as a design tool, thus enabling problem-solving activities. Lecturers recognised that they might need to change their teaching approach in teaching CAD and developing the: "…ability to answer technical questions and some non-linear thinking." (Lecturer-5).

On reflection, I was pleased that both students and lecturers, after only one cycle, recognised CAD's wider value as a versatile design tool. Reflecting on the shared experience of learning and applying the tool soon after using helped us to better define CAD as a primary school resource.

5.5.9 Designing ICT/CAD courses that are fit for primary schools

Interviews discussed CAD course's fitness for purpose in primary education. These included: gaining help from schools which teach CAD; finding additional resources on the internet; introducing free online CAD software; designing more culturally situated contextual examples; teaching the relationship between CAD and geometry to improve mathematics skills; and using the design process to link CAD to natural sciences and technology taught in primary schools. Lecturer-2 summed it up.

Lecturer-2: "It forces you to think out of the box, to solve problems within design. It's not a linear, or straightforward, problem when you're designing. It requires you to think, or attack a problem, by seeing it from multiple directions."

To facilitate a better CAD course, sub-themes emerged: staff requiring training in further CAD applications and examples; finding justification for teaching CAD in CAPS; more refinement of formative and summative assessment; and critique via peer review. For example, Lecturer-5 reflected on ICT-orientated assessment options he would use.

Lecturer-5: "One way is to say: 'You have to write something explaining what you did.' The other way is to say: 'It must be this height, this width and it must be able to […]' You stipulate criteria, and you mark them against that. I would probably take the latter route."

Preferred modes of learning were re-addressed, and preferences suggested, for example, blending of instructional videos, face-to-face lessons, and one-to-one tutorials with a mixture of formative and summative assessments. No single preferred pedagogy was dominant. The most poignant reflection on this came from Lecturer-5 referring to students' prior ICT learning:

"It depends on the exposure the students have had to computers before. […] It depends on what their level or previous experience is."

Pitching activities correctly for primary school teachers and designing authentic assessment for practical activities for school settings, were thought vital. At the core, creativity and design process thinking resonated with Lecturer-1: "I suppose the key skills would be allowing students to let their creativity run […]." Lecturer-1 valued the design-orientated approach used in the course: "I think the only way to do it is to follow the same style that your videos do and ask them to produce their own design in their own manner."

Building 21st century skills, and 4th Industrial Revolution consciousness, were used as wider socio-technical contextual justifications for learning CAD. Concern for the environment and high youth unemployment, were raised as real-world contexts for teaching transferrable skills.

Lecturer-1: "CAD is where people can come alive because they have no sets of instructions about what to do and how to go about doing it. In a sense, … it's helping them prepare for the real world because, when they get to a job, they won't have sets of instructions to follow."

I reflected that this technicist view (Petrina, 2003), in which the tool, rather than the mindset of the user, is considered emancipatory, was a prevailing viewpoint amongst the ICT lecturers. This is not surprising when ICT lecturers are programmed to convince students of the importance of ICT skills.

5.5.10 More flexible adaptable online and offline courses

The study identified a more flexible form of delivery for teaching CAD effectively using traditional offline lectures and one-to-one tutorials, as well as online videos and resources provided via the LMS. The convenience of having online options available was reinforced in Student-1's comment: "Sometimes online learning and videos and stuff really help if you have difficulties getting to campus." In-person engagement opportunities with lecturers were considered equally important: Student-3: "The face-to-face sessions also helped a lot especially after watching the videos and exploring the software on my own."

To improve online resources, scripting of video lessons, with subtitles, was deemed a future priority for those with hearing impairment or language difficulties. Scripting of online courses, as staff development, was valued for a portfolio-based form of higher education teaching portfolio, as I discussed with Lecturer-1. Researcher: "We are getting to a stage now where we might have to start keeping a record of how we teach. […] By moving things into an online course, you can present this as your lesson plan."

Students and staff presented varying views of their preferred modes of learning. Most of the research group pointed to instructional videos as a default for learning CAD in the online space. The research group valued the illustrated step-by-step guide and face-to-face options as references which augmented videos and was an inversion of the original motivation for creating videos to support the guides and live lessons.

5.5.10.1 Lecturers' learning mirrors students' learning

Lecturers (Lecturer-2 and Lecturer-5) learned CAD for the first time alongside the students. Both chose different pathways to learning. Lecturer-2 opted to study with the manuals and videos in a 'user trip', in a similar way to an online student, making himself a remote critical observant user (Open University, 2020). Lecturer-5 chose to attend the workshops and tutorials I presented for students as peer observation or 'work shadowing' (Cambridge Dictionary, 2020). Both lecturers' learning approaches assisted me in gaining deeper insight into pedagogical delivery within the first cycle.

Lecturer-2's experience of learning as an online student user produced feedback on the technical difficulties of learning CAD on a small single laptop screen: "For myself personally, I found it easier to work on a dual screen. Typically, when you work with graphical software you require a large desktop space." Lecturer-5's experience of observing CAD lectures I delivered informed his interpretation of pedagogy. For example, use of the advanced features taught in the clock exemplar: Lecturer-5: "I wouldn't have thought of using a clock myself, but I think it's a very good example. So long as it uses the rotation [tool]. Which is one of the advanced, but very clever, features."

Lecturer-2 and Lecturer-5 gave me fresh perspectives on the learning experience of staff and students. Lecturers trained previously did not experience the same training and resources as students. Lecturer-5 used his unique experience to reflect on technical challenges students might experience in schools: Lecturer-5: "I wonder about when they get into primary schools, whether any will have a device to use, daily, in the classroom? I think many of them

won't." Lecturer-5 also adopted the team-teaching approach I used with him in Cycle One in his online webinars in Cycle Two (Chapter 6).

5.5.10.2 Staff views on the most appropriate pedagogy for teaching CAD

Suggestions in interviews on the best pedagogical approaches for teaching CAD, returned to the multimodal approach presented in survey responses. These acted as a form of triangulation by returning to reflect on the action after the action (Schön, 1987). Staff interviews revealed varied appreciation of the value of student teachers' learning of CAD for teaching practice. All supported teaching CAD to student teachers at the end of the cycle. For example: Lecturer-3: "CAD will allow teachers to create their own resources."; Lecturer-4: "Teachers need drawn resources and can create their own with CAD."

When asked whether they would change their teaching style to teach CAD, none considered that they needed to modify their teaching style to teach CAD. For example, Lecturer-3 stated: "I think that the way in which we are teaching ICT at the moment is working well." Only Lecturer-2 considered that it might require lecturers to change their style and develop: "…ability to answer technical questions and some non-linear thinking." Lecturer-2's detachment as a contractor, and experienced online lecturer for other organisations, may have elicited his more worldly answer.

All five lecturers reinforced the use of alternative primary school contexts for primary school learning of CAD. For example, Lecturer-5 suggested: “I would have done a two-dimensional house, or a car or some sort of everyday object, that the kids draw a lot in class because they relate to it.” Such constructive suggestions are indicators that ICT lecturers became more interested in designing ICT/CAD courses that were contextually fit for purpose, through participation. This subscribes to ongoing concerns that ICT courses for teachers should align with 21st century classroom needs instead of simply teaching basic Office software (Kirlidog *et al.,* 2018).

5.5.11 Obstacles to CAD integration into the curriculum

Recognising the perceived and real obstacles to CAD was necessary in developing understanding of the best pedagogical approach to teaching the subject. Interviews exposed lecturers’ and students’ views on obstacles to changing practice. Conflicting perceptions of the value of *2D Design* CAD over other ICT resources, were shared: Lecturer-2: “Learning CAD may improve quality of teaching.” and Lecturer-1: “It’s time consuming and should be taught separately from the computer courses.”

Alternatives to *2D Design* were discussed; this was not a standard package used in South African schools. Lecturer-1 considered that Microsoft Office’s basic drawing tools were sufficient for student teachers: Lecturer-1: “I would rather teach a brief introduction to Paint.” However, Lecturer-5 suggested Google Sketchup as a more technical 3D CAD option.

The decision to teach CAD to generalist primary school teachers, was endorsed. Lecturer-2: “I think the course did a good job at pitching at a level where it takes a beginner through the basics.” Lecturer-1 was inclined to teach CAD in the final years of primary school. Lecturer-1: “I think grade 6 or grade 7 approaching high school level. Just because I find that their cognitive reasoning and understanding is more developed so they can understand why they are doing this.”

I reflected that one of the first questions that Lecturer-5 raised in the first planning meeting related to the relevance of CAD for primary school teachers. Given the success of participants in learning CAD for the first time, I reflected that some of the lecturers’ initial reticence came from their fear of the unknown rather than in appreciation of the potential and willingness of students to learn new skills.

5.5.12 Student teachers’ reported and observed use of CAD in teaching practice

Addressing Research Question 2, observations, dialogue from interviews, and visual resources drawn by students, provided me with further evidence of their use of CAD in creating visual resources for teaching practice (TPR). Students shared valuable anecdotes from their lived experience. Staff, as teaching practice assessors, also provided observed and hypothetical views on student teachers’ integration of CAD into primary schools.

5.5.13 Facilitating students' use of CAD for teaching practice (TPR)

The timing of training in the ICT programme was considered a crucial factor in supporting students' earlier use of CAD in TPR. Time spent practising ICT skills in teaching practice was seen by Student-11 as a key part of a degree.

Student-11: "With an education degree, I think more of it should be practical work. Quite a lot will be ICT-related stuff. I'm not sure how much time should be spent studying it, but we should spend a lot of time using it."

Student-11 also identified how he would introduce CAD in school:

"I would introduce it in, obviously, the computer literacy lessons. Maybe for 15 minutes, towards the end of the lesson maybe you could say: 'Let's design a robot! Okay, and we want to look at, obviously, the different forms of robot.'"

The institution's teaching practice policy requirement that students provide evidence of producing their own resources in their portfolio of evidence was considered an opportunity of promoting CAD skills. Student-11 emphasised CAD's value for developing resources. Student-11: "The main use for CAD would be in creating resources for teaching. So, worksheets, activities … that sort of thing, would be the most useful application of CAD." Lecturer-1 reinforced this.

Lecturer-1: "So, the teaching practice model, […]: students aren't allowed to copy a worksheet out of their textbook and add it into their portfolio. Students must create their own resources. So, CAD can be one way of creating their own resource for teaching practice."

I resolved that credit for doing this should be explicit in future teaching of portfolio assessment rubrics.

5.5.13.1 Obstacles to the use of CAD for teaching practice

Obstacles to the use of CAD in teaching practice (TPR) were raised in student and lecturer school-teaching observations and interviews. These included issues such as schools' perception of the value of ICT and CAD in classroom teaching; gaps in education between student teachers and incumbent teachers; overcoming the worksheet culture in SA schools, and practical hardware and software access issues.

The inconsistent distribution of resources across the school sector, was summarised by Student-4:

"I think it's mainly because some schools don't have the technology. So, it would be hard for me to teach [CAD] […] Obviously, you need computers. If you were teaching practically."

Students' lack of experience and resources to practice and teach ICT and CAD were also highlighted. Student-11 recounted his personal experience:

"I think there is also a big…trouble with students themselves, because a lot of them aren't used to working with computers naturally, because they are from an under-privileged background. I remember, where I grew up, we didn't get our computer until a few years afterwards. But then I picked it up."

Student-11 alluded to institutions providing devices for students. Student-11: “So, if everyone can have an assigned laptop, something they can work with all the time, that would aid in them getting used to the technology and then carrying on with CAD.”

Students were assumed to have their own device for study, given the institution’s BYOD policy. However, it emerged that some students borrow family or friends’ devices, to submit online assignments and download resources from the LMS on campus using the free Wi-Fi; while some rely on staffroom, or mentors’ computers, to complete work while on teaching practice. Both scenarios make it difficult to use or teach CAD effectively.

Student-11 summarised the ideal scenario for schoolteachers and students: “If everyone can have an assigned laptop, you know, something they can work with all the time. That would aid in them getting more used to the technology and then carrying on with CAD design.”

5.5.14 Schools’ ability or agency to integrate computer-aided design skills into the curriculum

Student teachers found it difficult to confront TPR schools regarding educational technology provision. Some reported not being permitted to use their own ICT resources for lessons. In some cases, there were no ICT facilities available. Student-1, for example: “The sad thing is that the school I’m in don’t have computers where we could show the learners what we actually did with CAD.”

Student teachers reported that schools were unwilling to allow students to innovate during their lessons and expected students to use the school’s prefabricated worksheets. Some

recognised TPR as an opportunity of using CAD to redevelop resources. Student-1: “I could also just take the worksheets that the school has prepared and recreate them my own way to beef up my portfolio.” Some proposed that schools’ unwillingness to embrace new technologies, such as CAD, came from fear of the unknown, and their own lack of competence in using ICT tools in teaching. Student-1: “The school I’m in… the only computers you have are in the office. So, children don’t have exposure to working on a computer.”

Some stated that an obstacle to integration of technology into classrooms was the teachers themselves. Some reported negative attitudes and lack of motivation of in-service teachers towards teaching with ICT.

Student-2: “I think a lot of the teachers now, particularly those that have been teaching the last fifteen, twenty, forty years, aren’t as proficient, or aren’t as willing to learn how to use CAD, and any different technology, to effectively teach it to our learners.”

Students also reported that peers had responded to teachers’ lack of ICT skills by providing in-service training on teaching practice. Student-11: “At my friends’ schools, they’ve had cases where they end up, … explaining how to run just basic software.”

Others reported that in-service teachers resorted to using their personal laptops when their schools were unable to provide resources. Some worked under strange conditions, with learners acting as technician/caretakers to ensure they didn’t misuse school laptops.

Student-1: “The school I’m in, there’s one laptop that student teachers are allowed to use. When we’re allowed to use it, they allow a student to set it up [...] When I asked to do a *PowerPoint*,

[…] Every time I needed the slide to change the teacher would say: 'It's ok you can use the student to change it', because the laptop was in the next office."

Reasons provided for learners – and student teachers' – lack of access to resources included schools' paranoia about vandalism; corruption in the supply chain; and theft and inadequate implementation of government's ICT in schools' policy. The perception that government schools are poorly resourced is reinforced by student teachers' personal TPR experience. Student-1: "Most of the schools in KZN are government schools, and you hardly find a school with proper technology, like projectors and stuff." Student-2 pointed to lack of teacher competence in ICT. "I think: A. The educators aren't... Not all of them are… good enough to teach it effectively and B. They just don't have the resources."

Participants reported that most problems in existing schools attended for TPR, were due to poor resourcing and lack of ICT training for in-service teachers. However, socio-technical barriers such as security and schools' provision of staff devices were identified as additional hindrances to implementation of ICT innovations in schools: Student-1: "They don't have a problem [teaching with computers], but it depends now if they use their own private laptop or the school laptop."

5.5.14.1 Students' lived teaching practice experience with CAD

Planning lessons that included ICT and CAD were considered important in raising awareness of CAD's value. Planning CAD lessons, on campus, as part of ICT lessons, was

seen as a good way of sharing practice, and preparing for teaching. This also enabled more appreciation of CAD for multidisciplinary subjects other than solely ICT lessons.

Student-1: "I did a [Maths] lesson on 'Symmetry' and because we couldn't get shapes that weren't coloured in, to show the lines of symmetry, I used *2D Design* … and printed it out and enlarged it so the learners could see."

Teaching practice portfolio assessments that include CAD examples, as assessed items, were stated as a motivator for learning and using CAD. The clock example was considered a good contextual resource for teaching time (both online and offline), as explained:

Student-2: "I will use the same one [clock], because it allows you to bring in the maths […]. So, not only are they learning a maths skill, and a life skill - learning to tell the time - they're learning the CAD skills."

Teaching CAD too early, before basic manual drawing skills have been developed, was considered problematic. It was suggested that manual drawing and CAD be taught in parallel as part of design projects. Participants admitted that learning CAD by teaching it in schools, was a good way of accelerating and supporting learning. Participants suggested that simpler examples teaching drawing of basic shapes within a clock template drawing, may motivate student teachers to create reusable CAD resources. Student-11: "[…] You could also do a very simple one with shapes. […] You could upload the clock face and just let them add the numbers in the correct order." This suggestion cheered me because it showed that Student-11 was thinking like a teacher and designer, by trying to improve on the example taught.

Lecturers endorsed teaching practice to practise CAD skills with observations from TPR assessments. Lecturer-3 reflected on recent TPR visits: “Students are required to complete a portfolio in 1st and 2nd year ICT modules, I have seen a few examples of students creating images using CAD for their worksheets or posters.” This was reinforced by MAT-1 (mathematics lecturer and CAD user): “Yah, they really amaze me when I go out to crit them […]. They will come with these 2D models, 3D models [designed on CAD] and they will actually teach.”

Participants pointed to CAD’s value as a pathway to learning other subjects for extension of technological knowledge in school. For example, Student-2: “I think it gets them comfortable … with the technology. Not just the CAD, it gets them comfortable with other technology as well.” Again, I was heartened that Student-2 considered alternative applications for CAD in teaching. This aligned with findings of my master’s study in Limpopo (Thompson & Alant, 2021), which revealed that out-of-school young mothers learned basic ICT skills, such as keyboard and mouse manipulation, more easily by means of drawing tools.

5.5.15 Student and staff perceptions of how to improve integration of CAD into teaching practice

Improving integration of digital skills, such as CAD, in TPR, is considered essential for 21st century primary school teaching (Department of Basic Education, 2021). To assist this process, it was suggested in interviews that the year-long ICTE200 course be relocated to the first year as a degree programme improvement.

Student-2: “I think it may be useful to teach this in first year so that when we start teaching practice in 2nd year, we are familiar with the programme and able to successfully create our own resources.”

To support increased online learning using diverse software packages, extra IT support for students was identified as a necessity. Up to this point, the organisation had relied on enthusiastic champions such as Lecturer-1.

Lecturer-1: “This method of delivery, where I’ve taken all the key features of contact lecturing and put it online, has been beneficial to the students. They can work in their own time, and at their own pace, if they meet the assessment deadlines.”

Lecturer-1 identified that there were inconsistencies in staff skills level, in student support on the other campuses, and in courses offered in traditional distance learning.

> Lecturer-1: “The other two campuses are on a little bit of a back foot because they don’t have the same expertise. […]. And distance learning students get no additional face to face support.”

Improving ICT and learning management system support, to aid multimodal online modes of delivery, was flagged. The need for this is summarised in Student-11’s recounting of his CAD studies: Student-11: “I attended a few of the lectures. I read through the beginning of the online Word guide, and the Techsoft tutorials, but then I couldn’t really understand what exactly was going on […] So, I ended up watching the videos on YouTube of how to get certain things done.” To assist with learning practical ICT software, an in-house video repository, or

dedicated online video channel, was eventually implemented by the institution. This may have been to mitigate the studying of students via freely available online resources on the internet.

I was proud of the video resources that I had produced and tried not to be upset that some students had reverted to YouTube to augment their studies. Lecturer-5 identified another issue with training students with videos.

Lecturer-5: "And as we are training our students online, are they not going to end up also teaching online? You'll have all of your kids at home, or wherever, looking at a screen of a teacher doing something. […] You won't be able touch it, or smell it, or taste it."

His vision of the dehumanisation of learning online, in early 2019, became a reality for us all in 2020 when we were forced into "emergency online teaching" (Singh, Proches, Leask, & Blewett, 2020) under the Covid-19 pandemic lockdown.

To encourage electronic portfolio work from ICT modules to be used in teaching practice, credit for TPR module assessments was suggested. Inclusion of resources produced with CAD in these was agreed on in the interviews as a rational approach. Lecturer-1: "I think CAD can be used in teaching practice, because, according to our model […], students aren't allowed to copy resources out of a textbook." and Student-2: "I would, say it should mostly be in terms of creating resources, because you don't want to see copying from textbooks and off the chalkboard."

I saw that integration of CAD into TPR was necessary as part of wider ICT skills training. Discussion of CAD with students raised suggestions of additional video production required by ICT skills student teachers: Student-1: "One thing that I wanted to know is […]

Like, how do you, you know [make them]? Some people have got all this animation on their videos." This final point suggests the need to move ICT and teacher-training courses away from solely teaching MSOffice end-user applications, to teaching multimedia ICT skills. Students were able to predict how these additional skills could be incorporated into lesson plans. Student-2: "I would introduce it [CAD] in, the computer literacy lessons… maybe for 15 minutes, towards the end of the lesson, you could say: 'Let's design a robot!'"

The benefits of using CAD to draw as an alternative to manual drawing for learners without natural drawing ability were discussed. Student-2: "It allows for those who maybe can't draw, but still have a desire to be part of design, to create something on the computer which is maybe just as good as someone who can draw manually."

Student teacher Student-1, acknowledging her limited drawing ability, conceded that CAD had empowered her to draw: Student-1: "Because I can't draw to save my life. […] CAD, it's just like Tick and Go! […] it's easier."

Varying opinions were shared regarding the preferred pedagogical methods for learning CAD in teacher education and transferring this into classroom teaching. Such was influenced by perceptions of cognitive levels and of teaching learners ICT in school computer labs.

Student-11: "I wouldn't teach in the same way we were taught. With learners of that age group, I think we would have to have a more hands-on approach […] I think they'd have to spend more time in the computer lab with the teacher talking them through it."

Student teachers used their personal experience to prioritise technical features to show learners, if teaching CAD themselves: Student-1: "The thing that I kept reminding myself was

to keep checking the degrees at the bottom [of the screen] because sometimes you go off, and then it's too big or too small. So, just to check it and make sure your lines are straight when you're selecting an image."

A form of "experiential learning" (Kolb, 1984), or learning in action, emerged as key to learning CAD. For example: learners should be allowed to learn from their mistakes and get things wrong: Student-2: "There's no shame in needing help. I think you've just got to remind them that you don't have to be an expert and there's nothing wrong with being wrong." This final quote is reassuring: it reveals that Student-2 had developed an empathic and inclusive attitude to classroom differentiation, and an appreciation of experiential learning.

5.6 Reflection: Staff and Students' Collaborative Reflections on the CAD Course Pedagogy

Findings from the reflective stages of the first cycle of the CPAR process are presented in the sections below. Reflection on the action research project included: peer critique of CAD outcomes; views on multimodal blended online pedagogy; use of CAD on teaching practice, and consideration of the wider socio-technical systems influencing students' learning and application of CAD in teaching practice. Lecturers and students reflected on the variety of pedagogical opportunities provided for learning CAD. They also reflected on appropriate use of CAD resources for teaching practice.

5.6.1 Peer critique of CAD outcomes

Lecturer-1, Lecturer-2, and Lecturer-5 trialled peer assessment of clocks, with students critiquing one another online, as a formative activity. In addition, CAD drawings were included in the portfolio of evidence, as examples of teaching resources, thus concluding the year-long course. Lecturer-1 developed the online peer assessment activity using a peer review '*Workshop*' activity provided on the LMS. I asked him in our post-implementation interview to explain how he did this. Lecturer-1: "Every person who has submitted can randomly review 5 or more other peoples' work. It's anonymous unless the students have put their names down. […] The students get a mark for submission as well as for being the assessor."

The tool enabled random or purposeful allocation of peers to critique one another's submissions online. Lecturer-1 developed the LMS-based portfolio submission portal allowing students to submit their CAD drawings for their e-portfolio. The peer-assessed activity was the clock design (Appendix 14). Students judged one another's designs holistically, because the drawing task did not have objective criteria for assessing the CAD drawings. I noted at the time of teaching that peer critique would be more meaningful to students should the drawing activities have clearer assessment objectives.

In theory, the use of student critique aligns well with teaching practical subjects as a participatory form of self-assessment (Petrina, 2018; Williams *et al*., 2017). The *Moodle* 'Workshop' tool works well for small online groups, in which submission times are monitored; and switching between allocating and responding to peers can be controlled. In this module, there were more than 200 students. One hundred and seventy-one students agreed to the

activity, therefore students emerged with large numbers to peer review. Each student's design was seen by between eight and twelve students, depending on the submission date. At this scale, the online peer critique became depersonalised; and may not have carried the same impact as a face-to-face critique (Petrina, 2018). Timing of the stages in the activity, applied by the lecturer, excluded students who failed to meet deadlines. From the student side, some did not assign marks to other students reciprocally. Those who received no grade did not grade another student at the first stage of the activity.

In the research group, ten out of eleven submitted their work. Seven of eleven received marks (63%) from their peers in the first stage. One failed to submit anything and one (Student-4) responded too late to receive marks from peers. Only four out of eleven (36%) received a peer grade from this activity. Students who completed the activity were supportive of this type of online formative assessment. Students appreciated the opportunity to review other students work; however, some were disappointed when the LMS settings excluded them for late submission. Student-3 reported her frustration via *WhatsApp*. Student-3: I submitted my feedback on the clocks I had to assess a few days ago, but now when I went to check for the feedback, it showed that my assessments of the other clocks didn't submit, and I can't access it now.

As the peer review activity was being trialled, some students did not grasp the reciprocal nature of the activity; and considered that they had completed the task once their peers had judged their work. Lecturer-1 commented on this later in his interview when commenting on the CAD course roll-out. Lecturer-1: "Just the peer reviews put the stress on me!"

It was concluded that more empathy may be required from lecturers when using online peer assessment with novice students. For example, Student-4 was allocated to two other students in the research group, however, Student-4 failed to grade them. She, in return, received no grade. We discussed this in her interview: Student-4: “I don’t know why it went that way. My peer assessment.” In her case, I concluded that she was contented with straightforward lecturer feedback. Researcher: “Would you prefer it was just marked by me?” Student-4: “Eh, yes.”

On reflection, I valued Lecturer-1’s initiative in using the *Workshop* tool to provide an online peer assessment. This was an attempt to introduce more authentic online assessment. However, student and staff feedback raised questions relating to definitions of authentic online assessment (Dagman & Wärmefjord, 2022). These became a theme in post-implementation surveys, and meeting dialogues. In my opinion, the online critique did not have the impact of the face-to-face ‘inquisition’ of a real critique amongst peers (Williams *et al*., 2017). However, *Moodle*’s *Workshop* tool did provide a ‘virtual option’ when there was no choice but to work online under second cycle pandemic lock-down conditions.

5.6.2 Multimodal blended online pedagogy

Students provided reflective feedback on the blended online resources in *WhatsApp* groups, and interviews. Students commented on the materials as they encountered them on the *WhatsApp* platform; and gave more detail in face-to-face interviews. The timing of the ICTE200 course as a second-year module was considered too late in the degree course. Student-

2 identified that ICTE200 would be more effective as a first-year module for completing assignments for his studies: Student-2: “I think if it was taught in first year, it would better help with the way that assignments are done.”

Survey feedback on timing of the course triggered departmental discussions about moving ICTE200 into the first year. I fed such comments back to lecturers via email. Researcher: “I just received the email (below) from one of our 2nd Year ICTE200 research group students. It fuels our argument to have ICT modules for degree students in First Year.” I reinforced the value of student feedback to lecturers at an early stage of the year opposed to traditional student surveys collected at the end of the year: Researcher: “Please send a paragraph to [Lecturer-1] so that he can collate these into the draft ACBO [Academic Board] Proposal. If you have any feedback from students, these can be quoted in the proposal. Often the student voice is missing.”

I submitted feedback on this finding with my monthly ACBO report to the Head of School at the end of the CAD unit delivery. This initiated an institutional process to change the ICTE200 module into a first-year module “ICTE100” which Lecturer-5 implemented in 2021.

5.6.3 Application of CAD to teaching practice

Lecturers’ and students’ interviews provided reinforcement of observed use of CAD resources on Teaching Practice (RQ2). Lecturers shared examples of students’ use of resources in primary teaching practice. Students either reported positive use of CAD resources and socio-

technical issues preventing them from applying these in host schools. Both groups shared a range of opinions on the value of CAD skills in primary teaching.

Staff shared their observations of students using CAD in their assignments, or in making portfolio resources, as evidence of students' resourcing TPR: Lecturer-5: "Students […] used it in NSTI101 [Natural Science and Technology first year module] assignments." While students reported their application of CAD, Student-10 gave two examples: "I designed a classroom layout on *2D Design* which I found quite simple. For TP, I made some drawings of maths shapes to show my learners."

Students who had not yet used CAD on TPR, gave hypothetical suggestions about teaching it. This revealed that they may not have learned enough to have confidence in using it. Student-4's vague answer exemplifies this. Student-4: "I would conduct sessions where I teach them step-by-step and help them understand." Student-2 and Student-10 wished to use CAD for creating resources for teaching practice. Student-2 aligned with the lecturers' proposal to learn CAD on a first-year ICT course.

Student-2: "I think it may be useful to learn this in first year so that when we start teaching prac in 2nd year we are already familiar with the program and are able to successfully create our own resources."

Student participants' practical experiences of learning and applying the 2D CAD software varied depending on their ability to learn the software skills, imaginatively applying these in schools which gave them freedom to do so. All student respondents recognised that the ICT e-portfolio of work, including CAD examples, was a good way of judging their

learning (Pegrum & Oakley, 2017). I realised that students and staff need more time to reflect on the broader value of ICT in resourcing their workplace. Both groups were more inclined to appreciate its value for personal use. The ability to apply technological learning in multidisciplinary settings (Petrina, 1998), and during TPR, is further discussed in Chapter 6, other external factors influencing students' ability to apply knowledge on TPR.

5.6.4 Wider socio-technical systems influencing CAD use in schools

During implementation, wider socio-technical systems influenced lecturers' ability to teach CAD, and students' ability to learn CAD both on campus and online. These included: 1) a Bring Your Own Device (BYOD) institutional policy requiring students to purchase their own computers for study; 2) variation of teaching facilities and educational technology across campuses; 3) lecturers' ability to teach CAD varying according to their prior experience; 4) students' access to ICT learning in first year; and finally, 5) issues relating to free access to CAD software.

Technical barriers to teaching CAD to student teachers, such as the BYOD policy versus campus-based computer rooms, were raised.

Lecturer-5: BYOD provides challenges, students all using different devices. Learning from online resources, such as we have produced for this unit, provides challenges, it being easier to learn CAD with an extended screen.

It is easier to learn CAD using two screens in 'extended screen' mode. Guides, or videos, can be viewed on one screen while completing drawings on another window. Facilitating this

requires institutional investment in hardware for lecturers, and a return to use of computer labs for students. Changes in ICT facilities on campuses are mentioned in all interviews. The effect of these on teaching and learning is discussed further in Chapters 7 and 8.

Lecturers' lack of prior experience of using and teaching with CAD was raised repeatedly; and this emerged as a potential barrier to students' learning. None mentioned the blended online approach for teaching CAD as being an obstacle. Their responses revealed that the preferred approach was multimodal teaching and learning. Students' feedback relating to item 4) enabled relocation of the second year ICT module to first year, mentioned in Section 5.6.2.

5.7 Synthesis

The findings presented in this chapter reveal genuine "communicative action" (Kemmis, 2014, pp. 34-36), or collaboration, in designing, teaching, and learning, and critique of the CAD course and students' drawing outcomes. The "communicative spaces" (Habernas, 1984, p. 86) created productive dialogue which enabled integration of CAD with the ICT module in an innovative manner; and allowed critique throughout the process.

Themes emerging from this chapter addressed Research Questions One and Two. Addressing Research Question 1, revealed the ways in which we collaborated in exploring the best pedagogical approach to teaching CAD. We used face-to-face and online choices in exploring multimodal and authentic approaches to learning (Onofrei & Ferry, 2020). Addressing Research Question 2, and students' willingness and ability to apply CAD in

teaching practice, the teaching practice model allowed me to explore students' use of CAD resources for teaching practice at the time of learning. Students attended teaching practice every second week during the CAD learning period; and could apply their knowledge immediately in schools. Some students actively did so at the time of learning. Some did not display confidence in CAD immediately (for example, the lecturers). However, they demonstrated understanding of the value of CAD resources for teaching; the course required CAD evidence submitted later in the year, as part of an electronic portfolio (Pegrum & Oakley, 2017).

The findings from the first cycle of the CAD implementation enabled me to explore wider socio-technical issues relating to the two research questions; and provided context to evaluate the course and in planning Cycle Two. The final refinement of themes took place in the nominal group workshop reported in Chapter 6. These are discussed in the next chapter and detailed in Appendix 32: Refinement of Coding Framework from Nominal Group Technique Workshop.

Participating lecturers were active at various stages of the first cycle. I was pleased when they self-selected their roles. For example, Lecturer-1 took an active operational role, while Lecturer-5 acted more like a critical observer, until he started lecturing CAD with me. Their stances seemed to be driven by professional interests in the study. Students seemed, in the early stages, more interested in giving critical feedback from the learning process than in re-designing the course. This may have been due to lack of knowledge of module design; their existing role as customers filling in module surveys; and limited experience of CAD. Students

who participated in interviews displayed more agency and confidence in speaking critically about wider issues.

Student and staff contributions using both the online and offline instruments appeared to be honest and focused on the action. *WhatsApp* dialogues demonstrated that students and staff operated differently in "online public spaces" (Gerber, Abrams, Curwood, & Magnifico, 2016, pp. 19-35) Participants used the opportunity to make worthwhile commentary on wider socio-technical contexts, which improved the course delivery and creation of additional resources.

I believed that the contributions of participants and technical experts as critics of study materials and videos helped to establish a wider form of "community of practice" (Lave & Wenger, 1991), which transcended traditional institutional curriculum development processes. Group evaluation of the course was more time consuming but led to deeper insights. Design of the refined drawing manuals and instructional videos, as valuable "reusable online objects" (Onofrei & Ferry, 2020), resulted from collaborative work with ICT lecturers, Lecturer-2 acting as a 'critical friend'. Critical feedback from students endorsed our approach in surveys and interviews.

My motivation to explore a multimodal approach to learning CAD came from enthusiasm for testing a blended online course and a desire to reduce the pressure for lecturers to become overnight CAD experts. Sharing of practical CAD lesson plans stimulated debate about best methods of planning a series of lectures. These could be reused in continuing professional development for creation of lecturers' teaching portfolios.

The blended learning approach, combining online with contact learning opportunities, was appreciated by students and lecturers for its flexibility and potential to ensure that those with different ICT experience achieved success. Recent studies have echoed similar results with teaching CAD to engineering students (Dagman & Wärmefjord, 2022; Liu, Xu, & Liu, 2021). Supporting learning with a variety of different forms of multimedia resources, including instructional videos, was appreciated. I saw the videos as a method of bolstering students' use of the written guide. My intention was to use them as a study guide augmentation tool. Some saw it the other way round. This reflects generational differences in views of distance learning which are topical subjects of argument in the institution.

The first cycle was difficult. I had to build trust, share a great deal, and encourage participants to be critical, using untested communication tools. I was pleased at how spontaneously students responded to questions and how willing staff were to experiment with the various modes of delivery. I discovered that students were more ready to use social media for research communications, while staff were more inclined to use a more formal online survey, or interview, to provide personalised feedback.

The findings reflect a significant difference between the CAD course and other institutional courses provided at the time. The CAD course provides choice in blended online learning with campus-based tutorials and multiple online resources. The instructional videos helped teach the same practical skills as the written guide but catered for those preferring a visual learning experience. The continuous assessment model used in ICTE200 involved incremental online practical activities, unit tests, and portfolio activities. This allowed CAD to

be integrated initially as mainly formative learning with summative marks for including drawings in a portfolio submission in the year-long course. This gave students choice and more time to practise and apply CAD in teaching before submitting drawings for assessment. In achieving success, students with prior ICT experience, and up-to-date devices, were at an advantage over those from less privileged backgrounds.

During the first cycle, the multimodal blended online approach was innovative for the organisation. In the second cycle, the Covid-19 pandemic forced an acceleration to implement this approach across all programmes, thus mitigating the school closures and students studying from home due to the national lockdown (Soudien *et al*., 2021). The second-cycle findings are presented in Chapter 6, in which post-implementation interviews, student results, and nominal group workshops illustrate how the second-cycle planning and delivery was disrupted by the Covid-19 pandemic. Findings show the ways in which the pandemic accelerated the adoption of modes of learning on all programmes which mirrored innovations that we tested in the first cycle. The final chapters discuss the disruption caused by the integration of CAD into ICT courses, its application in schools, and the socio-technical ripples created by providing students with more choice through blended online learning of CAD.

END OF CHAPTER

Chapter 6. Findings from the Post-Implementation and 2nd Action Research Cycle Disrupted by the Covid-19 Pandemic

6.1 Introduction

This chapter continues from Chapter 5 which presented findings from the first cycle of integration of the computer-aided design (CAD) into the ICTE200 ICT course for intermediate phase degree student teachers. The previous chapter reported the findings of the first cycle of collaborative design and teaching of the CAD course. This chapter takes up from the completion of the 2019 module, presenting findings from the students' module results and nominal group workshop which introduce the second cycle re-planning, action, observation, and reflections. These findings are supported by a second-cycle student survey, and 2020 student outcomes report.

Developing from the final stages of the first action research cycle, shown in Figure 4.1 Chapter 4, this chapter follows the transition to the second-cycle stages of the critical participatory action research (CPAR) process, and subsequent action under disrupted Covid-19 pandemic conditions illustrated in Figure 4.2, Chapter 4. The reflection and re-planning from Cycle One followed by the second-cycle action-research stages are described in this chapter. The anticipated second cycle and the actual reality were influenced by the Covid-19

pandemic which disrupted campus lecturing and prevented students from attending teaching practice.

The ICTE200 module was a year-long course; and CAD was taught quite early in the year. Subsequently, I was able to continue constructive dialogue and meet with lecturers and students for the rest of the academic year. I consider this reflexive dialogue (Qualley & Chiseri-Strater, 1994) very beneficial. The dialogue allowed us to reflect on our experience together, and to collaboratively plan improvements to teaching and application of CAD, before the second cycle was taught. This reflexivity, with participants, builds on Donald Schön's ideal reflective practitioner who reflects "for- in- and on-action" (Schon, 1983, p. 50); it shows that the activity created collective understanding as we improved the course. Schön later describes "knowing in action" (Schön, 1995) which acknowledges the complicit and collective understanding that comes through group reflection on action.

Finding ways of increasing and maintaining reflexivity (Valve & McNally, 2013), while maintaining progress with the operational elements of the project, proved to be a challenge, as students moved from CAD to subsequent units in the module, and their external teaching-programme pressures increased. Personally, I struggled to maintain participants' engagement with the project after CAD was taught in the first cycle. The nominal group workshop (Section 6.6) was a valuable opportunity of sharing experience and ideas face to face. This activity helped with refinement of the thematic framework in structuring findings and analysis of chapters; and helped with planned improvements for the second cycle.

The second cycle of action was supposed to continue with the same blended model of delivery, combining face-to-face lectures and tutorials with online learning via videos, CAD guide, and online portfolio development. The Covid-19 pandemic of 2020 interrupted the face-to-face teaching and forced all students online. Teaching practice was also suspended during the period when CAD was taught. This meant that recruitment of a new group of student participants was curtailed, in-venue observation of CAD teaching was cancelled, and second cycle development and online implementation was conducted by ICT lecturers. Student voices came from anonymised student surveys and module assessment reports completed at the end of the module.

6.2 (Re-) Reconnaissance

The following section illustrates the stages of reconnaissance in the second CPAR cycle. Because there were no changes of staffing, it was not necessary to retrain staff. Departmental meetings were used as a form of re-reconnaissance in preparing the way for re-planning at the end of 2019, in anticipation of recruiting new student participants in 2020. Covid-19 pandemic prevented recruitment of a new cohort of students. Lecturers continued to participate using online communication systems, and through sharing their results and student surveys.

6.2.1 Review of CAD course and student outcomes

CAD course outcomes produced for portfolios and formal LMS and SIMS reports on participation and student marks were reviewed. These were consolidated during a meeting in October 2019, in discussion of student performance on the module with lecturers. Final reporting came in November 2019 results reports.

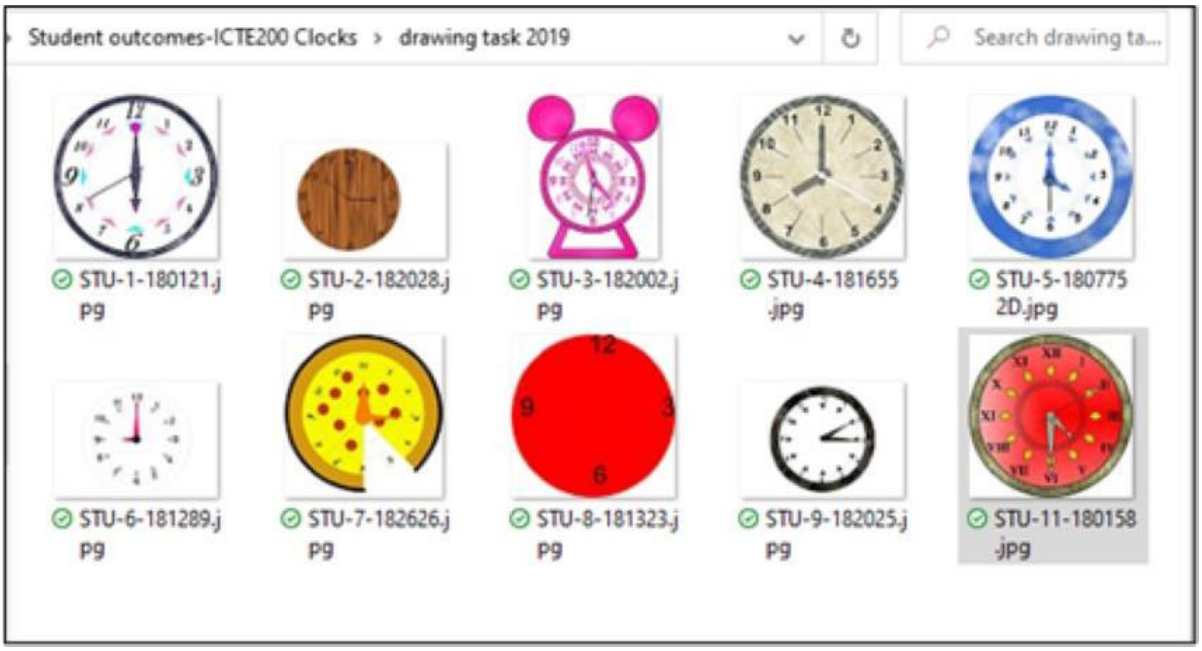
6.2.2 Students' e-portfolio CAD outcomes as teaching practice resources

Students' e-portfolio CAD outcomes, submitted at the end of the CAD unit, revealed that most of the students were able to complete the CAD resource production activity using a combination of face-to-face tutorials and online resources. Nine out of the ten in the research group completed the drawing without direct lecturer help; and only one failed to submit. Understanding the long-term value of CAD e-portfolio work was initially limited; many students saw the portfolio drawing simply as module marks rather than as a valuable resource for future use. Only one, Student-4, sought help by arranging an individual tutorial after the initial face-to-face group tutorial session. Student-4 completed the clock drawing, but requested assistance in completing the hands, and in placing these correctly on the clock face.

Comparing all completed clocks, in one montage of their submitted work (Figure 6.1), I observed that each student had personalised their designs after practising the guided tutorial example. I noted that students copying a taught example may be unnecessary, unless working to a tight assessment rubric. Affording students design freedom produced unique outcomes and assisted in quickly identifying plagiarism. In this case, every example submitted was different.

Figure 6.1

Student CAD Drawing Outcomes-2019-Clock Design (Research Group)



6.2.3 Observation of student outcomes from LMS data and SIMS reports

Learning management system (LMS) results, reflecting participants' CAD online participation, and formal marks from the student information management system (SIMS) imported from the LMS, assisted comparison of research group performance with the rest of the ICTE200 second-year cohort at the end of the 2019 academic year. Quantitative data collected helped to validate the study and in triangulating findings from the first cycle. For example, the raw data sources are listed in Appendix 20: ICTE200-Assessment-Results-By-

Module. Some of the data for analysis of findings is used in earlier chapters to indicate group demographics and to create context for student performance.

The most valuable data, in terms of students' learning and application of CAD, was extracted from the learning management system (LMS) (Appendix 20a). Quantitative data was used to establish and confirm whether participating students had applied CAD in assessed activities reflected in the LMS gradebook. The activity completion settings on formative and summative activities gave a 'register' of students' participation in each online activity. Using gradebook data downloaded in Excel spreadsheet format, at the conclusion of the module, it was possible to gauge whether collaboration in the project had ultimately been detrimental to student performance on the module.

Performances of the Cycle 1 research group compared with the whole ICTE200 second-year cohort were logged in a spreadsheet showing activity pass rates and average performance. The quantitative data contributed pragmatically to the "audit trail" enabling "confirmability", or validation of the learning process compared with participants' perception of their performance (Miles & Huberman, 1994, p. 282).

In comparing the CPAR group with the wider Campus-1 IP group, the following quantitative calculations were made:

1. Percentage of CPAR group submitting the clock compared with the whole group's submission.
2. Percentage completion of CPAR activity compared with the whole group's completion.
3. Percentage inclusion of CAD in *PowerPoint* compared with the whole group's inclusion.

4. Percentage inclusion of CAD in Portfolio compared with the whole group's inclusion.
5. Final percentage combined mark for CAD elements compared with final average percentage mark for CAD elements for the whole group.
6. Normal distribution of marks to compare research group with ICTE200 cohort group.

Results from the research group were compared with those of the whole cohort to show whether the two groups had followed a statistically 'normal distribution' of results (Lipsey *et al*., 2012), with CAD added to the course. Formal calculations of normal distribution of the quantitative data was used (Appendices 20 and 21). Comparing the research sample group with the whole group, final marks were positive for the research group, as shown in (Table 6.1):

Table 6.1

Comparison of Campus-1 CPAR Research IP group with whole campus IP group

Year Group	Students' (Contact Learning)	Passes (P) 50% to 74%	Percentage Passes (P) %	Percentage Merits (M) 75% to 84%	Percentage Distinctions (P/D) %	Fails (F) < 50%	Percentage Fails (F) %
ICTE200 Cohort	131	115	88%	21%	14%	16	12%
CPAR Research Group	11	10	91%	0	9%	1	9%

Performance of students completing the CAD clock drawing activity, online peer review activity, *PowerPoint* presentation (first CAD drawing), and portfolio (additional CAD drawing) was positive for the research group, and not significantly different from the cohort. Table 6.2 gives an anonymised breakdown of final grades and performance by activity.

Table 6.2

Summary Summative Results Table for ICTE200 Research Group

Code	Online Quiz	Online Test	Portfolio (with CAD)	Practical (Word/ Excel)	Power Point (CAD)	Total	Symbol Pass (P) Fail (F)	Fails, Merits
STU-1	88	86	90	93	76	**88**	P	Merit
STU -2	0	70	44	92	68	**53**	P	
STU -3	86	86	51	97	0	**57**	P	
STU -4	60	88	72	41	0	**57**	P	
STU -5	64	68	5	93	0	**30**	F	Fail
STU -6	86	82	72	91	0	**66**	P	
STU -7	55	76	57	96	76	**67**	P	
STU -8	59	69	70	70	0	**58**	P	
STU -9	98	82	69	47	0	**60**	P	
STU -10	63	85	73	86	62	**74**	P	
STU -11	83	84	65	89	0	**63**	P	
ve.	**67**	**80**	**61**	**81**	**26**	**61**	**10 (P) 1(F)**	**91% Passes**

The graphs (Figures 6.2 and 6.3) both show a normal distribution (See Appendix 21: Protocol for calculating normal distribution of results). The year group sample has a higher mean mark of 65 compared with the research group. The research group's mean of 61 indicates that they did not overtly benefit from membership of the research group The normal distribution curve of final marks for the whole IP ICTE200 group shows pass mark, mean (mean: 65.34, standard deviation: 20.47), merit, and distinction grades. The graph shows that the whole IP group's marks are 'normally distributed', marks being clustered between the 25^{th} and 75^{th} percentile. No one achieved full marks; however, there were 18 distinctions, with marks greater than or equal to 85% marks. At the other end of the graph, there was a 'normal' distribution of low marks with 16 failures between 49 and zero.

Figure 6.2

Normal Distribution Curve of Final Marks for IP ICCTE Cohort showing Pass Mark, Mean, Merit, and Distinction Grades (Mean: N = 65.34, Standard Deviation: N = 20.47)

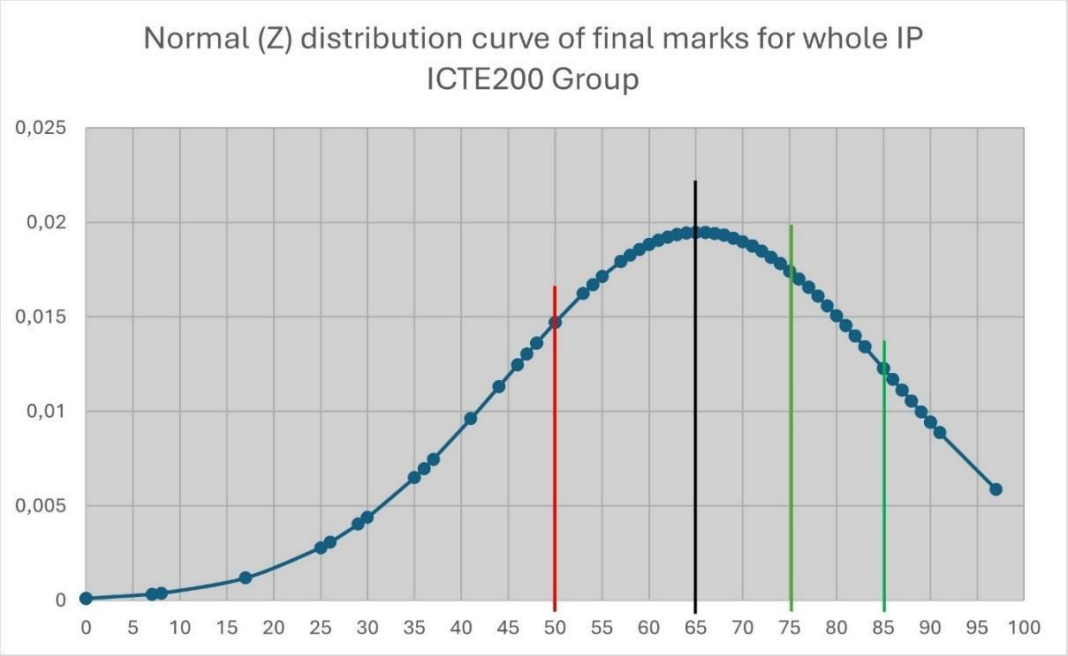
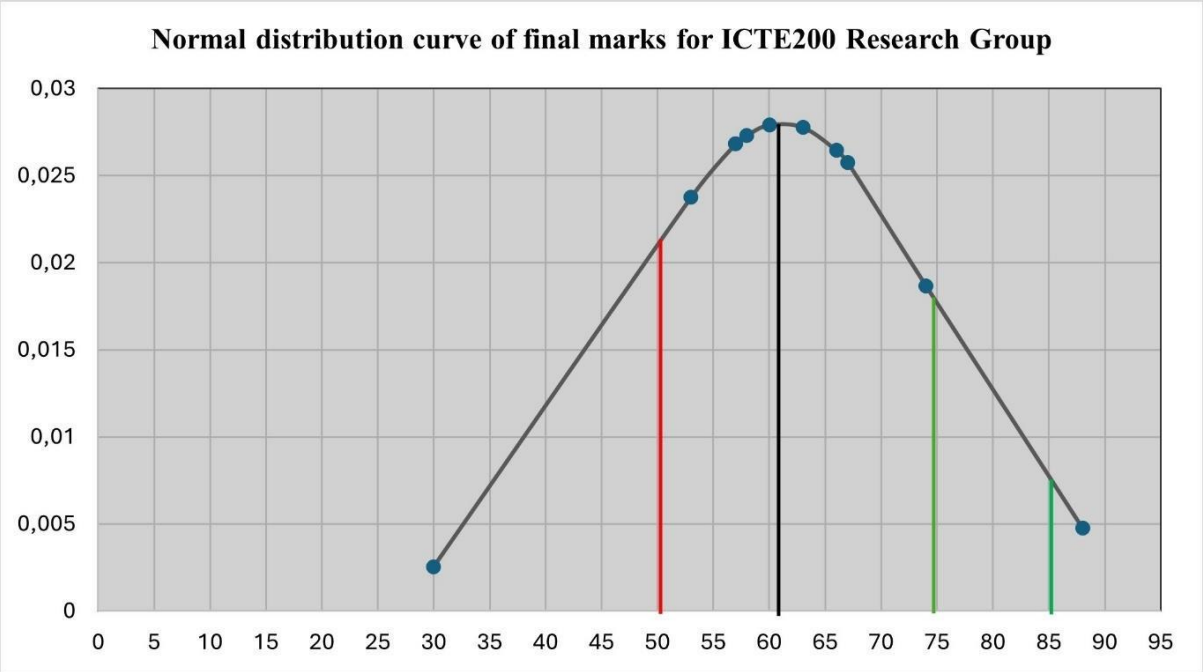


Figure 6.2 shows the normal distribution curve of final marks for the IP ICTE200 Research Group, with 11 members, showing pass mark, mean (mean: n= 61.2, standard deviation: n= 14.25), merit, and distinction grades. The graph shows that the research group's marks are also 'normal', marks being clustered between the 25th and 75th percentile. No one achieved full marks; however, there was one distinction, with marks either greater than or equal to 85%. At

the other end of the graph, there was a ‘normal’ distribution of low marks with one failure between 49% and zero.

Figure 6.3

Normal Distribution Curve of Final Marks for ICTE200 Research Group, showing Pass Mark, Mean, Merit, and Distinction Grades (mean: 61.2, standard deviation 14.25)



The study group mirrored the larger group in terms of engagement with CAD. The comparison of normal distribution curves for research group and whole group, revealed a statistical similarity in distribution of final marks for the two groups. The statistical similarity between the research group and whole ICTE200 cohort was reassuring, in that some may consider a

collaborative research group as having unfair advantage. The slightly lower average pass mark for CAD activities could be interpreted as consistent in an unbiased research project with somewhat lower scores resulting from participation in the research project. The research group's results for the module confounded the latter assumption − their overall pass rate was 91% compared with the cohort's 88% pass rate. This data provided a non-intrusive way of establishing whether the research group was being adversely affected by participating. This data also helped to triangulate with individual participants' actions (Gerber *et al*., 2016, pp. 85-86), for example, when a student became inactive or left the group.

The LMS at the time was not set up to gather data on lecturer practice. To compensate for this, lecturers were asked to comment in more detail about the effect of the CPAR project on their work. Lecturer-4, for example, commented positively on blended online learning using instructional videos: "I am in favour of the online mode, and I do think we should keep the videos as they were very helpful this year".

The automated gathering of peer assessment activities, lecturer-assigned marks and submitted visual examples from the LMS supported qualitative interpretation by recording students' results on the module in prescribed CAD drawing exercises. This reflected student ability to use CAD via online data. The quantitative analysis assisted in interpreting student outcomes per the online resources; the analysis gave a clearer indication of students' creation of CAD images as reusable teaching resources which they uploaded and peer assessed on the LMS.

6.2.4 Trial of new CAD resources

Lecturer-1 believed that the clock example was too difficult for some ICTE200 students; and more so for CPT101 students (Appendix 29: Planning-Post-NGW-Online Survey-Cycle 2-Dec 2019). Using one of the 2018 training examples, the dice net, he produced a set of instructional videos, like those produced for the clock, to enable students to learn a simpler cube net drawing. Lecturers endorsed the online learning design approach used in 2019 using a drawing guide as a script and a lesson plan to guide video production (Appendix 35: CAD Lesson Plan 4 - Dice activity).

To test the new resources, a free training opportunity was offered for final year students and lecturers, similar to the trial training completed in 2018 during the same weekly staff development time slot. SCR representatives were encouraged to invite students via *WhatsApp* (Appendix 19: Participant-Dialogues - Email-*WhatsApp*). Student attendance on the Friday session was poor. Only three fourth-year students attended. However, this enabled practice as a lecturing team of the alternative drawing. We resolved to add the dice net drawing to the portfolio as an extra activity (Appendix 37: ICT for Educators-ICTE200-CL-Assessment Guide-2020, p. 6), while using the clock as the assessed example.

6.3 Re-planning

Findings from the stages of planning the second cycle are shown below. To reflect on Cycle 1 outcomes and suggest improvements in planning the CAD course for teaching in 2020, a nominal group workshop was conducted; new assessment resources were developed; a

revised ‘emergency’ online version of the *Moodle* online course was implemented; an online survey was used to gain qualitative feedback on CAD learning online; and CAD resource use was assessed purely by students’ inclusion of CAD resources in e-portfolios.

6.3.1 Nominal group workshop

Following staff and student interviews, completion of module portfolios and analysis of module results, in October 2019, a nominal group workshop assisted by interpretation of Cycle One findings, developed ideas for re-planning in preparation for the 2020 second cycle. Seven members of the research group attended (Appendix 32). A summary of the findings in codebooks (Saldaña, 2013) was discussed. These combined *WhatsApp* dialogues, surveys, and interview transcripts with examples of students’ work in the form of a *PowerPoint* presentation. Attendees formed a working group using hard copies of codebooks, with themes and categories from my initial analysis, for reading and discussion. Recordings of their interpretation and ordering of themes in the first session were recorded on flipcharts sheets using sticky notes (Figure 6.4).

Figure 6.4

Nominal Group Workshop Charts organising Coded Data by Themes and Categories.



A gallery walk with flip-chart sheets and sticky notes stuck to the wall, was used to discuss the themes before agreeing on thematic order. Additional reordering was conducted with marker pen annotations on the sheets. After discussion of the rearranged notes agreed themes and categories were recorded and highlighted on the charts shown in Figure 6.4.

6.3.2 Participants' interpretation of initial thematic framework analysis

Themes addressing Research Questions 1 and 2 extracted from NVivo framework analysis were populated on the data codebooks. The themes were discussed using examples from data to illustrate their origin. Thereafter, themes considered as wider socio-technical issues were organised on additional sheets. Themes that were already in place from Excel and NVivo codebooks were reorganised and listed on flip-chart sheets, thus enabling presentation of the findings (Appendix 32). Participants used sticky notes to suggest either alternative wording or alternative themes. The gallery walk helped to collate and reorder these suggestions into a framework. These were posted on flipchart sheets and reorganised during the gallery walk. After further discussion, the categories and themes were recombined with original NVivo-themes and sub-categories as listed in Appendix 32. The refined themes and sub-themes assisted with organisation of Cycle Two and with presentation and analysis of findings.

The framework analysis, combined with face-to-face discussion at the NGW, allowed reduction of key themes to five per research question, with an additional five which relate to wider socio-technical issues affecting the implementation of the course. These are tabulated in Appendix 32. One of the major themes that was developed in discussion of coded transcripts

from the workshop was the need for an agreed definition of CAD apropos of its value for teaching in primary schools. This theme informed the organisation of sub-themes and the improvement of Cycle Two course introductory content. This theme reflected a return to Lecturer-5's original concern, in the first lecturer's focus group, regarding the relevance of teaching CAD in primary schools.

During summing up and in thanking participants for attending the NGW, I asked what motivated them to attend the workshop. Lecturers said that they were interested in learning more about research methods. Student-4 said: "Because you asked us nicely!" Considering that the workshop was assisting me in organising findings for my thesis, I was reminded that I needed to publicly acknowledge the contributions of all participants. This was recorded under the sub-themes: 'Motivating a CPAR research group'. After the event, I emailed all attendees a thank you message with copies of the refined coding framework sheets used in the analysis: Researcher: "What has emerged from these sheets is very interesting as it combines reflective comments on what we have done and suggestions on what we could do in future. It is evidence that our coming together in this way has positive benefits in creating a community of practice and developing a culture of communicative action."

As an additional sign of gratitude, I distributed certificates of participation, signed by the dean and myself, along with a t-shirt for each participant.

6.3.3 Developing new CAD teaching resources for assessment

At the end of the term ICT meeting on 18th October 2019, it was agreed to develop a question bank of short online quizzes for all units of the ICTE200 module. I agreed to produce an initial sample of 10 questions on CAD to load onto the question bank (Appendix 36: CAD Quiz - Question bank-for online course). This quiz was used in 2020 with the new cohort of students. During this planning period the Covid-19 pandemic had not yet affected the institution's campuses. Online unit quiz questions were to be trialled in live lectures and tutorials; and incorporated into the final online assessment at the end of the module, as an innovation in online learning for the institution.

6.3.4 Participants' preferred modes of learning and resources following the first cycle nominal group workshop

In November 2019, an additional mini online survey, prepared on *MS Forms*, was sent to participants to follow up on issues revealed from the nominal group workshop (Chisango *et al*., 2020) (Appendix 29: Planning-Post-NGW-Online Survey-Cycle 2-Dec 2019). Questions included a request for participants to share their preferred context for teaching CAD (dice or clock) and preferred mode of learning. I created this extra tool as a form of verification as reflection-on-action (Schön, 1995), after participants had completed the first cycle, to inform planning of the second cycle.

Three lecturers and three students gave feedback on the teaching resources used and the blended online version of the ICTE200 course. Lecturer-1 had previously recommended a

simpler contextual example (the dice) for teaching higher certificate students on ICT module (CPT100). Lecturer-1's observations were supported by Lecturer-4 and Lecturer-5's survey responses after they had discussed the dice example at the NGW: Lecturer-5: "The clock was too finnicky to work with, with too much latitude for error," and Lecturer-4: "I think the dice requires more creative thinking, which is good for the students."

The lecturers' views are contradicted by some of the students' views: Student-6: "The clock is simple and [you] can make a clock of different shapes and sizes," and Student-4: "Simple and easy to draw as a start-up point." The students differed in preferred mode of learning: Student-4 indicated "Face-to-face tutorials"; Student-6 chose "Videos" and Student-11 mirrored Lecturer-5's multimodal choice of "all the aforementioned resources".

I assumed that Lecturer-4 and Lecturer-5 opted for the simpler dice as their preferred context because they had had the least CAD practice and had not drawn the dice themselves. After spending time with me team-teaching, Lecturer-5 preferred the multimodal online and face-to-face learning, retaining the clock example. Lecturer-4 had not learned CAD with me previously, as a remote lecturer at Campus-3, and chose online "videos" as her preferred mode of learning. This was justified in her final response: Lecturer-4: "I am in favour of the online mode, and I do think we should keep the videos as they were very helpful this year."

Both Lecturer-5 and Student-6 took a wider socio-technical view, suggesting that the course be further refined: Lecturer-5, "I think we should simplify and streamline the course, as many students are not familiar with computers." Lecturer-5 suggested a differentiated approach to support weaker students: "We need to identify these students very early in the course and

make lectures compulsory for them". His suggestion that weaker students should have to attend face-to-face sessions on campus reflects the reality that weaker students had attended the extra CAD tutorials offered.

Student-6 suggested a change to the module structure: "ICTE should be a semester module, because of the workload, but we have learnt so much especially Excel and *2D Design*." Ironically, lecturers campaigned instead for semester modules to be made year-long modules[x].

6.4 Emergency Online Course

As a result of the nominal group workshop and follow-up survey, the refinements to the ICTE200 course enabled a smooth transition from blended to fully online teaching when Covid-16 restrictions were imposed in early 2020. The addition of online unit quizzes, additional taught CAD examples, and institution-wide implementation of live webinars to replace face-to-face sessions enabled continuity. Lecturers' planning focus shifted to individual development of strategies for teaching via live webinars.

6.4.1 Implementation of teaching practice e-portfolios

Prior to the Covid-19 lockdown, the teaching practice (TPR) department was exploring a shift from hard-copy teaching practice portfolios to using the LMS to assess discreet activities through e-portfolios (Mapundu & Musara, 2019). The inclusion of CAD drawings as evidence of application of CAD ICT skills was cemented as part of the ICTE200 portfolio. Plans to encourage the TPR department to include ICT resources for classroom teaching, as a

compulsory element of assessment, were postponed when they were forced to rush their *Moodle* e-portfolio online to provide evidence of student work in the absence of school teaching practice under Covid-19 lockdown restrictions.

6.4.2 Summary

Informed by students' results and feedback on the preferred mode of learning we resolved to keep the multimodal delivery with online resources, campus lecturers and face-to-face tutorials. In response to the NGW, and participants' follow-up survey feedback on learning context, the additional simpler dice net example was included as extra drawing practice in ICTE200. Lecturers also resolved to use more contextual examples and quiz questions to support theoretical and contextual teaching of CAD. I reflected that student who contributed in the nominal group workshop felt empowered to question module structure and its position in the programme. Their valuable final contributions assisted with creating an improved online version of the course for future students which was accelerated due to the Covid-19 pandemic.

6.5 Re-action

Findings from the CPAR action stages of the second cycle are presented in this section. Action in the second cycle involved implementing a fully online course using the additional resources developed in post implementation re-planning. As Covid-19 closed Campus-1, lecturers instead became online facilitators; and contact-learning students effectively became distance-learning blended-online students.

6.5.1 Fully online course

Covid-19 restrictions compelled implementation of a fully online ICTE200 course. The main difference between 2019 and 2020 was that students were unable to attend face-to-face lectures and tutorials on campus and were unable to conduct their fortnightly school-teaching practice rotations. Instead of campus lectures, students were expected to attend online webinar lectures and tutorials. Students continued to study and submit assigned work online via the LMS, using instructional videos and online guides. Because CAD had already been resourced with online teaching content in Cycle One, additional CAD resources served to augment existing material. Additional online quizzes were developed to assess learning of CAD terminology as continuous assessment (Appendix 36). These questions were shared with lecturers and refined during ICT meetings. Extra drawing examples were added to provide a simpler alternative to the clock; and to provide an alternative teaching context through drawing of a cube net, to make a dice for teaching geometrical design and probability in mathematics.

6.5.2 Implementing CAD in 2020

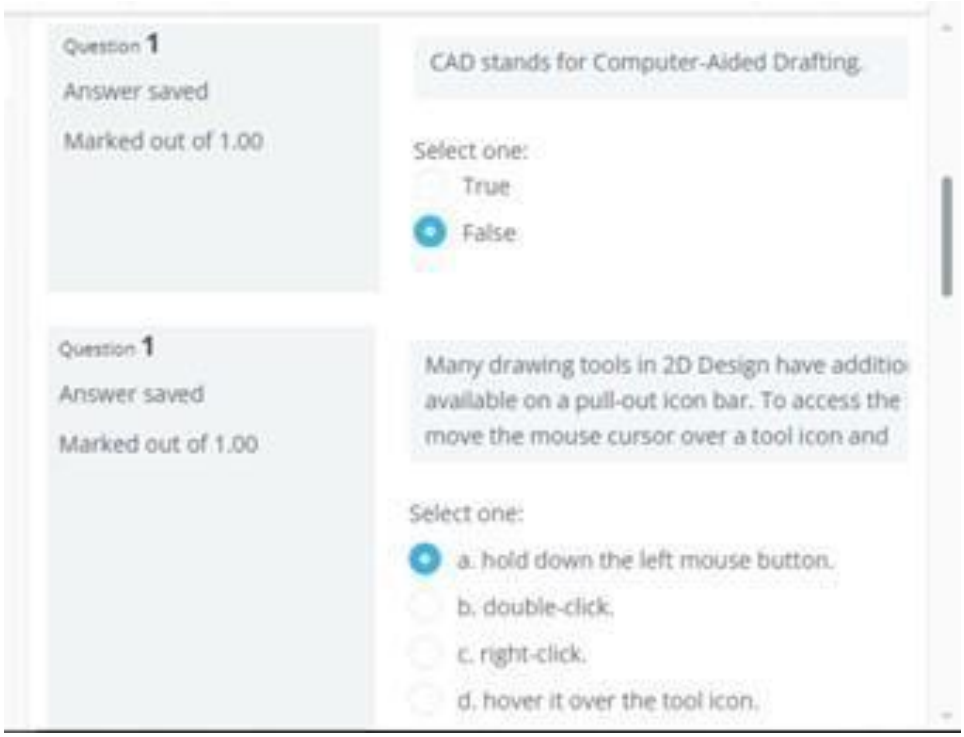
Because students were unable to access campus, ICTE200 was taught online using the 2019 guides and instructional videos I had created with Lecturer-1's assistance. We were all obliged to provide live online webinars to substitute for campus theory lectures during campus lockdown. These were facilitated by the centralised unit responsible for digitally enhanced teaching and learning and assessment using *Zoom* online webinar technology. Together we

shifted from presenting to a live room full of students to presenting their live CAD practical demonstrations and theory slideshows using a voice-over with a shared CAD screen on *Zoom.*

New online CAD instructional video for production of dice nets was added to the LMS to augment CAD learning (Appendix 37: ICT for Educators ICTE200 CL Assessment Guide 2020).

Figure 6.5

Screenshot from Online Quiz on the ICTE200 Moodle Course Page from 2020



Lecturer-5 used the entire CAD quiz bank in live online lectures, which he shared with Lecturer-3, to prepare students for the final assessment at the end of the module as part of their teaching strategy. In addition, Lecturer-5, now the module coordinator for ICTE200, added CAD multiple-choice questions to the final module online quiz (Figure 6.5).

6.5.3 Learning CAD both online and off campus

Due to campus Covid-19 lockdowns, students worked either from home or from their student accommodation. Some students remained in accommodation at Campus-3 until full campus closure forced them to go home. Because ICTE200 had already been developed as a blended online module, contact learning students studied CAD remotely as temporary distance-learning students, using the online study guides, instructional video, and submission portals created on the ICTE200 LMS course. In 2020, many other courses had to create this experience from scratch.

Unable to access campus for face-to face lectures, students instead, were provided with online lectures, or *Zoom* webinars, presented by module coordinators co-teaching online with campus lecturers. Remote campus lecturers attended as additional guests in these webinars. This created a form of online co-teaching which is reported on in anonymised student cohort surveys collected on *Moodle* (Appendix 28: ICTE200-CL Student Survey-Online learning 2020). This is discussed further in student reflections in Section 6.6. The learning technology unit, as the administrator, was able to add externally recorded material to all online modules.

The recorded *Zoom* webinars were saved on a YouTube channel and loaded to the learning management system as extra video content. This enabled students to watch recordings of 'live' lectures in their own time. Contact learning students effectively became online distance-learning students. The extra recorded material added more flexibility to their learning experience, but also increased the need for reliable devices, internet connections, and data for downloading recordings. Students also missed out on the social experience of campus-based study.

6.5.4 Using CAD evidence from e-portfolios

Schools were unable to accommodate student teachers during Covid-19 lockdown, and teaching practice was suspended during the period of the second cycle. Students instead developed online teaching e-portfolios for teaching practice. Although ICTE200 lecturers were not involved in developing the teaching practice department's 2020 e-portfolios, they prepared students for submitting home-produced lesson plans which included CAD resources. ICTE200 lecturers continued to assess students through the module's own mini e-portfolio assessment which included CAD developed in 2019.

6.6 Observation

The following section presents findings from the CPAR observation stages of the second cycle. In-person observation in the second cycle was replaced with staff dialogues, observation of students' online work, and email communications. In addition, feedback on the CAD course

was gathered from online student surveys and module assessment reports. Because the second cycle delivery period in May 2020 was disrupted by the Covid-19 pandemic, and students did not attend campus either for lectures or teaching practice, only generalised anonymised feedback from students' end-of-module online survey responses from the 2020 cohort were accessible.

With no teaching practice taking place, due to school and campus lockdowns, no data was collected on student use of CAD resources in teaching practice at the time of CAD teaching. Students' e-portfolios and survey responses reported use of CAD in resourcing e-portfolio lessons at the end of the year.

6.6.1 Staff *WhatsApp*, email, and meeting dialogues

Lecturer-1 and Lecturer-5 maintained the most regular dialogue during the transition from first to second cycle. In 2020, the module coordination role shifted from Lecturer-1 to Lecturer-5. Lecturer-5 provided reports of his observations of interactions in co-teaching webinars with Lecturer-3 and Lecturer-4 via email or verbal reports: Lecturer-5 [email] "It's going well. The webinar format works with CAD when we can share screen. Students also enjoy the online discussions with me and the other lecturers."

Early in 2021, both Lecturer-1 and Lecturer-5 shared formal reports on teaching CAD in their modules. Lecturer-5 collated student surveys and lecturers' module assessment reports on ICTE200 from all campuses and shared these by email (Appendix 25). Lecturer-1 shared student survey results for CPT100, now also a year-long module for first year higher certificate

students, which also included CAD teaching. ICTE200 survey responses and module assessment results produced comprehensive insights for the reflection stages of the second cycle.

6.6.2 Students' anonymised online survey feedback

Online observation and reflection on students' experience of learning CAD online in Cycle Two is drawn from sixty-three students who responded anonymously to the ICTE200 online *Moodle* LMS module survey at the end of the module (Appendix 28: Student Survey-ICTE200-2020-Cycle 2 ICTE200-CL Student_module_feedback-Post-Covid-2020). Although answering more open-ended questions in a generic survey, compared with the targeted 2019 CAD version, students gave useful feedback on learning experience under Covid-19 conditions; the experience of learning CAD using online resources and co-teaching webinars; and the value of e-portfolio-based assessment for building teaching practice resources. These are discussed in the reflections in Section 6.7.

6.6.3 Module assessment reports

Module assessment reports were produced at the end of each cycle of module assessment. Due to the Covid-19 lockdown, the ICTE200 2020 report was finalised by Lecturer-5 in early 2021. The 2020 report contained mark summaries from all campuses, module coordinator and lecturers' reflections on the outcomes, and a summary of student survey responses. ICTE200's 2020 module assessment outcomes showed a 95% pass rate on

the CAD clock task and 94% pass rate on the portfolio. These compared favourably with theory quizzes (94%) MS Office applications quizzes (96% and 95%), and the final quiz (99%). The high pass rate across the board endorses students' survey responses which celebrated the online delivery supported by live online webinar lectures and tutorials.

The relative success of students in completion of CAD activities, compared with other Office applications, is attributed to 2019 resourcing of the CAD course online, and the novelty of learning something new on an ICT course. Students' reflective survey responses in Section 6.6. repeatedly refer to CAD positively as something new, exciting, and challenging for students who had previous experience of ICT from school.

Campus-1 pass rates were excellent considering the two or three times more students compared with Gauteng's Campus-2 and Campus-3 (Appendix 25: ICTE200-CL-MC Report: ALL CAMPUSES 2020) This perhaps points to a need for a continuous cycle of training and retraining of staff on all campuses to maintain consistent delivery.

6.7 Reflection

The following section presents findings from the CPAR reflections stages of the second cycle. Reflection on the second cycle of implementation of CAD was based on results of anonymised students' critique of CAD outcomes, and lecturers' observations on effectiveness of the multimodal online pedagogy in comparison with the previous year's blended approach. Because teaching practice was interrupted, reflection on CAD use was based on e-portfolio submissions and survey feedback (Appendix 28). The forced switch to online learning as

opposed to blended online learning, due to Covid-19 lockdown of campuses, led to reflection on the various systems of delivery of CAD lecture content, and assessment using the learning management system (LMS) and meeting/webinar technology.

6.7.1 Online critique of CAD outcomes

Students used the 2020 survey to critique the two taught CAD activities, and to share opinions on learning CAD as opposed to other software. STU-22-2 enjoyed the novelty of learning CAD after studying computer application technology at school: “Using CAD was awesome; it was something completely new to me”. STU-19-2 valued the instructional videos: “The 2D drawing of the clock was quite tricky; but the videos uploaded on YouTube were really helpful”. STU-23-2 found the clock activity more difficult than the dice: “…the watch was worse, but I enjoyed the challenge.”

STU-45-2 reported appreciation of the unit quizzes which aided understanding of new concepts: “the module itself was made easy to understand by the questions in the form of quizzes were given for each unit.” STU-47-2 “enjoyed the interactive and practical setup of the quizzes; portfolio and the test.”

Finally, STU-60-2 highlighted enjoyment of CAD design critique and peer assessment activity: “I thought marking peers work was also fun and enjoyable to see their creativity.” This revealed the student teacher’s interest in using collaborative approaches in making assessment more accessible and varied.

6.7.2 Reflections on multimodal online pedagogy for teaching CAD to student teachers

The online study mode during Covid-19 was generally celebrated as successful by lecturers across all campuses; although Lecturer-5 regretted the shift away from blended to fully online mode compelled by the pandemic: "[2020] Started with a positive learning atmosphere in [face to face] lectures. Fate intervened." Lecturer-3, who co-taught with Lecturer-5 in online webinars, was positive about online lecturing: "Online delivery suits this module perfectly. There was generally good interaction during the online lectures in terms of commenting and questions."

However, Lecturer-3's module assessment comment is poignant: "The lowest number of passes is held by the assessment involving CAD, perhaps more support could be provided in this area." This may have been a personal call for support, the other campuses producing pass rates above 85% in the CAD task. Because both Lecturer-3 and Lecturer-4 reported lower CAD pass rates than Campus-1, this may be attributed to their working alone, or possibly to assessing more harshly. On Campus-1, Lecturer-1 and Lecturer-5 were able to collaborate more closely, in sharing an open-plan office with me.

Students' responses were equally positive about online live *Zoom* webinars in which lecturers used co-teaching to present practical CAD skills and theory: STU-51-2: "I feel that the online/*Zoom* approach was very successful. I think it should be continued in this module." STU-20-2 highlighted the good rapport between co-teaching lecturers: "I loved how Lecturer-5 and Lecturer-4 handled the content delivery. It was easy to understand and follow instructions." STU-1-2 appreciated the online dialogue with lecturers in *Zoom* lectures, and the

flexibility provided by provision of recorded videos of these: “There was responses to the *Zoom* questions, and we even got opportunities to be speak ourselves. I particular liked how there was a YouTube video.” Conversely, STU 51-2 revived the issue of defining technological terms clearly: “The terms used in all the units were quite difficult to remember. I found myself getting very confused when it came to this.”

The shift to online learning added an additional layer to peer assessment. Students not only critiqued each other’s work in the online peer assessment activity, they were also able to critique work in live online demonstrations: STU 29-2: “I enjoyed online lectures − engaging with lecturers and peers from all campuses.” STU60-2 endorsed this: “I thought marking peers work was fun and enjoyable to see their creativity.” This online replication of a public critique with a group is the type of process Petrina and Williams promoted as a necessary aspect of student development (Petrina, 2018; Williams *et al*., 2017).

6.7.3 Teaching practice use of CAD

Although students missed teaching practice during the second cycle, they were able to develop new resources for teaching using the ICTE200 lesson plan assignment and portfolio which included the CAD clock or dice resource. STU-15-2 stated: “I enjoyed the portfolio tasks; they were fun and exciting to do.” The less experienced student STU-1-2 reiterated the value of the CAD portfolio activity: “I got the hang of it and came out a more knowledgeable person for it. I look forward to using my clock in future teaching.”

Covid-19 compelled the teaching practice department to move permanently to the use of e-portfolios (Mapundu & Musara, 2019) in documenting assessment of students' planning. Students commented on the ICT lecturers' attempts to mitigate for the compulsory online learning. STU 23-2 reported on lecturers' empathy towards their studying from home: "Lecturers understood our situation and made life easy. Even before the [online webinar] teaching started, they would share positive comments, and we would engage freely." STU-2-2, with less ICT knowledge, appreciated that practical experience was necessary to learn and teach CAD: "whatever was taught was done practically for us to see and practice. so even students who were not computer literate, like me, were able to find their way." Although students were unable to apply their CAD learning in schools during Covid-19, they recognised that the way that they were taught CAD transferred to creating resources and teaching CAD in schools.

6.7.4 Socio-technical systems impacting on teaching and learning CAD

Although both staff and students reported enjoying the fully online teaching experience, under Covid-19 conditions, the survey also highlighted students' recurring issue of unreliable, or lack of, Wi-Fi connectivity and device issues: STU-21-2: "Sometimes it was bad because of connection problems and technical issues." STU-62-2 summed up the problem with online learning: "I found the online learning very difficult at times because I had difficulties in accessing the internet because of data and network." STU-34-2 also highlighted a perennial

device compatibility problem relating to the institution's bring-your-own-device (BYOD) policy: "The CAD design software programme was a problem for me as a Mac Book Pro user."

A new technical issue reported was the '*Zoom* freezing' in online webinars: STU-36-2: "Sometimes the *Zoom* videos would freeze as internet connection at home was a bit poor". STU-15-2: "Sometimes I had problems with logging in before it ended."

In response to working from home under Covid-19 lockdown conditions, STU-23-2 reported that good-humoured lecturer interaction was a key aspect of online study: "Due to Covid 19 we learnt online, but there was no pressure; lecturers kept us at ease." STU-52-2 reinforced this sentiment: "I enjoyed the online demonstrations as well as the banter." Underlying the quality of online teaching that students experienced was the additional online support work that was expected from lecturers working online. STU-3-2, praised this unrewarded online lecturer commitment: "I am a repeat student for ICTE and for the first time I enjoyed the module… He [Lecturer-5] always answered emails and had *Zoom* sessions with you if you had a problem … unlike previous lecturers."

Finally, assumptions that students with little prior knowledge of ICT would struggle with online learning were confounded by STU-16-2: "I never had a background in computers. In my high school we were never offered computer classes." He subsequently stated: "Keep the online sessions running. They were better than the contact sessions we had earlier in the year." This revealed that quality of blended online learning is as much about the quality of the lecturer as the novelty of studying using online tools.

6.8 Synthesis

The study of the implementation of CAD in IP student teachers' end-user computing module ICTE200 evolved over time in response to institutionally imposed change, through a digitalisation project, as well as through lecturer and student input during the collaborative action research project. The study combined integration of a new unit of work (the CAD unit) with a new mode of delivery (blended online) for the whole module. The CPAR approach provided a structure for managing and observing the action and for drawing on the experience of participants as they interacted over time. The first teaching cycle reflected the planned methodological approach, while the second cycle had to be adjusted in response to the Covid-19 pandemic.

Involving lecturers and students in co-creation of data, decisions on mode of delivery, course content, and data interpretation in a nominal group workshop, helped to democratise (Rambe & Moeti, 2017) the CAD learning process. This helped improve and challenge relationships across institutional student/lecturer/academic manager boundaries. The process also helped to expose individual prejudices about CAD, and its previously undefined role in technological primary education.

Post-implementation interviews and follow-up surveys helped with triangulation and verification of participants' qualitative contributions. Predictably, students were more willing to converse on social media groups than with lecturers. However, their sharing in interviews was commendable; and showed growth in agency as the project progressed, and they developed trust in me and the ICT lecturers. Lecturers provided more feedback in survey and interview

responses. Although students' and lecturers' viewpoints conflicted at times, the range and variety of responses added richness to the data.

Visual materials produced on CAD to resource the course enhanced the collaborative processes and aided interpretation. CAD examples produced by students (Figure 6.1) helped with appreciation of the diversity, design resourcefulness, and skills level of the first-cycle group; and informed lecturer assessment of student examples in Cycle 2. CAD examples also illustrated students' digital resourcefulness and creativity in introducing original ideas for teaching, peer assessing one another, and applying CAD in their teaching practice. Additionally, visual material, produced from observations, provided a source of presenting analysis with visual depictions as graphic interpretation of the socio-technical systems in which students and lecturers worked at different stages.

The first cycle of the action included exemplars which became reusable objects for the second cycle (Onofrei & Ferry, 2020). For example, the resources for the clock activity were reused, while additional resources were adopted to develop an extended resource bank for teaching CAD. Lecturers were stimulated to explore the use of the dice and revolved solids examples (Appendix 35: CAD Lesson Plan 4 - Dice activity). Lecturers' exposure to these examples enabled constructive discussion of future iterations of the course; and clearer differentiation of CAD teaching between higher certificate and degree modules using various taught examples.

Data from the second cycle reinforced mixed opinions relating to the best pedagogical approaches to teaching CAD in the ICT curriculum. The opinions on blended online learning

were more difficult to compare in the second cycle. Learning switched from optional campus-based lectures and tutorials to live online webinars only to compensate for campus closures caused by the Covid-19 campus lockdowns. In addition, the closure of schools meant that students were unable to apply their CAD knowledge directly in teaching practice. Various CAD learning pedagogies were explored through provision of multi-resource online learning pathways. Students could choose to learn CAD from a combination of online teach-yourself resources, instructional videos, and live webinar alternatives. This flexible approach was appreciated, but also acknowledged as a resource-intensive and expensive route to sustain in a profit-orientated business. Students' performance online reflected similar studies involving teaching CAD to engineering students (Dagman & Wärmefjord, 2022).

Most students were satisfied with the variety and delivery of online resources; however, some found it stressful, and would have found it difficult to complete the course without the option of access to lecturers at campus. The switch from manual to e-portfolios for teaching practice was implemented during this period. This disrupted plans to observe students' use of CAD in teaching practice lessons in schools. Because CAD drawings are electronically stored in ICTE200 portfolios for assessment, students had examples to include in their teaching practice portfolios. Systems for checking this integration of resources from ICT courses into teaching practice portfolio lesson planning must be enacted in future cycles.

Findings revealed differing approaches and strategies for the use of CAD in the primary school classroom. These included using CAD as a tool in visualising technological and mathematical concepts (Wan & Ivy, 2021). Students demonstrated that their CAD use was not

confined to technological subjects, but had application in other academic areas, for example, mathematics. Serious concerns with government schools' provision of ICT teaching facilities were raised by students and ICT lecturers working as teaching practice assessors. Changes to institutional delivery of teacher training, compelled by the Covid-19 pandemic lockdown, accelerated teaching of traditional contact and distance-learning modules in a hybrid form of blended online delivery. CAD enabled illustration of this change over time, using visual depictions based on researcher sketches and notes from observations.

The ICTE200 module CAD guides and video content gave the lecturers an opportunity of teaching themselves and observing ways in which online teaching and learning influenced students from the inside. The positive effect this had on the lecturers and students is visible in their dialogues and module results. The timing of the first cycle was fortuitous, as it prepared participants, in advance, for the unanticipated move to online study demanded by the Covid-19 higher education lockdown in early 2020.

The responses of students, as first-time users, reveal more about their perceptions of CAD and less about their lived experience. The lecturers, as novice users and CAD lecturers, displayed how the course influenced their perceptions of ICT teaching and the value of online teaching of multimedia skills. Both groups exposed research gaps, and curricular development opportunities, to be addressed in future action research, for example, teaching of video making and editing for online lesson creation.

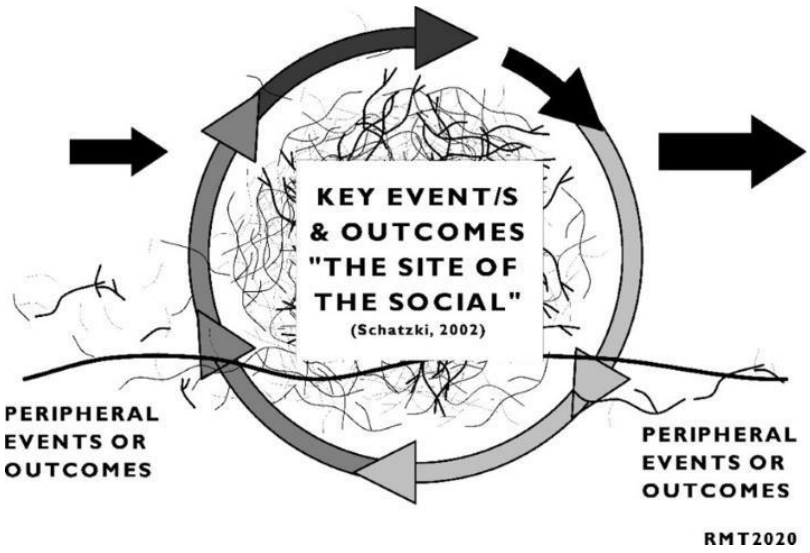
Quantitative data contributed to validating students' academic performance on the module; and assisted in confirming that inactive students in the CAD research group were also

underperforming on the major module assessments due to ICT knowledge deficits. The value of quantitative data in observing online behaviour was reinforced when it was not possible to observe student outcomes in face-to-face tutorials.

The action-research process was a purposeful activity, which had unpredictable outcomes and consequences, as natural human interactions tend to do (Whitehead & McNiff, 2006). After the first cycle learning activities were completed, participants engaged in further activities with CAD. Some were anticipated, and others were unexpected. Some became focal points for further development of the unit in the second cycle. In Figure 6.6, I present a 'tumbleweed' analogy in visualising the peripheral events or outcomes as 'spin-offs' from the main event or "site of the social" (Schatzki, 2002, p. 87). In this study, students completed the unit in various ways; and lecturers and students participated in co-creation of an academic unit of work at different times. The unplanned actions may have been the serendipitous results of the collaborative process and wider socio-political-environmental factors influencing the processes of co-creation, shared learning, and application of learning and reflection. Some planned activities, such as the critical review of CAD lesson plans, did not feature in discussions as much as the process of learning CAD itself. Expectations of students' continuous engagement in research activities, were optimistic, while students worked in parallel to pass the ICT module. Some peripheral events may have been 'spin-offs' from the main event, or "site of the social" (Schatzki, 2002, p. 7). For example, repeating students in Cycle Two provided interesting comparative feedback on their CAD learning from Cycles 1 and 2.

Figure 6.6

'Tumbleweed' Analogy illustrating the CPAR Process (Adapted From Schatzki, 2002)



The Covid-19 pandemic could not be predicted when planning the course in late 2018 and early 2019. The pandemic brought many negative elements to the study in coercing students and lecturers into isolation and preventing collaborative action in real social spaces. The second cycle suffered from loss of direct engagement with self-selecting students as research collaborators. In addition, many staff and students lost loved ones during this period, which had a direct impact on motivation and ability to complete studies. However, the pandemic's influence on the second cycle did not discredit the study; it reinforced the planned and improved online multimodal instructional innovations from First Cycle. The spontaneous

critique supplied by sixty-three (n = 63) 2020 students in anonymous course evaluation surveys compensated for missing active student participants; and supported findings from the first cycle. These surveys revealed that students' deprivation of campus learning may have encouraged them to engage more meaningfully in online activities. The commitment of lecturers to the educational project, evident in Cycle One contributions, was heightened by their adaptability in moving from face-to-face campus lectures to team-teaching in online live practical CAD webinars. The flexibility inherent in action research enabled reflection on students' switch from reporting on their teaching practice to submitting online e-portfolios as evidence of their use of CAD outside taught lectures.

The findings from Chapters 5 and 6 are discussed in Chapters 7 and 8 as both positive and negative outcomes from the action research are presented through a socio-technical theoretical lens, with references to recent literature. In these chapters, researcher-generated CAD drawings are used to illustrate and summarise some of the wider socio-technical influences which were observed as influential, or disruptive, as the action unfolded.

Chapter 7. Discussion: Integrating Computer-aided Design into Primary School Teacher Education

7.1 Introduction

As outlined in previous chapters, this study discusses the design, teaching, learning, and application of knowledge and skills in computer-aided design (CAD) for a primary school student teachers' ICT course. It also seeks to reveal ways in which students applied their CAD learning in the production of resources for teaching in primary schools, using critical participatory action research to explore the collaborative design and delivery of a new CAD course in an intermediate phase teachers' end-user computing module. The study followed the stages of reconnaissance, planning, action, observation, and evaluation of the course within changing socio-technical situations, over two cycles. While the first cycle followed an envisaged process, the second iteration was disrupted by the Covid-19 pandemic. The institutional and educational changes imposed by the planned implementation and pandemic conditions had both positive and negative influences on the CAD course and student choice in mode of study and teaching practice.

The two previous chapters presented findings from the 1st and 2nd cycles of the CPAR process, documenting the implementation of CAD in the ICT course, and detailing the disruptions to teaching, learning and application of CAD due to this implementation; and

subsequently from working under Covid-19 pandemic conditions. Findings were presented relating to the planned pedagogy for teaching CAD to student teachers, and their subsequent use of CAD in developing resources for teaching practice. Findings point to the need for more collaborative, flexible, multimodal pedagogies which utilise human and technological resources to meet the diverse needs of students from various social and cultural backgrounds. Findings also highlight collaborative course design, contextualised teaching, and constructive peer- and teacher-educator critique, as favoured approaches to sustaining the courses.

In addition, the findings considered various approaches that student teachers used in applying CAD knowledge to resource their teaching practice, and ultimately, in teaching CAD to school learners. In support of this, student teachers point to increased collaboration between specialisms and teaching practice departments, for monitoring application of ICT skills. The student teachers highlight the need for institutions to better facilitate teaching on campuses, thus reflecting school practice and better resourced CPTD training for in-service teachers in 21st century skills. Such would ensure that student teachers are properly mentored and assessed in schools.

The following chapter discusses ways in which the findings address the research questions; and how these can lead to improvements in learning, application, and teaching of CAD in primary school teacher training. It proposes that there is no single ideal CAD teaching pedagogy in a South African society, in which inequality prevails, and student teachers' background ICT experience and learning preferences are diverse. Global studies reinforce this as a rationale for foundational CAD and ICT teaching, internationally (Fraillon *et al*., 2018;

OECD, 2019). It is argued that blended online teaching and learning enables provision to some of choice in students' mode of learning; and it is suggested that this comes at a human and financial cost, regardless of the country in which training is located. Situational diagrams (Strauss & Corbin, 1998, p. 43) are used to illustrate ways in which the socio-technical changes impacted on lecturers' and students' learning and subsequent use of CAD. These changes were influenced by institutional decisions on mode of delivery, resources, and facilities. Using visual depictions to illustrate changing mode of delivery, technological provision, and facilities, it is argued that teaching and learning methods should remain adaptable and flexible. Meanwhile, institutions must adapt to available technologies and work harder to facilitate both online and offline learning for students from resource-limited educational backgrounds.

Responding to feedback from student teachers' school experiences, it is proposed that student teachers' learning of ICT skills, such as CAD, should not be confined to a single end-user computing course, but expanded to an extended programme. It is proposed that primary teacher training be expanded to develop wider software applications and ICT teaching skills for use in schools. Collaboration between ICT lecturers and teaching-practice departments is proposed to ensure that student teachers are credited for applying their CAD skills in resourcing lessons and eventually teaching with CAD.

Specifically, the following themes are discussed under Research Question 1: multimodal pedagogical delivery; pedagogical and structural disruption caused by the CAD course; and ideal contextualised pedagogical approaches to teaching CAD. Issues raised in relation to Research Question 2 are then discussed: student teachers' ability, or inability, to use

CAD in teaching practice; their initiatives in applying CAD in schools; and the ways in which teacher-training institutions and schools impact teachers' ability to develop and use resources in teaching practice. Finally, collaboration between ICT, teaching practice departments, and schools is proposed, which expands continuing teachers' professional development programmes to extend primary school teachers' ICT skills beyond basic end-user computing. It is argued that this is only possible should teacher-training institutions develop better ICT teaching courses and facilities. To meet the demands of new primary school courses such as coding and robotics, facilities should include more advanced software, such as CAD; and students should be encouraged to teach ICT as well as to apply it to produce resources.

Finally, the chapter reflects on wider socio-technical issues influencing CAD teaching pedagogy; the changing technical systems influencing CAD teaching in schools and higher education institutions; and implementation of CAD into the primary school curriculum. The chapter concludes by outlining a model for teaching CAD to primary-school student teachers, as part of a conceptual framework for teaching ICT in primary schools with CAD, in a carousel of subjects. This model is further expanded in the concluding chapter.

7.2 The Influence of Multimodal Pedagogy on the CAD Course

In this section, addressing RQ1: Which pedagogical approaches can best provide contextualised computer-aided design [CAD] education for enhancing intermediate-phase student teachers' learning? I consider how changes to ICT teaching infrastructure, campus

educational technology resource provision and mode of delivery have influenced pedagogical approaches used for teaching CAD.

During the study, the teaching of ICTE200 and the CAD unit was conducted using a combination of lectures delivered on campuses; online resources shared via the LMS; group tutorials; and one-to-one support tutorials (when requested by students). The changes in infrastructure and educational technology provision and their subsequent influence on modes of delivery are laid out below to illustrate the various 'options' provided to students. Additionally, provision of a choice of options for learning as a conscious pedagogical approach is explained.

7.2.1 Changes in campus infrastructure

In less than five years, the institution's campus infrastructure for teaching ICT altered radically. Early campus developments included computer labs with desktop computers and electronic whiteboards and digital projectors. Visual depictions taken from observational sketches were used to summarise socio-technical changes in teaching locations using standardised characters developed on *2D Design* CAD (Appendix 38: CAD Characters - Key for interpretive diagrams). Figure 7.1 illustrates the campus computer-room layout with hardwired computers used up until 2018 at the three contact-learning campuses.

Figure 7.1

Campus ICT Laboratories with Hardwired Desktop Computers

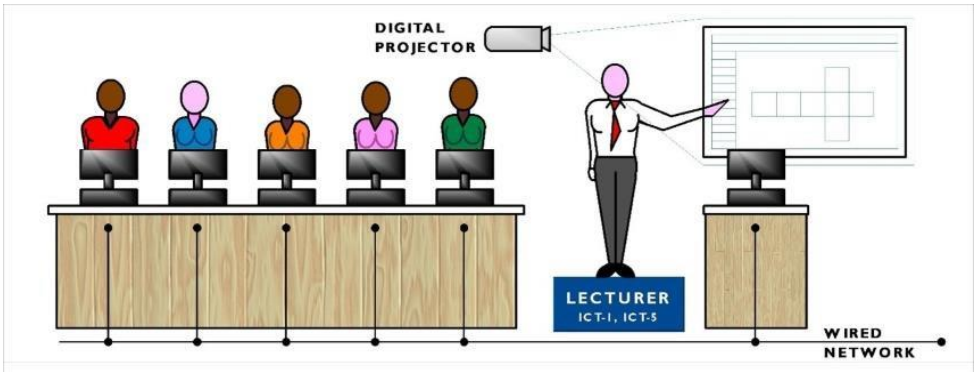
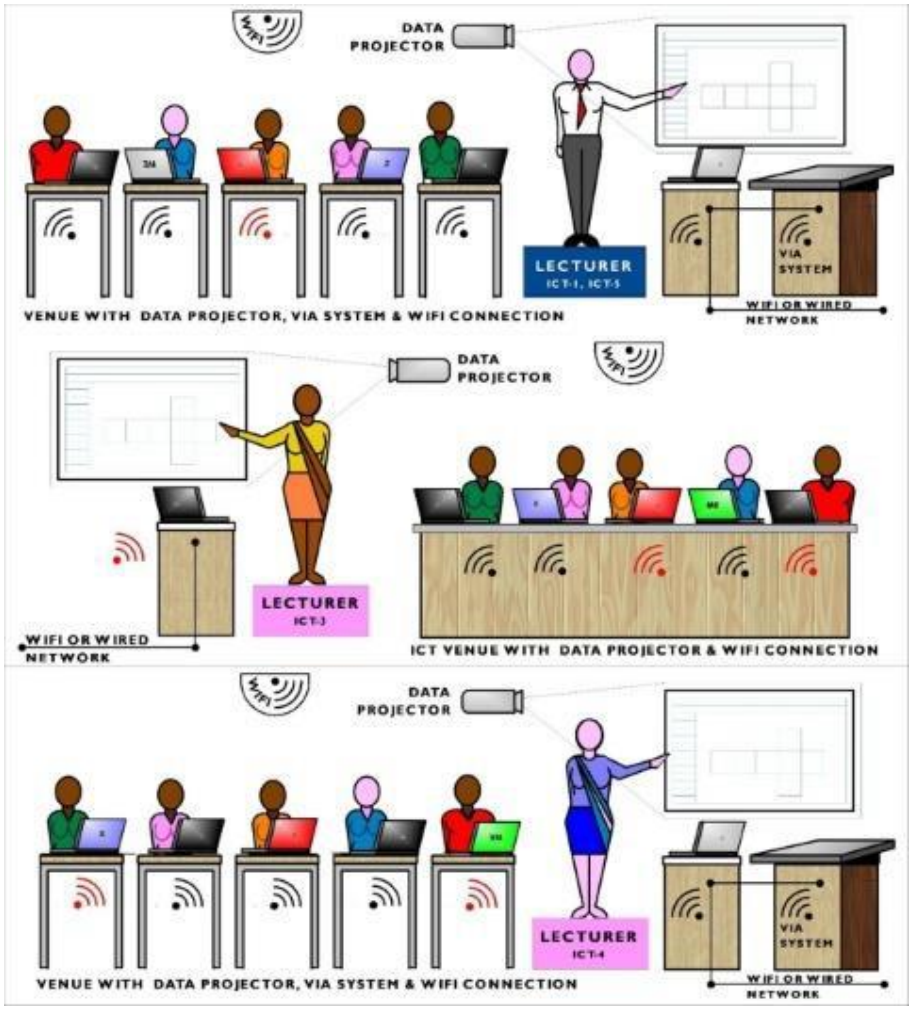


Figure 7.2 summarises the three main campuses. Their differences influenced the way in which face-to-face and online broadcasted sessions were conducted. This was due to the installation of SMART board lectern systems in some venues which could be used with, or separately from, staff laptops, to present lectures or to manage live broadcast events. For example, the 'gold standard' or most well-equipped lecture theatres, with video- and audio-recording technology linked to the lectern computer, enable recording of lecturer and audience, or focus on a slideshow presentation on the wall.

Figure 7.2

Lecture Venue Systems Available on Three Contact-Learning Campuses



Because these systems were not rolled out uniformly in every campus due to budget constraints, ICT lecturers had to adapt to different teaching areas. Educational technology varied at the

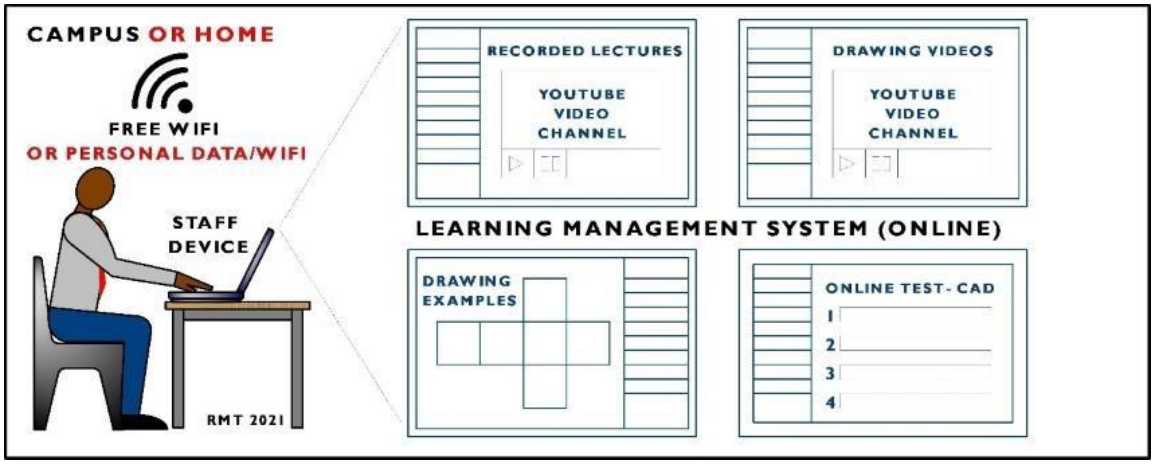
different campuses, along with the set-up of rooms. Some rooms had labs with large workbenches and stools, while others used exam desks and chairs. At the newest Gauteng campus, since 2022, provision of ICT labs has reverted to hard-wired desktop computers, the campus now including different schools offering education and ICT.

7.2.2 Use of digital tools to complement lectures and face-to-face tutorials

Considering the options available to lecturers at different locations, the method of delivery of learning content varied according to the facilities available (Boelens, Voet, & De Wever, 2018). However, shared standardised resources were pre-loaded to the learning management system (LMS). Module coordinators such as Lecturer-1 and Lecturer-5 concerned themselves with managing the LMS content and assessment materials (as shown in Figure 7.3 below); and the face-to-face lecture delivery was left to individual campus lecturers.

Figure 7.3

Online Resources for Learning CAD Developed and Provided by the Lecturer via the LMS



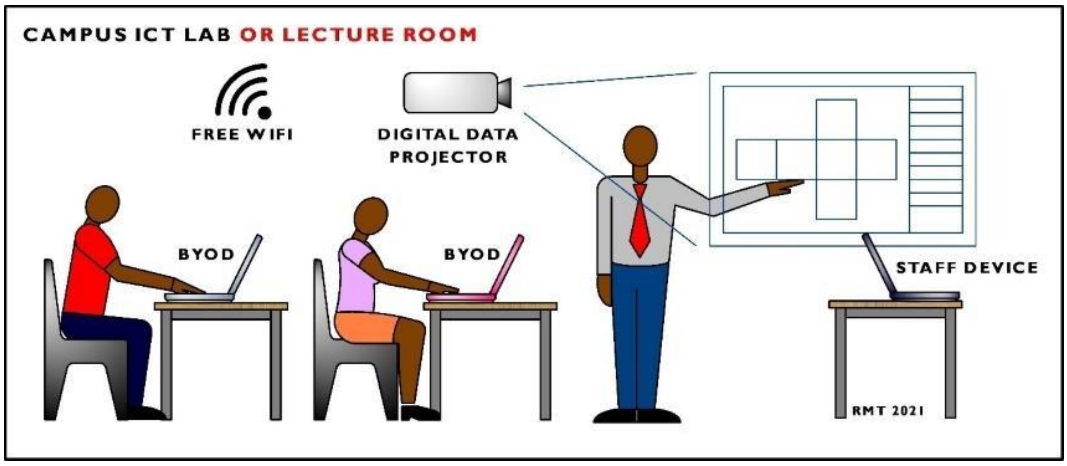
For the study, individual teaching of CAD face-to-face by campus lecturers, was augmented by the prepared slideshows, online guide, and video tutorials loaded onto the LMS. CAD teaching was therefore more uniform, and better resourced than some other ICT topics.

All campuses used contact lectures, or group tutorials, in delivering CAD training, as well as encouraging students to self-actuate using the LMS resources. Figures 7.4 and 7.5 illustrate ways in which lecturers defaulted to teaching with laptop and projector regardless of whether their venues had smart-lectern recording technology. Before Covid-19, there was no imperative to record lectures. The assumption was that students would either attend, or use the resources on the LMS, should they not attend. Because a significant investment of time had

gone into making instructional videos to teach practical skills, recording of videos of lecturers teaching the same theory topic was not considered a priority.

Figure 7.4

Live Practical Lecture, or Group Tutorial, at campus using either Online or Offline Resources



Following the first cycle of delivery, the rich multimodal implementation process provided a variety of opportunities for learning both on campus and online. Were the course to be audited, this may not appear financially sustainable. However, it reflects an ideal mode of delivery which caters to the various preferences of student teachers. Scaling up, this range of options may not be sustainable when factoring in hundreds of distance-learning students studying the same module remotely (Dagman & Wärmefjord, 2022). At the course level, the blended online

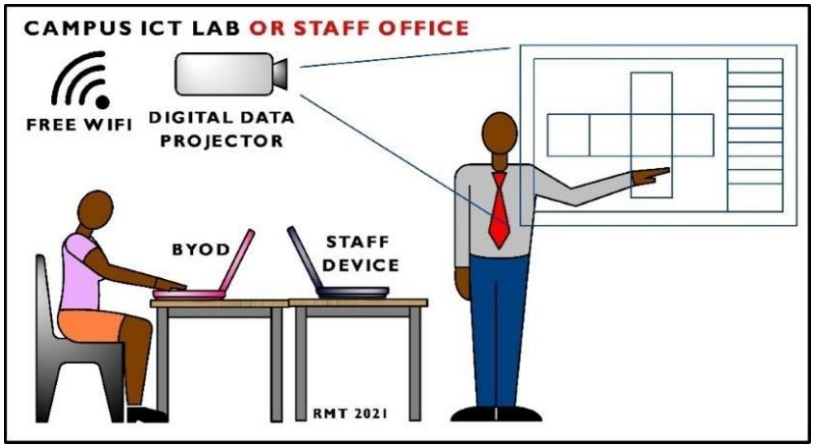
mode of delivery, with opportunities of attending face-to-face lectures and tutorials on campus was beneficial, providing a wide range of choices to fit the diverse student cohort.

7.2.3 Flexibility of face-to-face tutorials supported by online resources

The modes of learning sacrificed after the first cycle of implementation were the group tutorial, shown in Figure 7.4, and the individual tutorial, shown in Figure 7.5, due to reduced lecture periods; and eventually Covid-19 campus lockdown restrictions. During Covid-19 these modes were replaced by the recorded lecture, or instructional video, uploaded to YouTube. Tutorials could be replayed repeatedly by the student, if required, in their own time. Staff were able to work remotely from campus during Covid-19 campus lockdown using *Zoom* meeting technology to record lectures (Czerniewicz *et al*., 2020). The latter option was financially viable and provided greater flexibility in terms of delivery to the student. However, it lacked the interactive element which enables students to gain timely feedback on work or to engage on a personal level with a real person (U. Singh *et al*., 2020a).

Figure 7.5

Individual Tutorial by Appointment with Lecturer



7.3 Pedagogical and Structural Disruptions caused by Introduction of CAD Coupled with Wider Institutional Change

Viewing the wider socio-technical issues around the implementation, introduction of CAD into an existing module, and changing it into a fully online form of learning, could be interpreted as 'disruptive' (Estelami, 2017), 'Disruptive change' in the HEI setting can be seen as forced change imposed with little notice, or training (Al-Imarah & Shields, 2019). Technological, or financial efficiencies are the most common justification for such changes. Disruption innovation theory (Christensen, *et al.*, 2011) takes a more optimistic view of 'disruption' in business as: "new technologies that redefine an entire market and can improve

products or services in unexpected ways" (Al-Imarah & Shields, 2019, p. 3). Because the institution is a private business dealing in higher education, the struggle between balancing business and academic priorities was revealed in the study.

7.3.1 Institutional disruption in moving from contact to blended online learning

From a socio-technical systems viewpoint, disruption should be expected when the structure of an organisation, work design, and technical systems supporting work, are all changed simultaneously (Jones, *et al.*, 2013). The 'work design' in this case was the institutional change in mode of delivery and more flexible lecturing expectations. Change in the type of student engagement, from face-to-face supported learning to online learning, backed by email or LMS feedback, or online student support, was also highlighted as a challenge (Czerniewicz *et al*., 2020).

Details of the changes that took place to the ICTE200 module are presented in Table 7.1. These may be considered as disruptive innovation (Christensen *et al*., 2011). The move from purely contact learning (CL) mode to distance learning (DL), and subsequently blended online mode (Boelens *et al*., 2018), was accelerated for ICT courses by the institution in a 2017-18 EXCO digitalisation project. The long-term plan to offer programmes in CL and DL/blended online mode provided flexibility and access for remotely located students. Because DL was provided at a lower cost than CL, this enabled marketing which promoted increased access for a 'previously disadvantaged' student market.

In 2017, ICTE200 was initially converted to DL mode as a development task by Lecturer-3 as part of her CPD workload. The conversion of the module into online, and then a flexible hybrid blended online mode, was executed by Lecturer-1 and Lecturer-5 as they assumed the role of 'module coordinator' (MC) in 2018, and 2019, respectively. Table 7.1 below summarises some of the changes that the module underwent during its development to include CAD.

Table 7.1

Pedagogical, Physical, and Structural Disruptions in Pre-2019 and 2019 Versions of ICTE200 Course

	Different Modes of Delivery of ICTE200		
Key Pedagogical and Structural Disruptions	**Pre-2019 Contact Learning**	**Pre-2019 Distance Learning**	**2019 Online Combined 'Hybrid' Blended Online CL and DL Course**
Learning mode	Contact lectures. Contact practicals. Learning guided by three contact lecturers -one on each campus.	Distance learning. Self-guided with study guide (hard copy) and textbook. One nominiated DL lecturer provides oversight on ECI page and marks submissions.	Hybrid course with optional contact tutorials, some thory lectures and fully online study option supplemented by video and PDF step-by-step guides. LMS guided online study. Four lecturers. MC provides oversight on all CL and DL
ECI *Moodle* online learning management system provision	Separate CL page on CL server. CL students self-enrolled in campus groups. Assignment submitted online. One online test.	Separate DL page on DL server. DL students enrolled at registration in campus groups. One online test. Assignment submitted online	Combined CL and DL pages (identical content). Multiple groups CL and DL enrolled at registration. All work submitted online.

Different Modes of Delivery of ICTE200

Key Pedagogical and Structural Disruptions	Pre-2019 Contact Learning	Pre-2019 Distance Learning	2019 Online Combined 'Hybrid' Blended Online CL and DL Course
Resources provided (excluding LMS content)	Textbook only	Textbook, distance learning guide and hard copy study guide	Textbook only. Study guide now forms skeleton structure for the online ECI page.
Lectures/Lecturers	Four contact practical lectures and two theory lectures per fortnight. One week in on campus; one week out on teaching practice. Lecturers with some experience of CAD.	None. Study guide acts as a running narrative for students to study with a textbook and associated software. Some lecturers with prior experience of CAD and some working as novices.	Practical lectures converted to step-by-step videos. Some specialist practicals (e.g., CAD) offered as additional contact lectures. Theory taught through textbook, online glossaries and theory lectures.
Assessments	CASS assessment: Separately weighted CL and DL assessment.	CASS assessment: Separately weighted CL and DL assessment.	CASS assessment aligned in both DL and CL modes.
Student Feedback	Feedback in lectures. Written feedback on marked assignments and practical tasks. Students communicate with	Very little feedback given. Some feedback on marked assignments on request via telephonic call-backs.	Feedback via online marking of assignments using markable Turnitin feature. Online peer assessment. Self-marking online tests. CL

Different Modes of Delivery of ICTE200			
Key Pedagogical and Structural Disruptions	**Pre-2019 Contact Learning**	**Pre-2019 Distance Learning**	**2019 Online Combined 'Hybrid' Blended Online CL and DL Course**
	lecturers directly (by appointment), via ECI or Outlook email.	Students only able to communicate via scheduled call-backs through DL student support.	students have multiple channels for communication with lecturers.
Inclusion of additional software	Electronic whiteboard software (free trial download). CAD taught through contact lectures by guest lecturer (HOD).	Electronic whiteboard software (free trial download). CAD not available for DL. MS Paint instructions included as a compromise.	Electronic whiteboard software not included in 2019. CAD taught via online resources. Software available for CL and DL.

7.3.2 The CAD course modes of delivery as additional disruption to the ICT course

The research project began during the implementation of an alignment of contact and distance learning content using the *Moodle* learning management system. ICTE200 became a 'guinea pig' module in trialling various online learning and assessment tools. Implementing CAD was part of a greater disruption when moving ICT teaching to blended online mode. This

impacted lecturers' workload; and required them to provide student support online. Lecturers' willingness to, or resistance to, adapting and modifying the module was partly due to their historical involvement in developing the module in the years leading up to the study. Newer lecturers, such as Lecturer-4 and Lecturer-5 were faced with teaching CAD for the first time; while others had benefitted from earlier staff training in 2018. Their varied levels of enthusiasm mirror similar research examining differentiated instruction using blended online learning (Boelens *et al*., 2018).

Participants' responses to change are easier to understand when the wider socio-technical context is revealed. Judging the success of a system is also determined by the complex interaction of changing human, social and technical systems (Petrina, 2003). Churchman's assessment of the essence of systems as a mixture of "confusion as well as enlightenment" which only begins "when you first see the world through the eyes of another" (Churchman, 1968, pp. 230-231), reinforcing the assertion that the ideal pedagogy is unlikely to be static. It is more likely to be an entangled mixture of pedagogies and technologies (Fawns, 2022), which happen to be appropriate for the individual lecturer, particular student group, social context, and location.

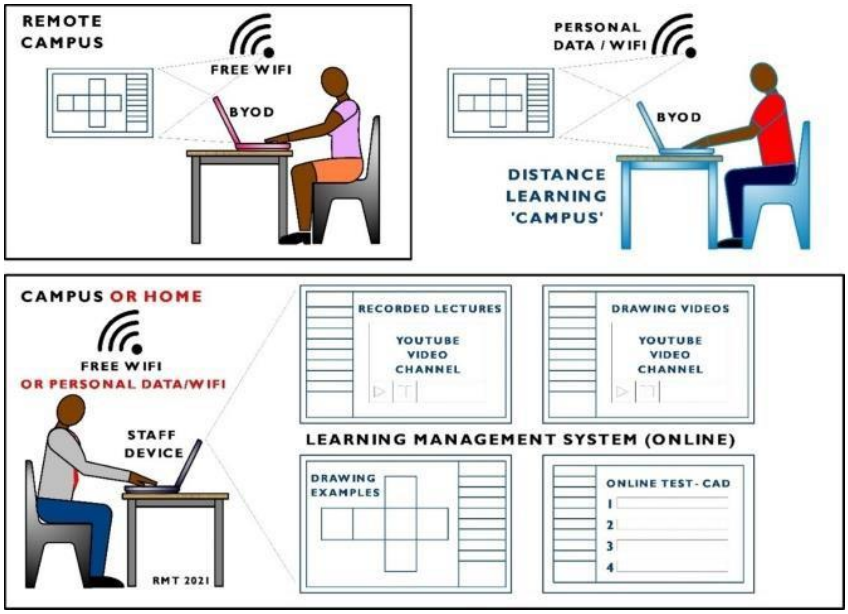
7.4 The Influence of Changing Institutional Teaching Systems on the CAD Course Accelerated by the Covid-19 Pandemic

The second cycle of implementation in 2020 was intended to repeat the first cycle delivery model with minor improvements. This was due to the positive results achieved in

2019. For the first two months, the second cycle followed the same format, with a combination of contact lectures and tutorials and LMS-based activities. By March of that year, this was not possible due to the Covid-19 lockdown of campuses. The mode of delivery, or pedagogical approach, was shifted from contact learning, with some resources provided via the LMS, to blended online mode of learning illustrated in Figure 7.6 using characters from Appendix 38. At this time, teaching practice was suspended, which meant that students could not apply CAD in school teaching.

Figure 7.6

Blended Online Mode of Learning CAD with Lecturer either at Home or in Office



Under Covid-19 restrictions, campuses were closed to students; and lectures were delivered using 'live' broadcast *Zoom* webinars; recorded 'canned' *Zoom* lectures with voice-over *PowerPoint* slideshows; or instructional videos saved on the LMS. Lecturers delivered these from home unless poor internet connectivity forced them to attend campus to broadcast. Figure 7.6 shows how this detachment of the lecturer from the lecture theatre, or ICT lab, enabled lecturers and students to work in isolation from home. The illustration also shows ways in which the delivery of lectures and course content could be conducted in the same manner for both contact-learning (CL) students forced to work from home, and distance-learning (DL) students who opted to work from home.

The effect this isolation from social face-to-face learning has on students and lecturers in the long run is subject to much debate in Covid-19 emergency online learning (Singh *et al*., 2021; Joia & Lorenzo, 2021) and in comparisons of distance-learning and contact-learning models (Tomei & Nelson, 2019). Debates about massification of learning through online study (Tlali *et al*., 2019; Kipchumba, 2019) are adjusted by the forced adoption of online learning by primary, secondary, and higher-education institutions during the pandemic (Maphalala & Adigan, 2021); and the increase in school drop-out rates, which resulted from students who were unable to adopt technology-assisted learning due to limited resources (Czerniewicz *et al*., 2020; Moscoviz & Evans, 2022).

7.4.1 Blurring of lines between contact and distance learning

The flexible blended online mode of learning removed many of the distinctions which separated contact (CL) from distance learning (DL) students, as their course content and assessment was delivered via the same LMS pages[xi]. One unobserved difference is that ICTE200 DL students would normally receive a study guide text as part of their remote study. The need for a physical guide faded away in 2020, as CL and DL courses provided resources, marking assignments and online assessment via the same LMS course pages. In this study, the online and offline CAD guides and instructional videos were produced separately from the traditional distance-learning module study guide, to be used for contact learning. Integrating these resources into a distance-learning study guide was not difficult; and in 2021, Lecturer-5 managed this process.

By the middle of 2020, more relaxed Covid-19 social distancing rules enabled a return to campus using a reduced lecture timetable. Management of venues to limit group sizes increased the workload for lecturers of large module groups. In some cases, overspill rooms had to be added to allow lecturers to deliver the same lecture simultaneously via a live streamed *Zoom* webinar; or lectures were repeated to multiple groups. This was not reported as a hindrance to ICTE200 students' learning of CAD, in that only small numbers attended campus due to ongoing fear of Covid-19. Students opted to study online using the CAD resources provided via the LMS.

Blended online learning effectively become the norm during Covid-19 restrictions (Czerniewicz *et al*., 2020; Sobuwa, 2020). The delivery of lectures, or learning events, to large

groups of students in a live setting remains reduced. The post-Covid-19 pandemic institutional landscape compressed the number of contact-learning sessions, while more students opted for the cheaper distance-learning option. Fortunately for 2020-2021 ICTE200 students, YouTube recordings were made available, via the LMS, immediately after recording of live lectures, in case students missed the broadcast at campus or chose not to attend. The importance of contact in the contact-learning module diminished, with reduced timetabled periods, and students opting to learn remotely to save money. Students on ICT modules completed the module without attending any campus lectures − online resources, videos, and assessments enabled complete immersion in the subject without lectures.

Online modes of study require more scrutiny in both developing and developed countries. The relative 'digital development' of countries has been thrown into the spotlight during this period. The technological deficits in developing countries are well reported (Czerniewicz *et al*., 2020; Francis & Webster, 2019; Tomei & Nelson, 2019). The Covid-19 pandemic revealed that countries with sophisticated technology and education systems struggled to adapt to online study in schools and HEIs (Kerres, 2020). In all education systems, it appears that "sound and aligned pedagogical concepts for the use of technology" (Kerres, 2020, p. 690) are required to ensure that online teaching is adapted for the majority. In the case of the CAD course, the multimodal pedagogical choice worked for many students with devices to study either offline or online via the learning management system, resources able to be downloaded and used offline. The cost of sustaining choice in mode of learning emerged as an

economic factor after Cycle Two when institutions attempted to attract contact learning students back to campus.

7.5 Disruption to CAD Teaching Pedagogy due to Changes to Facilities and Technical Provision for Learning

A recurring observation throughout this study has been the disruption to individuals' practice and practice architectures (Kemmis, McTaggart, & Nixon, 2014) caused by changes in facilities, human resources, technology, and ICT software. Throughout the institution's technical and organisation development, facilities and educational technology provision have been in a state of flux. This is illustrated by the number of different technologies used for teaching ICT over the last 4 years, shown in previous sections.

7.5.1 Changing teaching and learning spaces as a disruptor

From the lecturers' point of view, their teaching locations changed from fixed hardwired ICT labs (Figure 7.1) to general purpose lecture or tutorial rooms (Figure 7.2 – 7.5) and eventually to remote working from home during Covid-19 lockdown (Figure 7.6). Lecturers could no longer rely on campus teaching with standardised desktop computers and identical software installations. Instead, lecturers were faced with teaching students using whatever devices students opted to purchase.

Although the use of tablets declined prior to the implementation, improvements in smartphone technology enabled students to engage more in their studies using their cellphones,

the LMS (*Moodle*) becoming available in 2019 in mobile app format (Chamane, *et al.*, 2021). Students were unable to use the 2D CAD software to draw directly on smart phones but were able to view LMS information, video demonstrations, and guiding documentation. This meant that students could be more mobile or flexible in their choice of study location until such time as they had to complete coursework.

7.5.2 Computer-aided design requires a reliable electrical power supply

ICT labs and libraries in both private and state-run facilities are subject to the same power interruptions as schools through national load-shedding (Mojapelo, 2020). Ensuring reliable national electricity supply for powering computer devices in teaching, learning, and practising CAD at schools and HEIs is an issue which must be explored and resolved at government level (Kirlidog *et al*., 2018; Maphalala & Adigun, 2021). Reliable power supply and reliable internet connectivity is a constant requirement for delivering such learning efficiently.

Derar Serhan (Serhan, 2020) and Wei Bao (Bao, 2020) point to the need for contingencies to deal with unplanned outages, when using computer technology for higher education. Although separately, they present a balanced view of the advantages and disadvantages of online study, both pragmatically point out the effort required to ensure “high quality online learning” with careful “contingency planning” (Serhan, 2020, p. 340). The institution’s campuses currently benefit technically from backup power generation, running diesel generators, and providing free Wi-Fi for students. Provision of Wi-Fi access on

campuses does not guarantee that students and staff have access when local service providers suffer load-shedding. Diesel-generated electricity is also a significant burden for campuses in lost revenue. Developing human capacity and budgets to main choice in module delivery is an ongoing discussion.

7.5.3 Choice of CAD software as a potential curriculum disruptor

The CAD software utilised for the software, *2D Design*, had a disruptive effect on lecturers and students unused to designing of software, and unused to teaching design skills. Some had previously used various forms of commercial CAD, such as *AutoCAD* or *CorelDraw*; however, none had used software specifically designed for school use. Although *AutoCAD* is gradually being taught in schools in sub-Saharan Africa (Abusomwan & Osaigbovo, 2020), there has been little provision of CAD software for schools. Students responded well to the user-friendly design of the 2D CAD software; however, they were also conscious of its cost and of the free online alternatives.

South African schools follow the lead by Western countries, with most adopting commercial software such as *AutoCAD* for teaching EGD (Department of Basic Education, 2011) in high schools. There is currently little momentum to integrate CAD, or to develop appropriate software for use in primary schools that would prepare learners for high school. By exposing student teachers to a more learner-friendly form of CAD software it was intended that such software does find its way into primary schools. On other continents, 2D and 3D CAD are used in schools through technology subjects (Ng & Chan, 2019). Academics from various

disciplines are gradually recognising that CAD can assist in developing better understanding in mathematics and computational science (Eryilmaz & Deniz, 2021), as Lecturer-6 recognised early in this study.

Summing up changes in educational technology provision, one can see that keyboard-based devices such as desktop computers and laptops remain a constant need for students and lecturers. The physical campus venues, computer hardware, educational hardware, and CAD software are interconnected parts of the socio-technical system required to learn computer-based skills. A continuous challenge in South Africa currently is the unreliable electrical power supply and unstable internet connection disrupting computerisation of schools (Padayachee, 2017). In both schools and HEIs, appropriate hardware and software systems, together with reliable power supply, are essential (Kirlidog *et al*., 2018).

7.6 Summarising Disruption to Teaching and Learning During the CAD Course

It is difficult to illustrate 'disruption' to people. One can more easily illustrate the results of the disruption in spaces (See Figures 7.1 to 7.6). For example, one cannot see the Covid-19 virus; however, the visible results, in terms of infection rates and deaths, are palpable (Dhawan, 2020). In the case of the CAD implementation, the organisational disruption is illustrated using diagrammatical summaries. The effect that these changes had on staff and students can be compared by examining students' outcomes, and hearing what participants say about their learning experience.

The changes in social and technical systems (STS) over the first and second cycle are summarised in the summary roundel diagrams in Sections 7.6.6 and 7.7.2 below. The roundel diagrams show the various segmented organisational, human, technical, and institutional systems interacting around the core activity. These segments draw on specific actions and evidence which influence the core function. What emerged from viewing the real-life set-up of facilities is that these systems are interdependent (Fawns, 2022). Should one activity be disabled, for example 'access to software', the other activities are adversely affected due to lack of access to resources. This example is a common disruptor of the 'ideal scenario': both South African schools and HEIs suffer from resource shortages and loss of electrical supply through loadshedding (Kessy *et al*., 2006; Padayachee, 2017). Given the number of potentially disruptive variables, it is encouraging that some students were able to learn CAD and apply it to their teaching.

The situational diagrams represented in the previous sections helped me to clarify socio-technical issues (Baxter & Sommerville, 2011, pp. 34-36) which emerged from the data. The diagrams assisted me to visualise these issues under micro, meso and macro groupings. I developed summaries on CAD using a self-generated database of stock diagrams, 'characters', and technical systems reference drawings (Appendices 34 and 38, and Figures 7.1 – 7.6). The use of CAD here illustrates the way in which my application of the software as a research tool developed alongside participants in the course implementation process. CAD drawings helped to visually record changes I documented over time as discipline leader, implementing institutional policies and operational plans at a modular level.

Participants' engagement with educational technology changed, in a compressed space of time, as the institution made changes to accommodate the perceived need to digitalise and prepare teachers for future work in "Industry 4.0" (Bongomin, *et al*, 2020, p. 97). Some changes were made for economic and operational reasons to ensure consistency of delivery on multiple campuses. Some were due to forced transformation in response to the Covid-19 pandemic lockdown of campus-based lectures and tutorials (Czerniewicz *et al*., 2020).

Disruption caused by changes in operational and technical systems supporting practice architectures (Kemmis, Wilkinson, *et al.,* 2014b) had a causal effect on changes in lecturer and student practice. As a result of the development of the ICTE200 course, lecturers were partly prepared for the disruption caused by the Covid-19 pandemic by the time the first cycle of implementation concluded. What lecturers could not have anticipated was the workload implications, when all contact-learning modules had to be converted to blended-online mode of delivery (Crawford *et al*., 2020; U. Singh *et al*., 2020a).

7.6.1 Multimodal blended online delivery as an ideal pedagogical approach to teaching CAD

In answer to the Research Question 1, the study demonstrates a pedagogy for teaching CAD software, using a multimodal approach which linked student practice to vocational and commercial applications (Cheryl, *et al.,* 2021). This was influenced by Stephen Petrina's socio-technical approach to teaching CAD in university through various staged trials with students (Petrina, 2003).

This researcher's courses enabled a transition from manual drafting to 2D CAD and beyond to 3D CAD, taught within socio-technical theorical contexts, with 3D CAD replacing 2D CAD in many industries. In this study, Petrina's mapping of course structures (pp. 61-65) can be applied in mapping what exists now and what could, or should, be taught in primary schools. This is used in Table 7.1 as a comparison between changing and proposed practice architectures. Subsequently, Chapter 8 presents an example of how an improved course for student teachers was envisaged as part of the post-evaluation stage of the CPAR process.

Primary school education does not provide the same opportunity to work with learners, collaboratively, in improving the curriculum. However, student teachers will only learn to understand implementation of new technologies once they are willing to trial them and respond to learner feedback (Gracia-Ibáñez & Vergara, 2016). This implementation used a multimodal approach to confront students from various pedagogical angles as they learned CAD using guides, videos, lectures, and small-group, or one-to-one, tutorials. Future iterations may need to explore the teaching of CAD to learners; and gaining feedback from them to fully understand the transition from learning CAD as a user to teaching CAD to future users.

7.6.2 Multimodal education as a favourable business option to increase access to higher education

Private educational institutions, such as the subject of this study, appear to struggle to settle on an ideal mode of delivery as the teacher-education market changes in response to social and technological developments. This quest to find cost-effective, profitable, accessible

forms of higher education provision has led to rapid changes in pedagogical approach, which often follow the educational technology trends more than any specific pedagogical standard. Providing a range of learning opportunities, or 'events' in various formats, seems to have become the most fashionable approach (Boelens *et al*., 2018; Contact North, 2020). Providing students with flexibility, both to study and solve problems, can be promoted as a dragnet which enables more students to achieve success (Liu *et al*., 2021). Global trends mirror the approach used in this study (Onofrei & Ferry, 2020). These trends also show that private institutions wish to be seen to be providing more value for money than their public counterparts by offering greater flexibility.

Petrina's socio-technical systems approach linked traditional manual drafting with CAD theory and practice to create a contextualised course (Petrina, 2003, p. 65). This provided a good transitional connection for integrating CAD into established technology subjects in schools (Allan *et al*., 2018). Building a course, at a primary level, around CAD skills which can be taught online or offline, means that teaching can respond to challenges in power supply and internet connectivity, and provide more 'customer' flexibility. CAD becomes more easily understood when it is taught in the context of a practical technology project as part of the technological design process (Brink *et al*., 2022). Having demonstrated CAD teaching's feasibility in a blended online course, this study could be seen to endorse online forms of teacher training which are attractive to commercial teacher-training institutions. However, a group of students contradicted this by opting to attend campus face-to-face sessions to learn live with other students and lecturers. At an international level, CAD is taught with or without

CAM in art and technology subjects in some European, American and Asian countries (Fraillon *et al*., 2019, pp. 33 – 38) for planning, developing and evaluating products in high school technology activities. However, there is lack of a universal plan for what should be taught to primary school teachers, or how it should be taught. This study shows that mimicking and extending school design projects in teacher training prepares teachers to teach design with CAD.

7.6.3 Multimodal blended online learning enables massification

The phenomenon of massification in private institutions is understandable; such increases enrolments, and cuts operational costs, to satisfy shareholders' desire for profit on their investment. However, this can lead to compromises in terms of quality and levels of lecturer/student support (Contact North, 2020). In countries such as South Africa, higher education is often the default option for school-leavers. A constrained economy and growing evidence of state corruption act as an obstacle to economic growth, and meaningful employment, giving school-leavers fewer options (Tlali, *et al.*, 2019). Covid-19 caused a temporary global shift to online school teaching and learning using ICT; however, it did not address teachers' requests for more relevant training in teaching ICT skills (OECD, 2019, p. 152). Distinguishing between using ICT, teaching with ICT, and teaching ICT skills and theory to learners, must be made more explicit in collaborative global planning of educational systems. Evidence in the OECD study (2019) showed that little more than half of teachers in OECD countries had received training in teaching ICT skills as part of teacher training (p. 1).

The numbers enrolled on the compulsory ICTE200 module in contact- and distance-learning mode now exceeds a thousand students annually. Massification, in private higher-education institutions, has reduced the opportunity for more intimate forms of engagement and learning (Kipchumba, 2019). This is not because the venues no longer exist: it is due to space limitations and cost. It is neither feasible, nor sustainable, to engage with students meaningfully on a personal level in modules populated by hundreds of students (Kipchumba, 2019). Much of the learning content and assessment must be located on the learning management system to enable remote access and deployment of outsourced markers who assist lecturers with assessment. Students generally responded well to this blended approach to learn CAD before and during Covid-19. However, as distance learning became more prevalent, and student numbers soared due to lower course costs, student support in ICT subjects became more difficult online.

This module provided multimodal study as a choice in the first cycle. Choice was curtailed in the second cycle due to Covid-19. Post-Covid-19, the cost of providing choice and online resourcing is still to be calculated. This study has highlighted, at a micro level, the need for human resources to manage student numbers, maintain quality in delivery, and to ensure student satisfaction in both face-to-face and online spaces should a blended approach be used. It has also shown that LMS-based learning does not suit all students or match their limited ICT abilities. As quality of ICT education in schools varies so much nationally and internationally, it will continue to be difficult to develop minimum standards for entering teacher training, or to adequately standardise and police ICT qualifications required to enter the profession

(Fraillon *et al*., 2019, p. 38). More fundamentally, there is still a need to consider alternatives to certified higher-education pathways which do not suit all school leavers (Illich, 1976, p. 19). CAD does not suit all teachers either. Some still prefer manual drawing.

7.6.4 Technology which further enhances blended online teaching

Online meeting technology (e.g., *Zoom* and *MS Teams*), enabled live recording of presentations and software demonstrations during the second cycle (Joia & Lorenzo, 2021). Such provided a more personalised and customised demonstration of CAD drawing activities alongside the recorded instructional videos I created for the first cycle. These tools replaced more cumbersome professional recording and editing software used with Lecturer-1. The online meetings facilitate live 'drawing by demand' lectures when activities or skills can be re-presented after students have viewed an initial recording of the activity. However, the live online delivery in this format was not popular with all students (Serhan, 2020, p. 340). Students studying from home preferred to watch recorded versions of online lectures and tutorials in their own time. This effectively made the 'live' broadcast lectures the same as the recorded instructional videos. Teachers in many countries adapted to using ICT effectively to deliver teaching during the Covid-19 pandemic; however, the effectiveness of their pedagogical approaches adopted requires more longitudinal study. This is reinforced in the European Commission's *Digital Action Plan (2021-2027)* which prioritises "better use of digital technology for teaching and learning" and "improving education through better data analysis…" (European Commission, 2020, p. 4).

7.6.5 Improvements to the CAD pedagogy to encourage better integration in teaching and learning

Superficially, the planned pedagogical approach was successful; however, the more longitudinal question remains: Is the multimodal, flexible blended online approach efficient or sustainable as student numbers increase? The changes to institutional delivery of ICT teaching and learning, before, during, and after the implementation, had a direct impact on the CAD course. Changes to mode of delivery driven by Covid-19 directly affected teaching of the course in its second cycle; and moved blended online teaching of CAD to a point of no return.

The multimodal approach used in the first cycle emerged as sound practice; nevertheless, it was unsustainable when restrictions to contact lecturing were implemented during the Covid-19 pandemic. The move to flexible blended online teaching, together with the increased student numbers, impacted lecturers' ability to augment online content with face-to-face lectures and tutorials used initially. Institutional changes to venues, devices used, and technological approaches to support and deliver learning during Covid-19, had a destabilising effect on teaching and learning during the stages of implementation, which was mirrored in other countries (Dagman & Wärmefjord, 2022; Parker *et al*., 2020). The changes serve as a record of the disrupted institutional and operational conditions in which the study is located. Future iterations will need to remain flexible to incorporate alternative pedagogical options and allow for unexpected change.

Recommended online improvements, based on results data (e.g., incorporating an online CAD test and additional dice drawing example), were quickly absorbed and implemented as the second cycle started. Treating the specific design activities as reusable online learning objects (Onofrei & Ferry, 2020) meant that these resourced examples could be transferred to other modules, including CAD. Planned contact-learning changes could not be implemented because campuses were forced to shut down, and teaching was moved online.

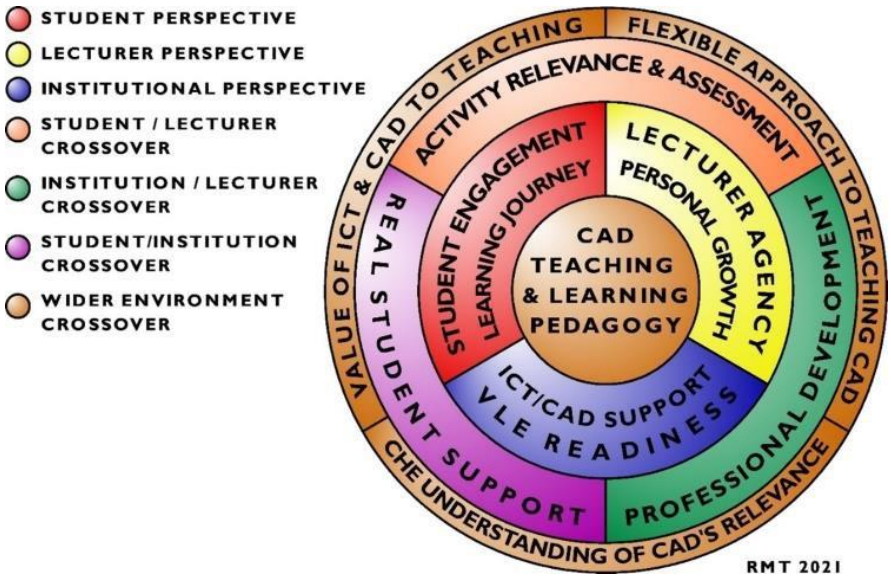
Delivery of contact learning ICT tutorials remains an ongoing dilemma for academic campus managers. The inclusion of CAD in the ICTE200 end-user course helped maintain it as an exclusive end-user ICT course. This was planned to raise students' and lecturers' awareness of the need for more design-orientated, multimedia, ICT training in primary schools. This mirrors what more progressive countries have implemented worldwide in general education plans (Fraillon *et al*., 2019, p. 38) but remains an innovative approach for primary school education.

7.6.6 Summarising Responses to Research Question 1

The earlier sections of this chapter mostly map changing operational delivery of ICT and CAD. The final summary reflects what was taught, how it was taught, and how the participants responded to this. Figure 7.7, below, summarises some of the key elements of the evolving CAD pedagogy from its central modes of delivery to wider contextual issues that form the basis for a redesigned version.

Figure 7.7

A Model CAD Teaching and Learning Pedagogy



The students', lecturers', and institutions' operational-management perspectives emerged as key factors. The figure's colour key shows these at the centre of the image represented by primary colours (red – students, yellow – lecturers, blue – institution). The research question's relationship to the wider context is indicated by the tertiary colour of the central title. This indicates that an 'ideal' pedagogy is not simply created in isolation by the lecturer. The pedagogy should include a combination of lecturers meeting the needs of students, within institutional parameters, with students maintaining agency to ensure personal growth alongside

changing technologies support systems. This is what Petrina calls "addressing the conventional boundaries between humans and machines" (Petrina, 2003, p. 70).

Where the interactions between these players generated relational issues, these are indicated in the second ring of secondary colours (purple – student and institution, green – institution and lecturer/assessor, and orange – student and lecturer). The outer ring (brown – tertiary colour) represents the wider environment, which includes social, technical, and political influences that may impact on student teachers', lecturers' and higher-education- institutions' ability to develop and sustain appropriate forms of pedagogy for teaching creative and technical computer skills such as CAD.

Design, evaluation and modification of module content and pedagogical approach was dealt with in meetings and workshops as part of the CPAR approach. These focused interactions became a form of departmental professional development. Additional staff development needs were identified in these spaces. These events gave lecturers more motivation to explore new approaches to teaching ICT and CAD. This collaborative approach was shared with lecturers in other specialisms during departmental meetings.

Participating students benefitted from trialling a range of options to complete CAD tasks using visual images, video, and written resources provided on the learning management system (LMS). Lecturers supported learning with live lectures, tutorials, and online communications through email and LMS mail. Commonly, the LMS resources guided the students on their journey; however, some were observed to benefit from direct interaction with lecturers in tutorials at campus. Pedagogical design was assisted by lecturers' constructive

criticism of activity relevance, and addition of meaningful assessment using peer critique and marked portfolio submissions.

Student engagement in lectures and tutorials acted as encouragement for students reluctant to learn independently online. Submission online enabled some to bypass this public interaction in favour of an individual approach. Remote/individual study was made possible by lecturers/facilitators collaborating with LMS administrators to ensure that content was online and fit for purpose. This type of collaboration has recently been found effective by public health experts working with the author in the remote training of nurses in rural South African settings (Chamane *et al*., 2021).

Students that did not benefit from the online provision were generally those with weak ICT skills. The ability to access 'real student support', as opposed to virtual support online, was raised by students and staff. Changes requested after the first cycle acted were generally motivated by the need for students to be taught general ICT skills in their first year to enable more advance systems such as CAD to be taught later in the programme.

The outer ring of Figure 7.7 signifies the wider social, environmental, or political issues affecting the teaching of CAD. Student ability to use and promote CAD was linked to their understanding of its purpose in different contexts, and their completion of drawing tutorials. This was reinforced when lecturers appreciated the value of CAD for teaching. Ideally, lecturers should have motivated students to apply CAD to teaching practice in the weeks following their campus learning. An improvement would be to have CAD activity immediately assessed by the lecturer, and the school mentor assessment used to validate the lecturer's

feedback. This school feedback would have encouraged further application during teaching practice, and brought lecturers closer to mentors in assessing students' CAD skills.

Viewing the wider environment, national educational bodies such as the DBE and CHE were considered important 'influencers' in the procurement, dissemination, and adoption of such technologies. Without common understanding of the value and application of modern design technologies in schools, these organisations can be perceived as obstacles to improving the national curriculum. To promote "digital readiness" in education, government institutions nationally and internationally need to lead by example by demonstrating more technological know-how; and adapting to change (European Commission, 2020, p. 5) alongside private institutions that have to adapt to technological change to remain profitable.

7.7 Students' Ability or Inability to Implement CAD Learning in their Teaching Practice

This RQ2 must be addressed: How might the use of CAD help intermediate-phase student teachers effectively to integrate ICT in developing teaching and learning support materials for their teaching practice? This section examines what influenced either students' ability or inability to integrate CAD in teaching firstly, by students creating resources for teaching practice and, secondly, in applying these resources in teaching, and thirdly, in teaching CAD to learners. Students' ability to use CAD to create resources for their teaching practice was influenced by their limited experience of the software, available time to practise, and the constraints of their prescribed teaching-practice portfolio activities set by the teaching practice

(TPR) department. Better facilitation of the teaching-practice expectations of the study by lecturers may have mobilised students to use the software immediately to create resources. Additionally, teaching students a curriculum-linked CAD resources activity, to be taught in the week of TPR, immediately after CAD training, might have produced better outcomes. By designing and creating their own resources to teach it could be argued that students tick international boxes for "digital competence" (European Commission, 2020, p. 7) by demonstrating: ICT literacy (combining CAD with regular resources); communicating (to learners); creating safe and appropriate digital content; and problem-solving (by developing their own design after practising with a taught example).

The reported issues highlight the importance of skillful facilitation of the research group (Schoonen, 2021). Issues also allude to systemic problems in the school system that have produced student teachers lacking confidence to create their own teaching materials without the use of the internet. A disturbing observation, from some interviewees, related to their default use of the internet to find resources. In place of self-developed designs, many cited the ease of access of resources, via the internet, as a disincentive to create originals. Using the work of others, as a default, is a sign that some student teachers lack willingness or agency to innovate. It also reflects international data which shows high usage of the internet by youth for social purposes compared with low application of ICT skills in school activities (OECD, 2019, p. 165). This observation is of concern in student teachers entering a profession which requires a willingness to learn and reflect to be role models for learners (Schön, 1987a).

Although the implementation enabled creation of a clock resource as part of the students' training, their use of CAD to apply their personally developed resources was not tracked beyond submission of portfolio pieces for the final module assessment. Feedback from surveys and interviews instead, informed this second element of the research question. Because students did not go to schools specifically to teach CAD, in this project, their reflections on how they applied their learning in schools were often linked to their personal motivation, their placement school, or the institution.

7.7.1 Students' initiatives to integrate and apply CAD in their teaching

Some students reassuringly recognised the value of learning 2D CAD as a skill to support their teaching for creating reusable resources (Onofrei & Ferry, 2020). Students also recognised that future schools must teach creative computer-based technological skills at an earlier stage than previously taught, which reflects global thinking on ICT education (European Commission, 2020, p. 7). Students brought up with unquestioning minds are likely to accept the status quo; and may miss the opportunities presented by new problem-solving skills (Freire, 1972). Reflecting results of earlier U.K. studies (Barlex & Miles-Pearson, 2008), some students saw that CAD could enhance their teaching resources and assist in their teaching of a wide range of subjects.

Cultivating positive critical attitudes, by introducing critical participatory methods to student teachers, was part of the motivation for this study. The collaborative nature of the project opened students' and lecturers' eyes to the value of both reflective and reflexive

research in their teaching careers (Schon, 1983). Student-11 stated this explicitly in his interview when appreciating the opportunity to be part of the project as an active participant. The inclusion of students' feedback on the use of CAD in teaching practice was designed to elicit comparison with their campus-based student learning. Such comparison encouraged critical reflection on the value of their learning and its application in their future workplace.

Students' feedback demonstrated attitudes which partly reflected their own background; school experience, or inexperience; desire to be seen to be doing the right thing; fear of an inequitable school system; and confusion about the role of school education in a transforming society. As Illich and Freire pointed out, in their studies of education decades earlier, teachers are victims of the system that they are paid to uphold (Freire, 1972; Illich, 1976). Teachers teach 'The System' they are programmed to live in. This way learners are expected to follow in teachers' footsteps: unquestioning and passive to maintain social order. Sustaining the old order, in the South African context, maintains the privileged and keeps the underprivileged out of sight, creating "barriers in their development, to humiliate and discourage them" (Sikakane, 1977, p. 39).

Some students recognised that CAD could help them enhance their teaching, develop greater agency, and look beyond teaching as a permanent career choice. They recognised that learning design tools such as CAD in schools, at an early age, would enable students and teachers to embrace modern design and technology at a more formative stage in their development (Woolfolk, 2016). Learning designing skills enables learners and teachers to think about practical technological problems in various ways (Neill, 1915). Thinking more critically

and creatively inevitably helps students engage with wider issues in more critical ways (Williams *et al*., 2017).

In a South African context, critical thinking can include developing ways of including indigenous knowledge as context for designing and solving practical problems (Gumbo, 2015) which can enable learners to become independent and innovative thinkers. The Department of Education, in SA, in 2020-21, has partly recognised this need in attempts to bring coding and robotics into primary school curricula nationally (Department of Basic Education, 2021). Unfortunately, this context has still to be formalised at all phases (Mzekandaba, 2021); and there is little acknowledgement that real coding and robotics requires deeper understanding and experience of computer science and applied design process skills which include CAD.

7.7.2 Students' application of CAD to produce resources for teaching practice

Students' ability to use CAD effectively depends on many factors (Breckon, 2000; Brink *et al*., 2022). In this study, willingness to apply CAD directly in schools was partly influenced by how well students thought they had achieved in the module. Their marks for the portfolio (including CAD marks) only came at the end of the year-long module, in November. Confidence to use CAD immediately after learning may have been negatively influenced by lack of feedback from lecturers (Brink *et al*., 2022). The online peer assessment activity, which took place immediately after the drawing exercise, enabled students to receive initial feedback. Because this came from fellow students lacking expertise themselves, this may not have boosted the students' confidence to apply their knowledge in teaching practice.

Student teachers' application of CAD on teaching practice can be viewed as part of an interaction between students, lecturers (or the teacher-training institution), and school. These three players interact during the different phases of teaching practice, for example, lecturers and schools interact in setting up TPR assessments; and they meet mentors and head teachers on school visits. Student teachers interact with lecturers during TPR visits, but also during campus or online distance-learning lectures. Schools interact with students during TPR placements and, it is hoped, after students qualify and seek employment in schools. Figure 7.8 summarises some key elements of these three-way interactions; and how they are influenced by one another and by wider environmental or social factors.

Figure 7.8

Socio-Technical Systems Influencing Student Teachers' Use of CAD for Teaching

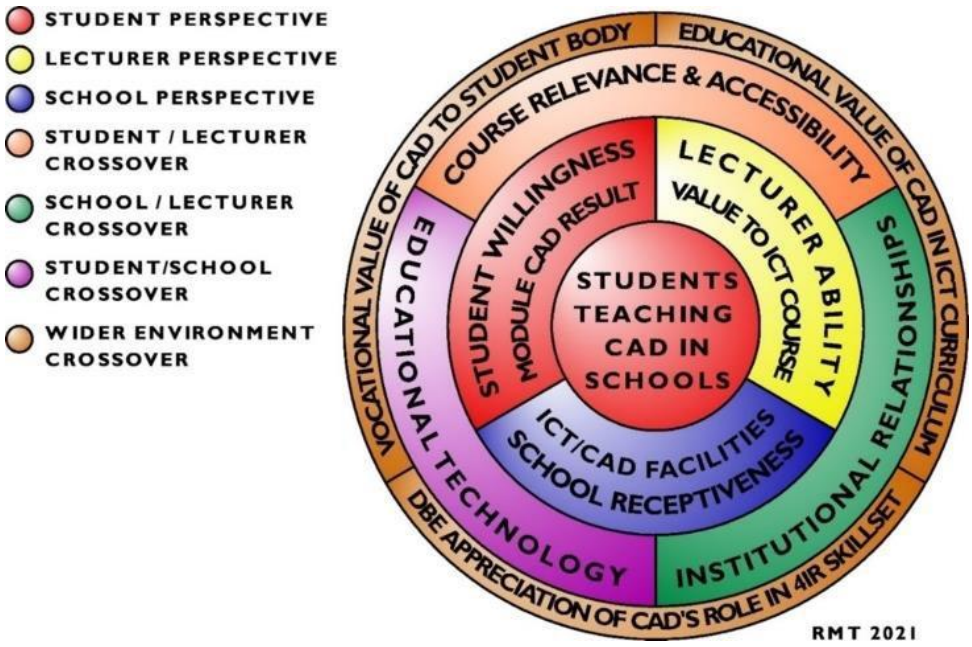


Figure 7.8 presents a summary of key perspectives which impact on student teachers' ability to implement CAD in resourcing their lessons for teaching practice. This summary is drawn from findings presented in Chapter 6.

The students', lecturers'/assessors', and schools' perspectives emerged as the major players. The figure's colour key shows these at the centre of the image represented by primary colours (red – students, yellow – lecturers, blue – schools). The student is located at the centre

indicated by the red colour of the central title. Where the interactions between these players generated relational issues, these are indicated in the second ring of secondary colours (purple – student and school, green – school and lecturer/assessor, and orange – student and lecturer). The outer ring (brown – tertiary colour) represents the wider environment, which includes social, technical, and political influences that may impact on student teachers', schools' and institutions' ability to teach and implement CAD in schools.

Some of the students who used CAD to create resources for school teaching had experienced CAD in the previous year in mathematics coursework; received positive feedback in marks; and had early exposure to the software's strengths and limitations. A weakness of the course identified by the nominal group workshop was the need for clearer definition of CAD. Previous experience and understanding of CAD, and its extended value in the curriculum, assisted student teachers to apply CAD more readily.

Wider issues which affected their ability to use CAD effectively included students' and their lecturer's varied interpretations of CAD's relevance to the course and to the primary schools' curriculum. Had all parties been better informed of the DBE's impending piloting of a new coding and robotics curriculum for primary schools in 2020-21 (Mzekandaba, 2021), the various parties may have exercised different views.

7.7.3 Teaching practice schools' ability to support student teachers' use of ICT and CAD

In the second cycle of implementation, following the March 2020 onset of the Covid-19 pandemic, schools were obliged to follow radical changes in teaching to accommodate learners studying from home during 'hard' lockdown; and later, in a phased return to school under Covid-19 rules (Czerniewicz *et al*., 2020). Subsequently, this new behaviour severely limited student teachers' ability to conduct teaching practice and to use any resources developed on their CAD course unless these were shared online.

State schools, with high numbers of enrolled students, were forced to operate 'one day in one day out' limited access procedures to enable socially distanced class sizes in what were commonly over-crowded classrooms (Ardington, *et al.*, 2021; Joia & Lorenzo, 2021). Learners thus were disadvantaged by missing half of the time they should be at school. This caused problems with home supervision and pacing of the curriculum. State schools were provided some resources to assist learners to study from home which included television and internet channels broadcasting lessons throughout the day. However, indigent learners without access to educational technology at home, via TV or computer, endured an interrupted part-time education (Ardington *et al*., 2021). The two years of disruption saw some students lose out on a full year of education, and a disturbing increase in drop-out rates (Moscoviz & Evans, 2022).

Private schools were not propelled into the same mode of operation as state schools in that their class sizes are customarily smaller, and social distancing was possible (Soudien *et al*., 2021). Learners at such schools benefitted from both LMS-based online learning and

assessment during 'hard' lockdown, and classroom learning supported by online resources during the period after they were returned to school. As with the lecturers of the School of Education, the burden of content creation and online class management, to allow for online delivery, fell on classroom teachers themselves, whether they resided in the state or the private education system. In-service and student teachers' resilience and dedication was greatly tested during this period (Soudien *et al*., 2021); while some South African schools, without resources, saw students lose out on the equivalent of a year of basic literacy education (Ardington *et al*., 2021).

Given the restrictions in opening of schools over the course of the post-implementation year, teaching practice (TPR) for student teachers was greatly constrained. Students' ability to try out new skills such as CAD in developing resources for teaching was restricted to an online academic exercise. Utilisation of any self-designed resources in schools was severely limited by the reduced time student teachers were allowed in schools. Portfolios of evidence previously submitted and marked in hard copy were changed to online e-portfolios (Carl & Strydom, 2017; Pegrum & Oakley, 2017). These included activities assessed remotely by lecturers who would normally observe student teachers in schools giving live lessons.

Some of the activities that student teachers were asked to perform for teaching practice mimicked the pedagogical approaches that ICT lecturers adopted in ICTE200's portfolio. An example of this is the lesson video taught around an online resource. Students recorded themselves teaching a lesson to an imaginary audience and submitted these as an alternative to presenting a live classroom lesson. This prepared student teachers for the possibility of teaching

online to students stranded at home during the pandemic lockdown. Students of ICTE200 experienced this earlier in their CAD video-learning experience and were more prepared for the transition to preparing video lessons for schools.

The online e-portfolio approach to teaching practice assumed a certain level of ICT skill that was lacking in some students and in-service teachers (Carl & Strydom, 2017). Another unacknowledged change in TPR was the online marking that teaching assessors were obliged to conduct (Pegrum & Oakley, 2017). There was no one-to-one engagement with students' work in a school setting. The relationship between student teacher and TPR assessor became virtual. There is a difference between remote written criticism, or feedback, and direct verbal feedback. The former is generally more considered and 'colder'. The latter has more relation to the moment and emotions at the time, and carries greater weight (Williams *et al*., 2017).

7.7.4 Contextualised training on institutional courses to encourage teaching practice with computer-aided design

Lecturers' ability to promote CAD as a tool for teaching practice depended on their own ability as users, and their personal bias towards its relevance in their ICT end-user computing course. Those who were less invested in creating the course: Lecturer-2, Lecturer- 3, and Lecturer-5, were more open minded to its possibilities. Lecturer-1 had invested most time developing ICTE200 and was more sceptical about its value in the course. However, after teaching one cycle, he appreciated its contextual value in applied technology and design teaching.

Lecturers' direct involvement in following up CAD use by student teachers in schools, was underutilised in this study. However, CAD use was observed. For example, both Lecturer-5 and Lecturer-6 reported observing students using mathematics resources designed on CAD in school visits. Lecturer tracking of student use of CAD would have been easier had application been linked to assessment in the taught ICTE200 module or TPR assessment e-portfolio. The latter would require better mapping of ICT specialisms with TPR portfolio assessments and better inter-departmental collaboration.

7.7.5 More ICT and CAD CPTD to motivate newly qualified and in-service teachers.

Students, lecturers, and schools emerged as being loyal, or unquestioning of, the current curriculum. This is not surprising, the schools' curriculum being linked to South Africa's transformative constitution (McConnachie, *et al.*, 2017). However, lecturers and students alike alluded to the curriculum being out of date in some areas – particularly in teaching of and access to ICT. Student teachers also reported that host schools lacked ICT teaching technology and facilities; and they were asked to assist with training in-service teachers in ICT skills. Encouraging alternative approaches to teaching, with and without technology, is an important role of higher-education training institutes; however, it also requires school buy-in. Schools, in turn, should advocate and lobby for more investment in technology (Padayachee, 2016), and for better continuing professional teacher development (CPTD) training (Padayachee, 2017). Involving student teachers in CPTD is one way that the students can extend their pedagogical experience and trial resources with a critical audience.

7.7.6 Interdepartmental and inter-institutional collaboration to encourage assessment of application of CAD skills in schools

Institutional relationships emerged as a key area requiring development to introduce new technologies to the classroom during teaching practice. Student teachers often bring new ideas and experience of modern systems to teaching. Often these innovations are downplayed by schools in favour of maintaining the status quo, using dated systems which are more familiar to in-service teachers. Student teacher/school relationships are also constricted by the formality of teaching practice assessment for marks. Better institution-school-student relationships will help schools to appreciate where new technology and ideas fit into their school ethos (Fares, Fowler, & Vegas, 2021). These relationships should be reciprocal and should enable teacher-training institutions to listen to schools and understand their needs and concerns. These relationships can be developed through face-to-face engagements, online seminar/webinars, and institutionally hosted events which bring stakeholders together.

7.7.7 Continuing professional teacher development to empower mentor teachers and support student teachers' use of CAD

Student teachers highlighted the 21st century ICT skills deficit between themselves and host-school mentor teachers. Shared continuing professional teacher development (CPTD) events involving students, lecturers, and in-service teachers were suggested to encourage communities of practice; and to allow private higher-education institutions to give back to the

schools community that hosts their students. CAD learning could be incorporated into 21st century skills training events for natural sciences and technology, life skills, and coding and robotics courses for primary schools (de Souza Almeida, *et al.*, 2020). Were student teachers to be encouraged to provide CPTD sessions for in-service teachers, such may assist with rolling out technologies more efficiently in schools (Mzekandaba, 2021).

The increased national footprint of private teacher-training institutions may cause a change in the current reciprocal teaching practice arrangements. Schools that currently host privately educated student teachers free of charge may question the relationship when their numbers equal, or exceed, state university student teachers. In 2022, the School of Education registered more than 2000 PGCE student teachers. Placing these numbers in high schools is challenging enough but becomes more problematic when these students compete for finite school places with students from state universities. Maintaining good interpersonal relationships with schools becomes more difficult with massification (Kipchumba, 2019). If students from private teacher-training organisations can add value to schools by introducing new technologies and pedagogical approaches, this may go some way to justifying a continuation of their free teaching-practice experience in schools.

The diagrams (Figures 7.7 and 7.8) reflect interpretation of results from the CAD implementation study from students and lecturers' points of view. The schools' view is based on their observations and experience of teaching in schools. Future studies may benefit from in-service teacher/school collaboration to assist in broadening relationships which sustain the current model of teacher training. Such collaborations may include a pilot in which students

spend some teaching-practice time conducting in-service training for teachers in new technologies such as CAD.

7.7.8 Better ICT courses to train student teachers to apply and teach advanced ICT skills, in practice, such as computer aided design

The implementation did not follow students to schools to observe them using resources, or attempting to teach CAD, as part of teaching practice. This is due to the separation of ICT training from teaching practice at a modular level. The 'one week in one week out' model of teaching practice allowed for almost immediate checking of students' use of the software in schools; therefore, students were instead asked to report via *WhatsApp* and in final interviews. Because the planned intervention did not explicitly state that students must use CAD in their TPR placements, this was unenforceable in the first cycle.

Intended follow-up of resource use in TPR in the second cycle was denied by the Covid-19 lockdown. Public-health restrictions led to cancellation of school placements. Instead, discussion of the need to resource lessons in classroom teaching became a feature of CAD training. Participants shared their lived experience in interviews. Promoting production of CAD resources as part of more novel e-portfolios may be a way of promoting their use in future (Mapundu & Musara, 2019).

What emerged from dialogues with students was the different levels at which they applied their use of CAD. Some created resources and used them. Others could not appreciate CAD's value at all, and did not transfer CAD learning from course to TPR practice. Some saw

endless possibilities for the creation of resources for teaching. Most cited lack of time to apply what they were learning in ICT and to convert this into resources, which was exacerbated by Covid-19. Students acknowledged that the resource drawing they had produced for ICTE200 was useful for teaching practice.

7.7.9 Collaborate with teaching practice departments to develop better ICT courses which deliver relevant 21st century skills

Tracking students' lessons in schools and observing their teaching of specialisms is difficult under the current prescribed teaching practice regime. Given the increasing numbers of students requiring placement in schools, simply finding teaching practice (TPR) placements is becoming more laborious. Collaborative planning with TPR administrators, may improve facilitation and students' application of CAD knowledge in teaching practice by co-creating e-portfolio resource production activities (Pegrum & Oakley, 2017). Developing such "communicative spaces" (Kemmis *et al*., 2014, pp. 89-90) will help bring the study into a more "public sphere" in which knowledge is constructed between disciplines to train better equipped teachers for 21st century education.

In future, the blended online pedagogical approach being used to teach CAD, integrated with teaching practice e-portfolios, may enable better assessment of students' ability to use software. This may be by producing recorded lessons which include e-resources using meeting broadcasting and recording technology − such as *Zoom* (Mapundu & Musara, 2019). Equally,

students could demonstrate use of CAD resources in traditional observed lessons and be credited for doing so in TPR portfolios.

7.7.10 Using critique to refine CAD pedagogy and encourage use of CAD resources for teaching practice

This study has reinforced that a natural way of meaningfully engaging, in a higher-education setting, is through students' collaborative critique of their courses (Petrina, 2003). Publications promoting 'ideal' forms of action research stress meaningfully engaging in critique with all participants (Burns & Worsley, 2015; Giatti, 2019; Kemmis, McTaggart, *et al*., 2014; Schoonen, 2021). Formal critique of this course was elicited through *WhatsApp* dialogue and interview questions. Critique of students' CAD work was first invited in the peer-review activity, and then followed up in the interviews. Findings showed that this critique was valuable for improving course design; and as a way of bringing lecturers and students together in a form of community of practice (Lave & Wenger, 1991). The critique also created a forum in which to reflect on the best methods of integrating CAD into teaching practice, discussing barriers to such.

Expectations that all participants who consent to engage in action research will engage consistently while learning CAD, are unrealistic (Gracia-Ibáñez & Vergara, 2016). Just as students of modern educational institutions expect flexible learning (Contact North, 2020), the reliance on participants to share their experience critically, should be more flexible. In this

study, I had to be flexible to adjust plans to meet the needs of participants within the socio-technical constraints of the institution.

A recent paper by Schoonen, Wood and Kruger (Schoonen, 2021) points to participants becoming "active producers of knowledge rather than informants and recipients" (p. 18). I would argue that the participants can fill all roles at different times in the process. For example, Student-1 and Student-2 provided reflective contributions during the interview phases, but became inactive at the workshop phase, whereas Lecturer-5, Student-11, and Student-4 provided constructive input throughout, in addition to reflecting on teaching practice. Lecturer-1 appeared negative at the early stages of the implementation; however, grew, through collaborating on video production, to make significant contributions to redeveloping the course in the latter stages.

Knowing where and when to critique a process, as it proceeds in real time, is the challenge. Success is only possible if the group collaborates when required. Both Wood (Wood, 2019) and Zuber-Skerritt (Zuber-Skerritt, 2018) reflect on this need for a shared vision and shared experience in creating transformation in learning. What is overlooked is that voluntary action can include transient participants, whose contributions can diverge and converge as they come and go in the action (Noffke & Somekh, 2009). This was evident in Lecturer-1's transfer of ideas from the study into his CPT100 module using a simplified CAD example (Appendix 35). Inculcating an attitude of continuous improvement in lecturers and students is possible if participants have agency and feel empowered to enact change (Yurkofsky, *et al*, 2020).

This study managed collaboratively to generate action and critical reflection. There was a natural undulation of interaction which caused wider ripples, meaning that critical engagement on a project level was finite. However, the value of critique is that it can outlive the engagement (Petrina, 2017), and should stimulate improved versions of the original study as continuous improvement (Yurkofsky *et al*., 2020).

7.8 Conclusion - Turning CAD Implementation in a Module into CAD Integration into the Curriculum

The title of this chapter could have been: "Implementing or Integrating Computer-aided Design Education in Primary School Teacher Training?". 'Implementation', in a collaborative sense, is revealed as a multifaceted process; and 'integration' is identified as more apt terminology to use in a CPAR process which draws on the participants' experience and ideas of implementation from within linked practice architectures (Kemmis, e*t al*., 2014a). 'Implementation' seems to be ambiguous when it comes to collaborative action; and therefore, may be better replaced by 'integration'. Such implies a more democratic process, where change is discussed with all stakeholders, and eventually converted into practice and practice architectures by users of the system.

Introduction of new subjects, technologies, and skills in a teaching curriculum is not simply about implementation. Implementation invokes clear definition; and enacting this is like fitting the pieces of a pre-determined jigsaw. The visual and dialogical material from earlier results chapters highlights the need for better integration, collaboration, and extended study to

improve ICT courses. Understanding that these various socio-technical systems are designed and controlled by different human players makes it easier to overcome challenges in integrating new technology into school curricula.

This study highlighted the importance of students and lecturers collaborating as ‘users’ in the course, while also as students learning CAD with the resources. Socio-technical systems theory emphasises the importance of human users collaborating and using constructive critique in designing of sustainable and effective systems (Petrina, 2017). The CAD course was part of a group of intertwined systems (Fawns, 2022) which were dependent on social, cultural, organisational, and technical elements. Effectively, the participants were not just users of CAD technology but co-participants in designing and applying such (Dron, 2022).

Returning to Figures 7.7 and 7.8, these diagrams illustrate that pedagogy is not simply the result of a small working group or action-research project. The appropriate pedagogy to use is one which ensures the growth of the student, as well as the lecturer, while working with appropriate support systems provided by the institution. Because campus operations have embraced more flexible modes of delivery universally, to allow for remote learning during Covid-19 pandemic and increased distance learning enrolments, the flexible approach used to teach CAD was innovative.

Flexibility is required in mode of delivery in meeting the needs of changing technologies for learning (Serhan, 2020). Flexibility, or adaptability, is also needed in the mindsets of students and lecturers. Under current conditions, all parties must appreciate that learning has become a multimedia event. Some researchers have labelled this a “growth

mindset" (Blewett, 2016). The opposite of growth is stagnation, and eventually decline. Stagnant pedagogy may ensure that students achieve the marks required to pass a summative assessment; however, this will not ensure understanding of the value of what is learnt, application of knowledge in teaching practice, or retention and adaption of knowledge to contribute to society (Freire, 1972).

CAD has some advantages over other traditional subjects taught in higher education: it is designed for use on computers; it can be taught either offline or online; lessons can be recorded using online meeting technology (e.g., *Zoom*, *MS Teams*, and *Google Meets*); and CAD is used to create images which have application in a myriad of subjects. A disadvantage that naturally accompanies these advantages, is that CAD perpetuates study and work on computers during a time when the student community is 'overdosing' on computers when online data and electrical power is neither unlimited nor free.

What has changed during the period of this study, under the unexpected influence of the Covid-19 pandemic, is the shift to greater reliance on internet-based course delivery and assessment (Maphalala & Adigun, 2021). Providing multiple opportunities of learning a skill such as CAD was confined to resources available via the learning management system (e.g., illustrated document, recorded lecture, instructional video and online quiz or portfolio assignment). Because CAD is computer software, it can be taught quite effectively using a blended online pedagogy. The software can be used offline once installed on a device. However, the study revealed that the blended mode of learning is not desired by all students – especially those who have paid for a contact-learning experience. Better communication with

students enables better understanding of their preferred modes of learning; and helps curriculum planners to provide a sustainable form of flexibility.

By further researching the student teachers' experience of using and teaching of CAD in schools, greater insight will be had into how best to teach CAD, and how best to train teachers to teach the skill. Choosing the correct mix of learning opportunities to cover the various preferences of fee-paying students is difficult without more detailed research into the specific effectiveness of the options currently on offer. This view is endorsed by Bao (Bao, 2020, p. 115), when pointing out that both offline self-learning and online phases are required to make the online phase fully effective. A well-structured approach to institutional course critique and teaching practice evaluation is necessary for improving CAD pedagogy (Petrina, 2003), and to ensure viability of future modes of learning. As numbers on ICT courses increase in private institutions, the need for flexibility and choice increases; students' background and experience must be factored into course design.

The implementation of CAD was influenced by quality of and access to institutional and schools' technological systems, and students' readiness and willingness to use these. It is proposed that further integration between state and private education institutions can have a positive influence on a damaged and divided education system, by improving teachers' and learners' ICT and design skills from primary school upwards (Adegbenro *et al*., 2017). This requires better-focused ICT skills training for teachers in higher-education institutions; and ongoing effective in-service training for teachers in primary and high school sectors, which could include student teachers as facilitators (Gumbo, *et al*., 2012).

The CAD intervention was disruptive in a constructive manner. The results of the implementation are an improved ICTE200 course which is more adaptable to differing modes of delivery during uncertain times. The ICTE200 course has remained flexible and relevant despite the darkness of the Covid-19 pandemic, together with institutional moves to dilute and standardise end-user ICT computing. CAD has remained a strong element of the module despite changes to prescribed software. Integration of new content into the CAD unit, thus improving the course at a micro level, has opened the way to considering ICT teaching and learning at a higher level. This can be achieved by incorporating students' teaching of ICT into courses and assessment of such in teaching practice.

Chapter 8 concludes the study, reflects on its achievements and limitations, and presents a suggested approach to teaching CAD in primary schools alongside other ICT specialisms with a flexible form of ICT course custom-designed for teachers. This model is derived from research in South Africa; however, it is applicable to any primary school environment, globally.

END OF CHAPTER

Chapter 8. Integrating CAD into the Primary School Curriculum

8.1 Introduction

This thesis set out to explore the most suitable pedagogical approaches to teaching computer-aided design (CAD) to student teachers as part of their ICT training for their intermediate-phase degree course. It also sought to explore student teachers' application of their CAD skills, producing personalised resources for teaching practice. To expose the most sustainable and appropriate ways of teaching CAD to primary school teachers, critical participatory action research was used, thus encouraging collaboration in design, delivery, and critique of the course between student teachers and lecturers. A socio-technical systems lens was used to aid theoretical interpretation of the wide range of systems influential to the integration of CAD into the teacher-training course. The study revealed that students' learning, application, and my own teaching of CAD to learners in primary schools, was an incremental pedagogical process that required collaborative design and integration of various socio-technical systems, over the course of a teacher-training qualification. This process requires cooperation across institutional disciplines and structures. Implementation of CAD and other technological design applications in student teachers' ICT courses is a favourable way of broadening teachers' technological skills, and introducing technological subjects earlier in the school system, to align with modern vocations and modes of learning. This applies to teaching

systems internationally, in which basic ICT skills and design applications such as CAD are not taught uniformly in schools and they are not compulsory skills for entering the teaching profession in all countries (Fraillon, *et al.*, 2019, p. 15). Universally, school curriculum plans acknowledge the need for a wide range of ICT skills, including design tools (Fraillon *et al*., 2019, p. 33). The issues reported that are inhibiting teacher training and implementation of CAD in primary schools in South Africa are not unique to a single country. The unequal division of wealth in developing and developed countries is reflected in unequal provision of technology education resources and training of teachers (OECD, 2019, p. 29). More international collaboration in development of resources, pedagogical design, and training of teachers is being encouraged in standardising provision in schools and allowing for more reliable assessment of learners through collaborative hubs such as the European Digital Education Hub[xii].

In the previous chapter, I discussed the findings of the study using a socio-technical systems framework, supported by interpretive diagramming, to address the research questions. The chapter revealed significant factors which contributed to developing a sustainable pedagogy for teaching CAD to primary school student teachers as part of a carousel of ICT skills necessary for functioning in the modern classroom. The discussion also detailed wider socio-technical factors influencing students' application of CAD in developing resources and augmenting the teaching of technology, mathematics, and science subjects.

This chapter highlights key recommendations, reflections, implications, limitations, and conclusions from the study. An extended CAD education process is proposed which

requires student teachers to learn, apply, and teach CAD skills over the course of their degree studies. A revised 'ICT for Teachers' curriculum is also presented, which includes CAD as a multimedia application in a carousel of specialisms. I also indicate where the CPAR approach has taken me, and the participants; and the limitations this approach has highlighted. Dissemination of findings by sharing with the study group (Kemmis, 2014, p. 187) and wider publication are presented as a consolidation phase of the action-research process (Zuber-Skerritt, 2018). The chapter concludes with an explanation of this study's importance in a global sense, responding to questions raised by the study which may stimulate further research. Finally, teaching of CAD incrementally, integrating available offline and online technologies, is presented as a pragmatic socio-technical theoretical approach to producing more practical teachers capable of operating in both well-resourced and resource-limited settings.

8.2 The Pedagogical Approaches to Providing Contextualized Computer-aided Design Education for Student Teachers' Learning (RQ1)

The study showed that a multimodal and multi-resource blended online computer aided design (CAD) course was favourable. Pedagogical tools included live campus lectures and small-group practical tutorials, combined with online learning, through video instruction, online quizzes, discussions, and study guides. Implementing the CAD course in an end-user computing course enabled inclusion of ICT-literate lecturers who were able to learn and teach CAD competently. Student collaboration in the course design enabled 'real time' observation of learning activities and feedback on the specific resources and methods used in teaching the

course; and revealed the challenges faced in accessing resources, learning online, and meeting course outcomes.

Deeper reflection on the outcomes of the research revealed that the collaborative design of the course, training of student teachers, and their subsequent application of experience in teaching practice were components of a continuum of CAD learning. This starts in their initial ICT course which is normally restricted to learning Microsoft Office tools with limited application in practical design activities. The missing element of the pedagogical approach is students' ability to apply and teach CAD. This is explained using a practical framework for teaching CAD within a revised ICT curriculum for primary school student teachers. The framework suggests that the ideal approach to teaching CAD is as part of a longitudinal ICT education delivered in each year of teacher training.

Early years of teacher training should include basic ICT end-user skills; however, subsequent years should build on this to explore alternative software applications (such as CAD); basic programming; learning management systems used for education; design of online resources; development of instructional video; and management and assessment of learners' ICT learning in physical and online learning environments. This type of multimedia approach is generally proposed for school systems internationally; however, it is not specifically refined for training of teachers and delivery in primary schools in Fraillon *et al.*'s (2019) report: *Preparing for Life in a Digital World: IEA International Computer and Information Literacy Study 2018*, in which 60 countries and over 110 education systems are reviewed.

8.3 A Multimodal Approach to Learning CAD Using Blended Online and Contact Learning Methods to Integrate Pedagogy and Technology

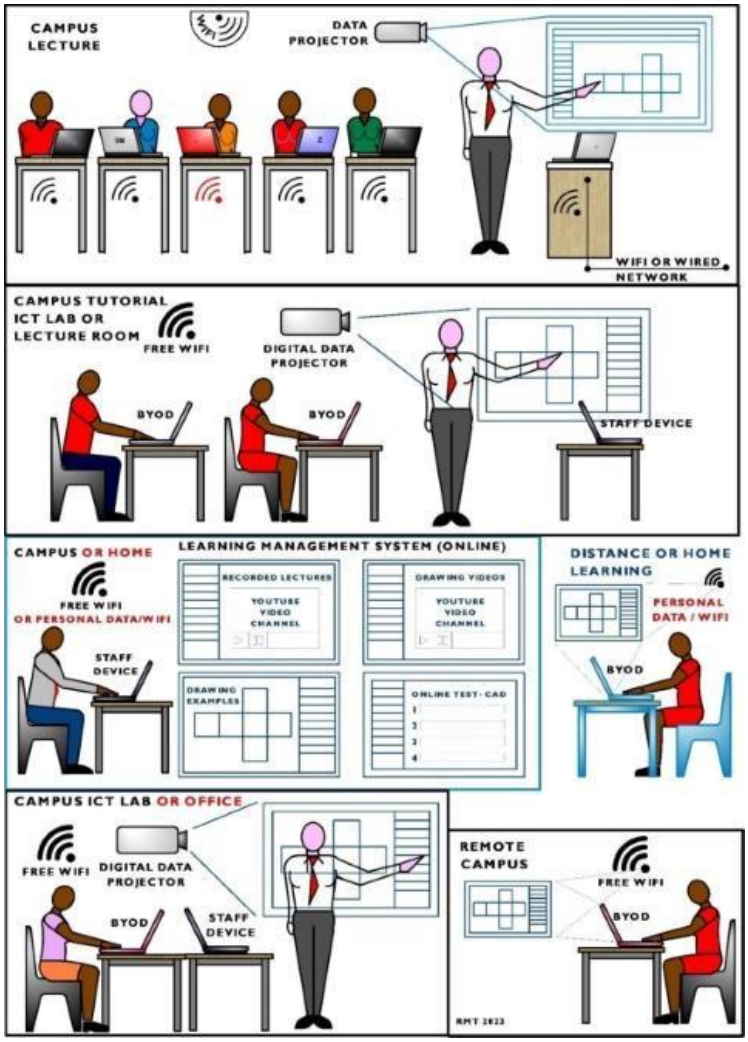
Teaching CAD using a variety of modes, including lecturers, practical tutorials, online study guides and instructional videos, enabled students to opt to study remotely, either on campus or in a combination of modes of learning. Students' success in learning CAD was dependent on their prior ICT skills, ability to access resources; ability to attend face-to-face lectures and tutorials offline; or to engage online via the learning management system. Provision of learning options was negotiated in course design and discussed as the course progressed. Lecturer and student willingness to try various options provided evidence that enabling choice was preferable if students, from different experiential backgrounds, were going to benefit from the course.

Socio-technically, the interdependence of pedagogy and technology (Fawns, 2022) emerged as an important factor in design of a post-digital 21st century course for student teachers (Fawns, 2019). The study of teachers' learning of CAD in a blended online mode, as a technical digital skill, highlighted that basic digital skills are now an inherent part of all learning activities in higher education. Deficits in basic digital literacy had a knock-on effect in the learning of CAD. The Covid-19 pandemic also exposed second-cycle students to more intense online study, which presented online learning and assessment of learning as a socially meaningful and embodied experience for modern students of teaching (Fawns, *et al*, 2019).

In private higher education, the provision of choice in mode of learning can conflict with the economies of scale. As an institution grows, student numbers on ICT modules grow. It becomes harder to provide unlimited flexibility in mode of learning. Choice becomes restricted as numbers grow and human and technical resources are stretched. The choice provided for students learning CAD on this course is summarised graphically in Figure 8.1, using standardised characters and locations (Appendices 24 and 38). With options to attend campus for lectures, tutorials, and on-to-one support, or to study online via the resources on the LMS, these students were given more options compared with other modules. The impact was beneficial in terms of choice.

Figure 8.1

Multimodal Blended Online Learning with Campus Sessions and Online Sessions supported by Learning Management System (LMS) Learning



However, staff were expected to become more flexible and adaptable, when it came to engagement with students, and more ICT literate themselves to provision LMS-based learning and live online broadcasts. The blended online, LMS-based, versions of modules were interpreted by some as a compromise allowing video recorded, or live-streamed online 'learning events' to replace live lectures and tutorials. Although there is recent existing research material available on the benefits of flexible hybrid online modes of study (Tomei & Nelson, 2019; Young, *et al.*, 2016), research draws generalised data from programmes and not specialised technologies such as CAD. This is a potential research gap. Because students were given the choice between learning on campus, online, or by combining both, a variety of preferences emerged.

Creating and researching blended or online versions of courses using CPAR, enabled authentic investigation of modules using practical data gathered in real-time from the learning management system and direct dialogue. Collaborating with participants in face-to-face lectures, tutorials and workshops was also vital in gaining authentic feedback. Facilitating co-creation of content and researching the benefits of various modes of learning with students and lecturers, using both online and offline communication channels, emerged as an effective way of developing learning material, and exploring the relationship between technology education and pedagogy.

8.4 Contextual Teaching to Give CAD Relevance in Primary Education

Participants appreciated learning to draw clock faces which could be used to teach learners to read the time on an analogue clockface. This context was consciously chosen in teaching students to create a resource for school use. Student teachers were also shown how the resource could be animated using *PowerPoint* presentations, when teaching learners to tell the time. Transforming the resource from an inanimate drawing to an animated clock, using basic presentation tools, illustrated the versatility of CAD as a resource for teaching technical drawing, and creating visual tools for teaching life skills and other subjects.

On another level, using CAD as a tool in creating the study materials for teaching CAD (Appendix 14) illustrated its power in authoring teaching materials. Lecturer-1 recognised the value of CAD in this context, which motivated him to create a YouTube repository (Appendix 16) for locating clock and dice video resources for our future use, alongside the illustrated study guides.

Finally, teaching CAD as a drawing tool within the end-user ICT course encouraged lecturers to source simpler alternatives which could be used by students should they be unable to access the *2D Design* software, following completion of their degree. This revealed that lecturers were considering real-life teaching contexts, beyond the institution's educational provisions, acknowledging that student teachers need to use free-to-access CAD software, or simpler software, such as *MS Paint* and *PowerPoint* drawing tools. Lecturer sensitivity to the needs of students appears to have been heightened by their collaboration in the study.

8.4.1 Defining CAD contextually to improve student teachers' ability to use and teach CAD

For student teachers to appreciate CAD for personal use and teaching, participants stressed that better contextual definition was required. The study showed that student teachers must become aware that CAD extends manual drawing to a computer-based virtual realm, revealing new vocational opportunities (Redeker, 2018). Students also appreciated that CAD skills enable teachers and students with minimal skill in manual drawing, to create drawings using image libraries and grids.

Additionally, students gained awareness that CAD traditionally resides in specific specialist subjects: technology, design studies, engineering graphics and robotics; and makes these subjects more relevant to the modern world (Barlex & Miles-Pearson, 2008). In the current South African curriculum, students must recognise CAD's function in the teaching of coding and robotics as a new primary school technological subject (Brink *et al*., 2022; Eryilmaz & Deniz, 2021). Students must also understand that CAD skills are not confined to technology (the subject), but can be applied in all subjects in which accurate illustration of concepts is necessary (Wan & Ivy, 2021).

From a socio-economic perspective, teachers must be aware that teaching of CAD is not formally enforced in primary or secondary education curriculum policy frameworks in South Africa. This is technically due to CAD hardware and software cost; schools not having operational computer labs; unreliable power supplies and internet connections which provide

the software. Teachers must also be aware that lack of standardisation of software nationally makes it difficult to prescribe affordable software and training.

Student teachers must be conscious that basic end-user computer skills have taken priority in global ICT education, regardless of qualification (Ainley *et al*., 2016). This has skewed teacher-training courses away from including multimedia software such as CAD. This may not seem a major concern to a profession that considers reading, writing, and arithmetic to be the educational fundamentals required for human development. However, students should understand that design tools such as CAD assist in rapidly converting scientific ideas into manufacturable reality (Dagman & Wärmefjord, 2022); and combined with computer-aided manufacturing (CAM) enable rapid prototyping of ideas (Allan *et al*., 2018, p. 39). Understanding CAD/CAM's ability to prototype virtual ideas rapidly into physical reality explains the need for exposure to CAD/CAM at a school level (Brink *et al*., 2022).

Appreciating the context for CAD technology commercially helps give wider definition of CAD as a socio-technical phenomenon; and enables better appreciation of its role in developing enterprise and creativity in schools (Petrina, 2003). Such appreciation recognises that the contextual definition of CAD technology assists in developing theoretical understanding of its value and limitations. This is important for student teachers who aspire to teach CAD alongside creating resources.

8.4.2 Use of critique to monitor and evaluate learning and application of computer-aided design

Lecturers and students critiqued resources and the design of the course in the early stages of the research project. As the course progressed, both groups critiqued the technical delivery and wider organisational and institutional issues affecting their learning. Once resource designs had been completed, the parties critiqued their peers' work. Finally, they commented on their experience of the course in interviews and *WhatsApp* discussions. These layered critiques proved valuable in designing an effective CAD course which included participants' contributions as technical, pedagogical, and social critique (Petrina, 2018; Williams *et al*., 2017). Critique at various stages of the course implementation mirrors the suggested model for sustainable learning, application, and teaching of CAD as a teacher-training activity, discussed in Section 8.4.4.

Opportunities to collaborate critically were appreciated by participants; their contributions enabled improvements to the course design and delivery in subsequent cycles. Early lecturer critique stimulated real-time improvements through creation of additional videos which enhanced multimodal learning. Lecturers suggested the addition of an online quiz to test contextual knowledge and to help define CAD. This process of continuous improvement of the course design was enhanced by students' critique of the resources as they used them.

On another level, the addition of a peer-assessment tool to the learning management system for critiquing students' CAD drawings enabled evaluation of their designs and application of CAD skills. Such was reinforced through lecturer marking of their CAD designs

in final portfolio submissions. The formative assessment by peers, and additional summative assessment by lecturers, combined to make the assessment more authentic. This assessment also enabled discussion of ways in which to assess graphical material. The layered critiques provided a valuable contribution to the research process, by introducing collaborative evaluation of the various stages of the process. Such enabled critique of the technology (Petrina, 2017), educational process (Williams *et al*., 2017), multidisciplinary learning (Petrina, 1998), and the wider social impact of technology education (Petrina, 2003).

8.5 The Disruption Caused by the Institutional and Organisational Move to a Blended Online Course Using Students' Devices

The institutional and organisational context in which students had to learn their ICT skills had an impact on their learning of CAD. The move to a blended online mode of delivery was disruptive for staff and students alike. Some students benefitted and performed well with the freedom to work in their own space and time on their own devices. The students who struggled were those with limited or no prior practical computing experience, who had to buy devices to enable learning. Effectively, the online course benefitted the 'digital natives' (Prensky, 2001, 2009), and inhibited the progress of the 'digitally marginalised' or those forced to study using unfamiliar modes of online learning (Singh *et al*., 2020a).

Without compulsory contact learning sessions, it was difficult to gauge whether students failing to complete the CAD unit were doing so for technical operational reasons, or because they did not have the software installed on their devices. More proactive, technical

student support systems are needed in HEIs to ensure that all students are fully equipped and operational at the start of any course. Students relied on one IT technician covering the whole campus; or they co-opted ICT lecturers to troubleshoot their personal devices and to access learning management systems (LMS). This led to criticism of the service provided. Improving students' technical support can empower students to work both online and offline and both inside and outside the contact lecture space. However, students also need to develop agency to manage the hardware and software they use on their personal devices, and to appreciate alternative modes of learning.

Assuming that students and lecturers all want to become self-activating technophiles is presumptuous (Boelens *et al*., 2018). Such thinking ignores the true purpose of teaching which should be to elicit human potential, and to promote what Jack Whitehead states as the "flourishing of humanity as a species" (Whitehead, 2018, p. 1). Recognising that education is "not a process of instilling skills and facts, but of preparing human beings to live, work and play" (Dron, 2021, p. 30) reminds us that technology should exist to support learning in whatever mode in which a human is orchestrated to learn.

8.6 Students' Integration of CAD skills to Develop Teaching Practice Resources and Future CAD Teaching (RQ2+)

Participants showed evidence that they could produce teaching resources using CAD. Monitoring how, where, and when they used these was not possible in an empirical manner, CAD use not having been built into their formal teaching practice assessments. Students

informed me of their use of CAD in interviews and online via *WhatsApp* dialogues (Appendices 19 and 30). The pleasing result of these discussions was that most students sought to create their own original resources for teaching.

Students accessed and used CAD software and associated resources and completed portfolio activities including CAD. Students, once exposed to the software, were keen to use it on TPR for creating resources. None of the students reported teaching CAD to learners in their schools. This is not surprising because the curriculum does not expect this; and they were not explicitly asked to do so. However, students did appreciate that teaching CAD to learners was a desirable future target.

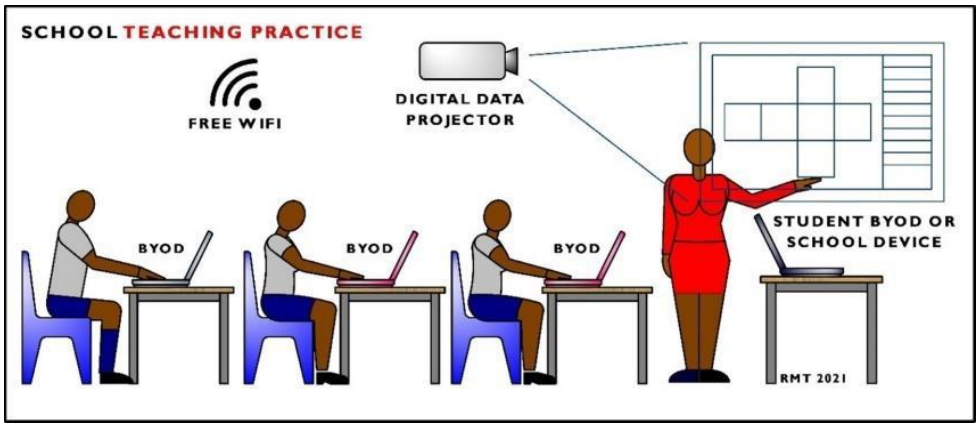
Differentiating between learning to use and apply graphic software vocationally, and teaching others how to use it, has been overlooked in the institution's end-user computing courses. The multimodal resources designed for teaching students CAD could be simplified and used to teach learners similar skills. However, my voice as the instructor may have to be replaced by the voice of the teacher, to provide a more authentic experience. Automatic transcription of recorded video is now commonplace on YouTube, *MS Teams*, and *Zoom* platforms. This could enable over-dubbing of instructional video with the voice, and even the native language, of the teacher (Thompson & Alant, 2021). Ideally, student teachers should be trained to teach ICT skills as an extension of learning to apply them. This may require an additional 'Teaching ICT' course as part of the teacher-training programme.

8.7 Using Diagramming to Explore Pedagogical and Technological Systems Experienced by Students on Teaching Practice

The study summarised ‘graphically’ the student teachers’ learning, application, and teaching of CAD in various campus and school settings on teaching practice. Such helped representation of modes of delivery in relation to technological systems available in different classrooms. The summary also helped to explain why some students were inhibited from using CAD resources in host schools. In Figure 8.2, a range of scaled-down learners and a student-teacher character are used to represent a student teacher on teaching practice.

Figure 8.2

Student Teacher Teaching using a CAD Resource, or Teaching CAD to Learners On Teaching Practice



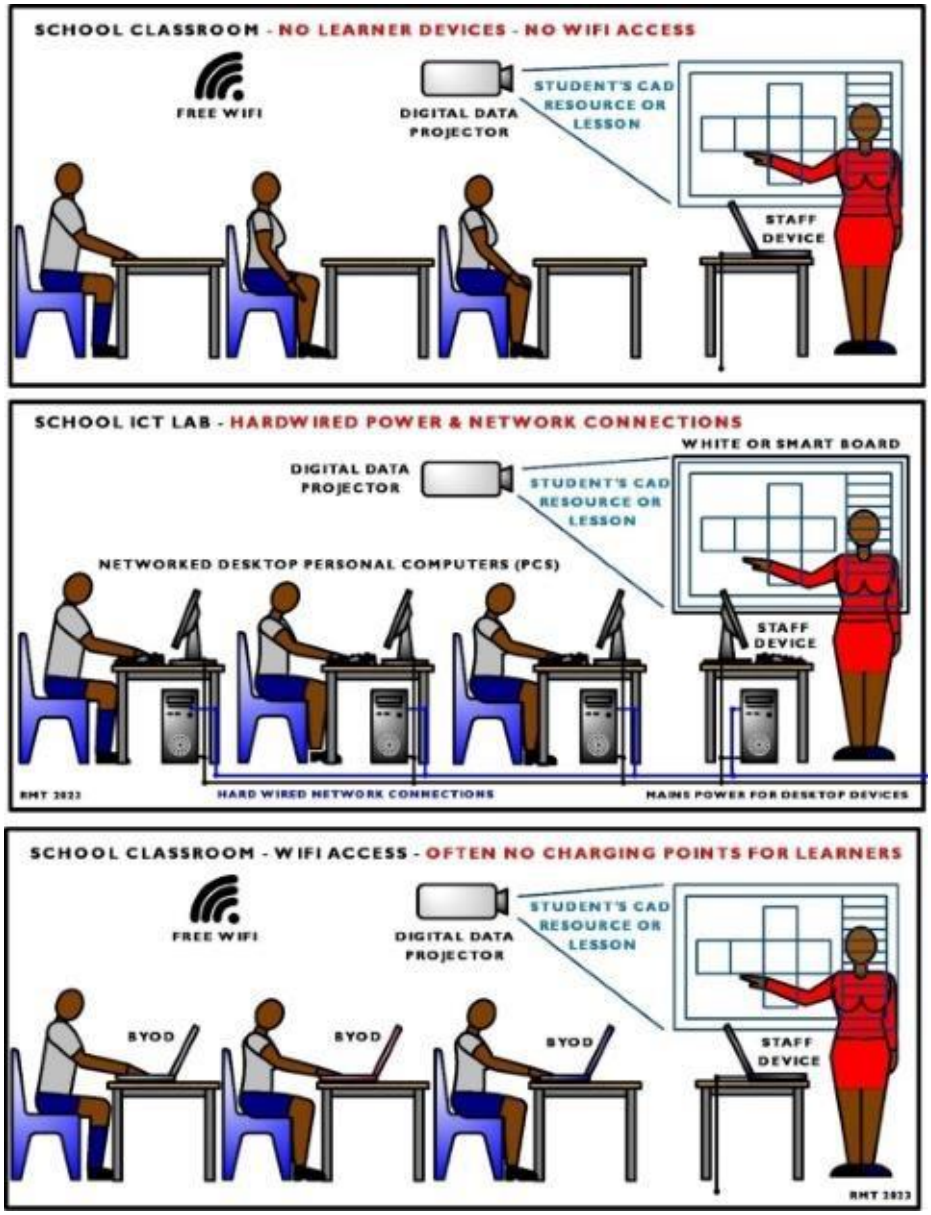
Students were not asked to comment on the technological systems they used in their TPR studies or teaching of CAD to learners. However, some shared technological issues experienced in schools. Their introduction to CAD was not designed to make them experts in teaching the topic. The expectation was that some students might choose to use the software to create resources for lessons, rather than planning CAD lessons for learners. A few students reported the use of CAD in creating resources, while some reported confidence in using CAD for this purpose in future.

Varying practice architectures (Kemmis, 2014) were experienced by students on teaching practice (TPR), as summarised in Figure 8.3. In the first example, the student teacher (ST) is teaching learners who have no devices, with a CAD resource, a computer, and a projector. In the second, the ST is teaching learners in a computer lab with networked personal computers. In the third, the ST is teaching learners who have their own devices. Given the variety of socio-technical scenarios reported in schools, it is understandable that some students did not immediately apply their CAD skills in TPR. This also illustrates the entanglement of pedagogical method and technology (Fawns, 2022) application, or the teaching of new technologies in schools. If students design personal resources, and have access to a device and projector, they ought to be able to teach with CAD should software be accessible. Learners who have no access to devices to practice CAD, find their learning limited to theoretical learning. Teaching learners to use CAD meaningfully requires learners to have devices to practice with, as shown in the final two scenarios in Figure 8.3. Once modes of learning skills are considered as context, student teachers should be encouraged to experiment with various

modal approaches to learning and teaching CAD. With many schools now using learning management systems (LMSs) to resource homework and lessons for absent children (Post-Covid 19), it is possible to replicate students' blended online CAD learning experience, used in this study, in a school setting (Joia & Lorenzo, 2021).

Figure 8.3

Three Different Classroom Scenarios in which Students can Resource Teaching with CAD or Teach CAD to Learners



8.8 A Practical Contextualised CAD Education for Student Teachers Which Includes Learning, Application, and Teaching in Schools

Acknowledgement of past technological histories is vital in grounding any technical course of study (Petrina, 2003). In CAD, the integration of manual sketching and drawing, in a combined introductory drawing course, links the earliest forms of graphic communication to modern advanced design tools. Incremental project-based learning of CAD progressing from two-dimensional to three-dimensional formats enables better visualisation and understanding of the development of complex designs (Bhaduri *et al*., 2021). This course selected examples which could be used either for manual or CAD drawing practice.

The end-user ICT course (ICTE200) may not be the final location for teaching CAD. Specialised modules in digital skills, and robotics and coding, are being updated to include design-project tools such as CAD (Department of Basic Education, 2021). Regardless of location, a recurring feature is that manual sketching and drawing skills must be taught alongside CAD. This was proposed by Petrina in his contextual CAD course twenty years ago (Petrina, 2003). By applying Petrina's proposal, CAD students understand where fundamental drawing elements of standardisation, accuracy and neatness come from.

Teaching CAD contextually enables teachers to recognise CAD as part of an integrated set of 'ICT life skills' that equips them to create resources; manage teaching effectively; deliver memorable lessons; and to empower learners through practical learning (Beetham & Sharpe,

2013). How to fit CAD into a formal primary curriculum structure Table 8.1 below illustrates the study implementation and possible future 'aspirational' (Fawns, 2022) pedagogical formats for teaching CAD. Further mapping of activity against Bloom's Taxonomy (Bloom, 1956) in a digital format (Churches, 2008), and South African qualification standards (South Africa Department of Education, 1995) would assist with quality assurance of CAD teaching.

Table 8.1

Initial Implementation of Practice Architecture Activity Mapping Process for Units of Work in Developing an Ideal CAD Course

Type of Activity	Implementation Practice Architecture	Future Aspirational Practice Architectures
CAD Activities (Student practice)	Read instructional guide/s and download CAD software. Watch instructional videos and attend CAD lecture. Draw a clock face using CAD software following an instructional guide.	Read instructional guide/s; download CAD software. Watch instructional video and/or attend CAD lecture/tutorials. Draw a clock, dice net and 3D vase using CAD software using instructional guide. Complete online unit test on CAD theory.
Teaching Activities	Create resources for teaching practice using CAD for physical portfolio.	Create original lesson resources for teaching practice using CAD for

Type of Activity	Implementation Practice Architecture	Future Aspirational Practice Architectures
(Student practice)		assessed TPR portfolio and include in ICT portfolio. Contribute to a face-to-face meeting to discuss CAD resources used in TPR.
Assessed CAD Activities (Student practice)	Complete a peer assessment of another student's clock design. Include clock face CAD drawing in ICT portfolio of evidence.	Complete an original clock face CAD design for marks (marked by lecturer). Complete a peer assessment of another student's clock design. Complete online CAD theory test. Include an original CAD drawing in ICT portfolio of evidence.
Lecturer Practice	Develop original resources for LMS. Create original CAD activities following assessment policy. Facilitate lectures and tutorials. Manage peer-review activities. Mark portfolio, including CAD, and provide feedback to students.	Review previous version of unit. Update resources on LMS. Create additional CAD activities following assessment policy. Facilitate lessons, lectures, and tutorials. Manage peer-review activities, mark e-portfolio, including CAD, and provide feedback.

Table 8.1 indicates a reflective approach to continuous assessment using online tools: online test, blog, and e-portfolio, as a blended online mode of study (Boelens *et al*., 2018). Addition

of an online CAD theory test, introduced by Lecturer-5, aligns the unit with other units in the module which have terminal summative tests. This addition also recognises teaching practice work as part of the formal module assessment which could contribute to a more expanded e-portfolio (Mapundu & Musara, 2019).

Linking TPR assessment to a specialist CAD module resourced activity is recommended in ensuring that students follow through and extend their CAD skills. Repeated practice is the best way of developing CAD proficiency. The institution's week-in-week-out undergraduate model of teaching practice should have enabled students to practise CAD learned at campus in the following week at school. With sustained practice and critique in schools, student confidence will grow in applying CAD skills to produce resources and eventually teach lessons in schools.

8.9 Changes Stimulated by Teaching a Collaboratively Designed CAD Course to Student Teachers and their Application of it in Resource Design

The following recommendations are based on the critical participatory action research undertaken with lecturers and students of CAD on the intermediate-phase teacher-training ICT course. Firstly, I make recommendations based on blended online learning in teaching of ICT and CAD. Secondly, I make recommendations regarding integration of CAD technology within an established ICT curriculum. Finally, I reflect on the ideal process for teaching, learning, and application of CAD knowledge and skills as part of a more extensive technological education

for student teachers. Such a process should empower student teachers to learn, apply, and teach specialist ICT skills within various contexts.

8.9.1 Recommendations relating to multimodal blended online teaching of CAD

This course implementation revealed that designing blended online continuous assessment courses that fit students' work patterns, financial capabilities, and preferred modes of learning will assist in improving engagement and outcomes. The course design was constrained by institutional, technical, and human limitations. However, the study recommends that more collaborative course design, and purposeful use of learning management systems, can overcome challenges, empower more students, and provide more responsive course delivery which combines face-to-face learning and online learning.

Data analytics, provided with the LMS, were used to monitor activity completion automatically, and to assist in quantitative data analysis. Ironically, this tool has exposed some of the weaknesses of online courses which are not identified through dialogue with participants. Some students did not follow the logical order of the unit provided by the lecturer. Some used a 'cherry picking' approach in prioritising activities that produced maximum marks; and targeted the high stakes summative assessments over the formative ones. This additional data revealed by human screening of online results shows the need for better integration of human interventions and interpretations in automated reporting from learning management systems.

8.9.2 Changes to teaching of ICT and CAD through better institutional technology integration

Researching a single CAD unit in a second-year module has revealed the disruption caused by institutional change which appears driven by technology. Deeper reflection reveals that pedagogical methods and technology are entangled (Fawns, 2022) with pedagogy and technology, both impacting on the approach used to deliver a meaningful contextualised CAD course for student teachers.

In the CAD unit, the first cycle of delivery revealed that the multimodal approach to learning, through a range of online and offline resources and learning opportunities, was popular for the ICT-literate students. Creating the multimodal approach required a commitment of development time and resources which was not anticipated by academic management. Although this approach produced good results for some, the final outcomes revealed that more human collaboration was required to produce optimal results and provide better learning opportunities for the weaker students. This follows a socio-technical systems approach. Some improvements for the near future are recommended in Table 8.1.

The contextual (clock) example, used for teaching CAD, was observed by some as overly complex for novice students. Additional simpler examples were designed and trialled with senior students. These are now available for use in ICT modules and a PGCE engineering graphics and design (EGD) module, in the same multimodal format, to aid learning using either online resources, video, or face-to-face lecturers. Creating such reusable online resources

(Onofrei & Ferry, 2020), which can be deployed on various ICT courses, was actioned as a result of this study. This is recommended in reducing replication of work.

Feedback from participants revealed the need for teaching more background context to situate CAD within primary teaching. This mirrors Petrina's recommendations for more socio-technically contextualised technology courses (Petrina, 2003, p. 69): "It's time we seriously attended to ethical-personal and socio-political knowledge in these courses." Petrina's vision of critical technological literacy (Petrina, 2000b, p. 182) complements a CAD suggested technology integrated pedagogy which situates learning using real-life contexts to add value to student-teachers' experience.

This CAD unit was a digital novelty being taught for the first time. It was envisaged that the students would engage with online study as 'digital natives'(Prensky, 2001). This was not the case for all. Many students required both online and offline support due to their limited exposure to previous ICT training. Parallel with this research, additional specialist computer applications technology (CAT-FET phase) and computer practice for teachers (CPT101) courses have been added to the PGCE programme. This ensures that more CAT teachers are trained in South Africa, and that more PGCE students graduate with basic ICT skills. An ICT teaching course for primary and intermediate teachers is an identified gap in the education curriculum 'market'. It is recommended that this gap be filled by including multimedia skills such as CAD. A new 'cradle-to-grave' ICT curriculum is required in South Africa to ensure that all learners leave school with computing skills relevant to the 21st century workplace, which includes higher education (Department of Basic Education, 2018).

Research conducted recently in SA pertains to the use of ICT for teaching by teachers (Padayachee, 2016, 2017). There is little quantitative research available relating to learners' use of ICT in the classroom (George & Ogunniyi, 2016). Researching the reality of classrooms in SA schools is difficult when some provinces struggle to report on the most basic indicators of school management. Research is recommended, as a matter of regular government procedure, to track usage of classroom technology and computer integration in teaching.

Remedial ICT training for in-service teachers, in effective application and teaching of ICT in the classroom, is recommended to align schools better with newly qualified students. A University of Pretoria and UNISA needs analysis collaboration (Adegbenro, *et al.*, 2017) explored what Gauteng-based teachers wanted from ICT training. The collaboration revealed that teachers wanted to learn new skills, and to learn ways of effectively integrating their ICT skills into teaching. Inclusion of alternative multimedia software in remedial training is recommended in moving teachers beyond basic end-user computing skills.

Post-implementation participant feedback revealed that previously reticent lecturing staff used the resources created for students for self-training, and to resource other courses. The written step-by-step CAD guide partnered with instructional video is now acknowledged as a valuable learning and revision method, enabling offline study, and providing a transcribed script for video narration and subtitling for deaf learners. Better alignment of written study guides with instructional video and LMS design is recommended in maintaining alignment of resources for teaching and assessment.

After studying of just one unit, students reported lack of readiness to teach CAD in schools but acknowledged that this may be possible given practice. Opportunities for practice exist already. For example, YouTube videos of me teaching *2D Design*, from this study, were organised by Lecturer-1 to protect content and enable wider sharing. Creating online resource banks, in which lecturers can safely store and share their teaching materials and video content is recommended for sustaining multimodal courses.

8.9.3 A practical framework for student teachers' ICT courses including CAD and other more advanced software tools

Chapter 7 posed a conceptual pedagogical framework for ICT courses, including computer-aided design (CAD). The adoption of the course and integration into an improved version is considered a useful outcome from the CPAR process. To be fully achievable, further dialogue with stakeholders is recommended as an 'extension phase' of the action research. This could include a review of all ICT units taught in the module, together with their socio-technical relevance and appropriate level in the national qualifications' framework (South Africa Department of Basic Education, 1995; South Africa Department of Education & Department of Labour, 2002).

After three years of delivery, ICTE200 is ready for a review. This coincides with a programme review which begins in 2024. Research-led reviews of ICT courses can influence policy relating to ICT courses required as compulsory modules in degree programmes. The organic changes introduced by participants, combined with those coerced by institutional

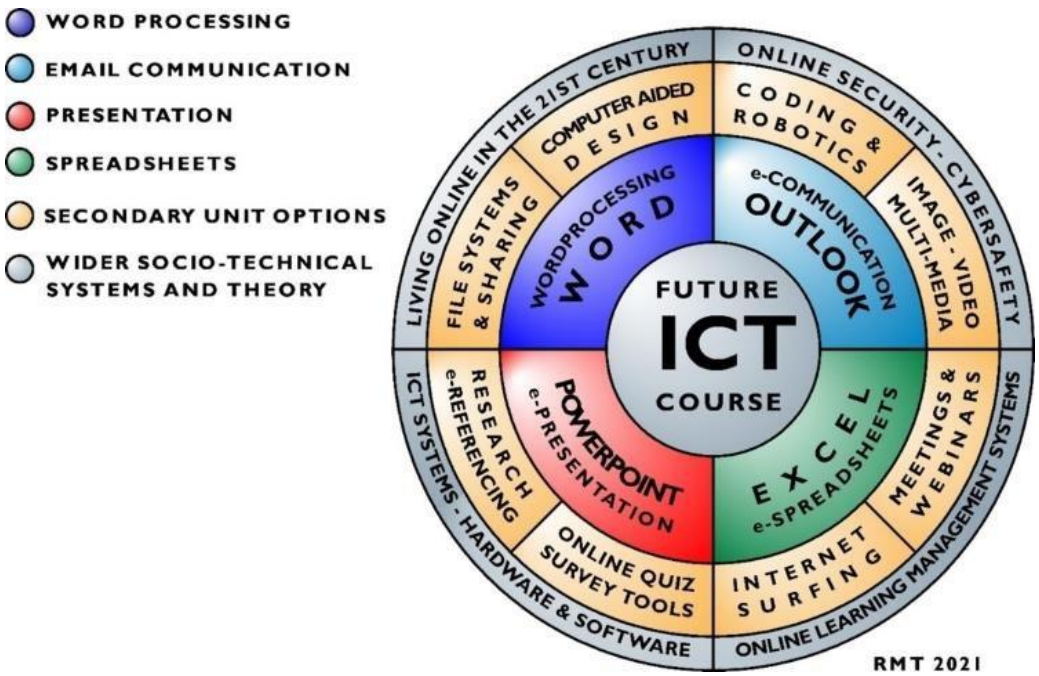
socio-technical priorities, have created a recommended form of CAD course which is responsive to change and may become a standard for other organisations.

A suggested structure for a new ICT course, including CAD, is presented diagrammatically in Figure 8.4. Core content remains linked to teaching end-user Office tools; however, additional communication tools specialisms are added as a ‘secondary’ layer. The wider socio-technical content of the course relating to living online, hardware and software systems, and theoretical content, is included as a tertiary layer. This outer ‘macro’ layer offers opportunities for teaching contextually culturally relevant content (Gumbo, 2015).

Decisions relating to NQF level of content and assessment (DHET, 2011) are linked to the programme in which the course ultimately resides. However, if the diagram is treated as a carousel, in which there is choice of secondary and tertiary options, it is possible to see the potential model for designing progressive NQF 5 to NQF 7 level ICT courses to fit various programme years. Should the NQF 7 course contain the pedagogical content existing lower NQF level ICT ‘user’ qualifications may be less disrupted.

Figure 8.4

Proposed Future ICT Course Incorporating CAD and Other 21st Century ICT Tools



The proposed course structure presented graphically in Figure 8.4 uses the ‘colour wheel’ design, introduced in Chapter 7 (Figures 7.7 and 7.8), modified to present a complete ICT course in three layers. Practical MS Office tools (Word, Excel, *PowerPoint* and Outlook) are located at the centre due to organisational ties with Microsoft Education and national trends in ICT education.

The addition of other practical software options in the secondary layers acknowledges the need to include alternative software to avoid monopoly influence. Computer-aided design, coding and robotics, video-image editing, meetings-webinars, internet surfing, online quizzes-surveys, research, electronic referencing, and file systems-sharing are added as secondary layers. All can be taught with software from various commercial and free online sources.

Finally, the outer ring contains theoretical content related to living online in the 21st century, security and cyber-safety and online learning management systems, and hardware & software systems. The segment layers, or rings, are not fixed to adjacent inner segments in the diagram, but rotate (if the diagram is animated) to reveal multiple relationships between topics. For example, CAD could be used to illustrate examples in any of the office tools.

ICT courses must remain flexible to facilitate inclusion of new technologies such as meeting-webinar technology, quiz tools and video-production tools which are necessary for creating and delivering content for online teaching (Adegbenro *et al*., 2017). New courses must also be aligned with global trends in ICT education (Carretero, *et al*., 2017), and informed measures of competence such as "DigCompEdu" European digital competence framework (Caena & Redecker, 2019).

The course outline above may cover relevant unit headings for a valid NQF 7 level end-user computing ICT course; however, it does not cover teaching of ICT as a primary school teacher's skill. There may be a misguided assumption in teacher education that completion of an end-user computing module is a qualification for teaching ICT. This gap has been acknowledged by some South African academics, with the development of recent teacher-

training ICT books such as *Teaching with Information and Communication Technology (ICT)* (Hardman, 2018).

One area of learning which can help student teachers facilitate new modes of CAD learning, is the learning of meeting-webinar technologies such as *Zoom* and MS Teams within the ICT course (Serhan, 2020). These technologies came to the fore during the Covid-19 pandemic (Singh *et al*., 2020b). Relevant technologies should be taught to student teachers to help create recorded online lessons, including computer-generated resources, or demonstrations of CAD software teaching.

Courses for training teachers to teach ICT at a further education and training (FET) level already exist in the institution's PGCE course. As pointed out in Chapter 7, there is a gap in the market for a 'Teaching Information Communication Technology' course for primary and senior phase school use (Padayachee, 2017). Regrettably, existing 'Teaching ICT' resources books (Hardman *et al*., 2018) do not include 'Teaching CAD' in the ICT mix. This approach is recommended for further course development.

This study introduced CAD through demonstrated examples using age-appropriate contexts. Additional development of assessed teaching practice activities is recommended in providing opportunities for more readily assessing students' use of CAD resources in schools. Development of specialised ICT courses, including CAD, for various school phases, is envisaged as plans to provide more digital skills courses in primary and middle school phases are rolled out (Department of Basic Education, 2018).

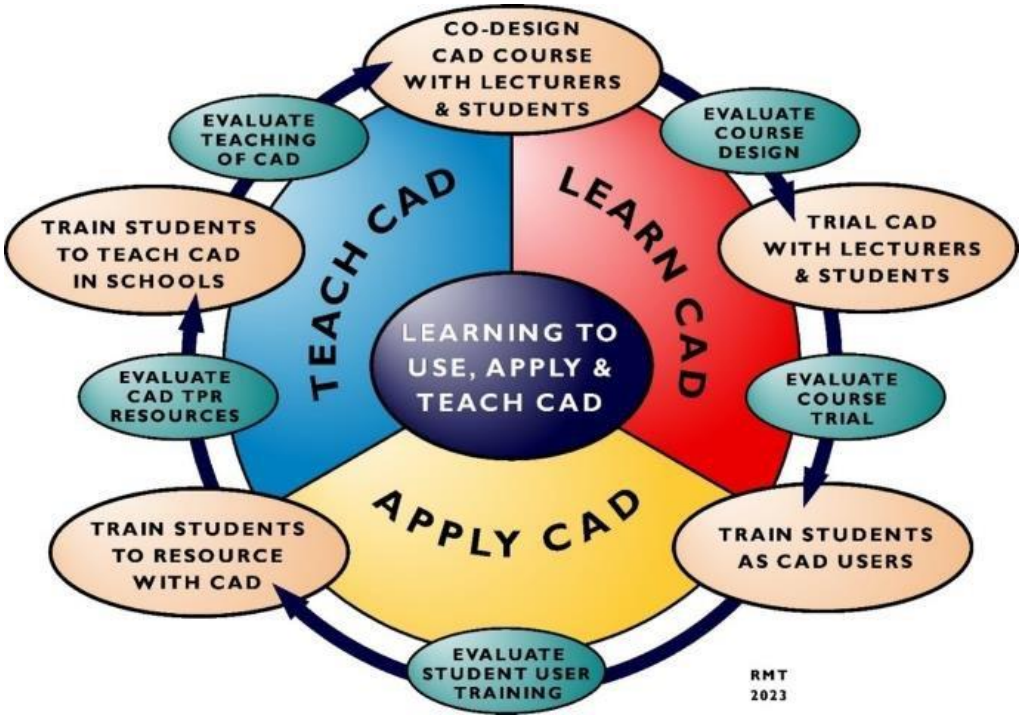
8.9.4 An aspirational ideal CAD pedagogy for student teachers

This study revealed that students who practised CAD exercises diligently could create resources and use these in teaching. It also revealed that this end-point could be part of a larger aspirational learning process (Table 8.1) for creating better teachers of subjects which incorporate design and technology (Fawns, 2022; Govender & Khoza, 2024). The interconnectedness of pedagogy, technology, and context becomes clearer as students learn to use, apply, and teach CAD.

Teaching the use of CAD for creating resources does not necessarily create good teachers of CAD. Student-lecturer collaboration in flexible course design applies relevant socio-historical contexts, and embraces social diversity as the ideal approach (Fawns, 2022, p. 719). In an ideal teacher-training course, this involves students learning to use, apply, and teach CAD skills alongside other ICT skills. Monitoring such learning requires better processes for observing and listening to both students and lecturers (Lareau, 2021; Khoza & Fomunyam, 2020). This is a long-term project. Figure 8.5 below illustrates a cyclical process of learning CAD which includes the three stages.

Figure 8.5

An Ideal Cycle for Learning to Use, Apply, and Teach CAD in Primary Schools



The course design created for this study went as far as assessing students' ability to learn CAD and to create two or three CAD resources, depending on whether they applied CAD in their e-portfolio. Assessing students' ability to fully utilise CAD requires additional focused training on designing original resources for specified lessons, using a wider range of CAD drawing features. The ultimate test of student teachers' learning of specialist skills is their ability to

teach their newfound skills. To reach this stage, Figure 8.5 shows three stages, with discreet evaluation phases, progressing from novice CAD user to student teacher able to resource and teach lessons. By evaluating each stage, improvements can be made incrementally to the training pedagogies at each step.

The School of Education traditionally separates teaching of specialist content knowledge from pedagogical knowledge using different modules. So far, this has not been applied in ICT courses: the priority has been training of students to create resources for teaching using educational technology as part of the wider context in which students acquire technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2009; Mishra 2019). The next phase is to develop teachers who can merge teaching ICT technology in relevant multidisciplinary contexts (Fawns, 2022, p. 721). These developments require investment of both human and financial resources in developing ICT and digital skills courses which teach students how to teach ICT and to use it tactically.

When context is considered in the three-stage model in Figure 8.5, context for initial student learning of CAD may differ from that for applying CAD as a resource, or for teaching CAD in a school. Contexts for learning CAD may draw on historical examples, or they may encourage students to design a new resource. Contexts for applying CAD resources in school may be related to illustrating subjects or creating designs, for example, the clock drawing animated to teach analogue timekeeping, or the dice net to teach efficient packaging design. Finally, contexts for teaching CAD in schools may draw on student experience from their CAD training, specific subject topics, or introduction of CAD as a design tool in projects. Once

student teachers can use CAD in different contexts, they are more likely to produce learners who use CAD effectively in their schooling and vocational futures.

8.10 Critical, Participatory Action Research as a Methodology for Understanding Computer-aided Design Education

Having studied product design, engineering, and technology education, my initial research inclination was towards quantitative methods (Devitt *et al*., 1993). Through my master's study, collaboration with supervisors and community engagement, I developed interest in action-research methodologies (Creswell, 2014; Kemmis, McTaggart, *et al*., 2014) which include qualitative and quantitative elements, use of multidisciplinary teams, and multimodal research tools (Gerber *et al*., 2016).

Because more research is conducted in online spaces, it is imperative to use more flexible approaches should African research be competing in the academic world. Through my fieldwork, I have observed that South Africa is a complex location for educational research, which requires global and local perspectives on addressing the complex needs of its diverse population. I have discovered that local context, culture, history, and traditional practices have equal value in socio-technical systems (Carl & Strydom, 2017; Porras-Hernández & Salinas-Amescua, 2013).

As a discipline leader in the School of Education, I have introduced updated approaches to communication, data collection, analysis and training using ICT tools. I have sought out and promoted the use of appropriate resources such as CAD, to develop students and learners

beyond basic end-user computing courses. I have also learned that academic leaders have the responsibility of promoting research and encouraging innovative thinking about research (Wood, 2014; Zuber-Skerritt & Fletcher, 2007).

This PhD study has drawn me towards participatory forms of research, in that these produce innovative research outcomes, globally (Bergold & Thomas, 2012). Such interest comes from a desire for research to be more inclusive, relevant to participants' needs, and less researcher biased. The CPAR approach has enabled me, through direct collaboration, to develop better understanding of the problems that face both South African student teachers and lecturers. Designing blended online teaching courses has also revealed to me the need for technologically integrated pedagogies for digitally mediated education (Burnett *et al*., 2014; Gerber *et al*., 2016).

I believe that participatory approaches to educational research aid in participant motivation and help to challenge outdated power dynamics inherent in post-colonial institutions (Zuber-Skerritt, 2018; Bergold & Thomas, 2012; Morrell, 2006; Onwuegbuzie & Frels, 2013). I have witnessed inclusive, evidence-informed research in action, reflecting the real needs of participants, which has sustainable value (Thompson & Alant, 2021). Participatory approaches to improving technological education improve practical outcomes; however, they also improve participants' knowledge through collaboration in change of praxis (Kemmis, Wilkinson, *et al*., 2014). Teachers can self-actuate within a supportive community of practice as a form of continuous self-improvement, instead of being forced to re-train as part of compulsory institutional courses (Lave & Wenger, 1991). Teachers also enable greater

forms of transformation or “emancipatory outcomes” which change the way research is formalised and the way in which participants perceive and value themselves (Wood, 2014, p. 668).

Specifically, the personal interactions shared with lecturers and students on this journey reinforced my trust in participatory action research as a just and inclusive way of researching human activity in technological education. Without the contributions and constructive critique received from colleagues, students, and supervisors, this study would simply have been a project implementation, rather than a research thesis.

8.10.1 Quantitative data as an extra validator of action research and vice versa

My experience of managing a CPAR project showed that provision should be made, from the outset, for collection and retention of quantitative data in supporting validation of qualitative material. Gathering participatory evidence using instruments located on a learning management system (LMS), assisted with automatic generation of background quantitative data. Such evidence also indicated whether students’ prior general ICT knowledge was inhibiting learning of specialisms such as CAD. Assumptions that the current generation of student teachers are experienced ‘digital natives’ (Prensky, 2001), and hence more ICT literate than previous students, may be unfounded. Quantitative data reinforced a well-reported gap in digital literacy between those from privileged and disadvantaged backgrounds (Moletsane & Reddy, 2008). Black female students from poorer school backgrounds, or remote locations, did

not achieve as well as White and Indian students in the study group and in the whole module cohort.

South African research (Takavarasha *et al*., 2018) suggests that university students are lagging behind Western countries due to lack of digital literacy, or digital fluency, and are constrained in becoming 'digital citizens' (Al-Zahrani, 2015). The institution requires students to demonstrate digital competency to complete programmes; and uses diagnostic tests to measure some basic competencies. ICT fluency demands a level of fluency in English language, but also assumes a visual fluency which involves interpretation of icons, diagrams, software layouts and learning management systems (graphical interfaces). Institutions assume a level of prior English competence and a measure of experience of one brand of (Microsoft) office software, when judging ICT skill (Thompson & Alant, 2021). Students without English as a first language are therefore disadvantaged in learning CAD, in that CAD also uses English language by default. Measuring students' engagement with different graphic interfaces and activities online added an additional layer of understanding of blended online learning.

South African institutions must develop measures similar to the European "DigCompEdu" programme (Redeker, 2018, p. 5) in establishing measurable standards which are relevant to the African ICT learning context. South African institutions must also consider education in various types of computer software (such as CAD) which use different graphical interfaces.

Quantitative data in this study revealed patterns in student activity, such as submission and pass rates on CAD activities. The findings raised questions about how data from multiple

sources should be used to reveal the ways in which learning CAD impacts on student teachers' ability to apply new knowledge productively. Understanding of students' general literacy, ICT literacy, numeracy, and graphical literacy, and their influence on learning CAD, is emphasised as an area which requires more attention.

8.10.2 Evidence of students' improved digital and visual literacy on the CAD course

My study suggests that wider socio-economic factors influence students' ICT literacy and ability to learn new skills such as CAD. Designing contextually relevant ICT courses can help improve students' skills and critical social engagement with new technologies (Petrina, 2018). Courses also help differentiate between 'general ICT literacy' and 'professional vocational ICT literacy'. MS Office skills tend to fall under the former, while CAD skills would fall in the latter category.

An additional literacy emerged from this study: 'graphical interface literacy' which relates to visual literacy. This could be defined as students' ability to learn from both online and offline graphical interfaces. Quantitative data showed that students engaged with various learning resources provided online; however, it did not provide evidence of why the students chose different learning options. Petrina's research into digital literacy in teacher education with Guo and Dobson (Guo *et al*., 2008) uses quantitative data from a longitudinal study of pre-service teachers, demonstrating that age difference does not significantly affect ICT literacy. Participants' contributions in qualitative critiques helped explain students' choice of learning pathway; but did not identify whether the way information was presented graphically

in still images and video significantly influenced their learning. In the South African context, evidence that limited prior access to computer technology is hampering learning in higher education is more starkly evident (Padayachee, 2017). In the wider international context, access to hardware and software (both online and offline) that extends student teachers' ICT learning beyond basic end-user computing skills is neither universal, nor consistent, in developing and well-resourced countries (OECD, 2019).

Conclusions from quantitative data in this study are subjective interpretations using "measures of central tendency" (e.g., averages or means) or "practical significance" (Mertler, 2016, p. 171). These interpretations reinforce answers to some qualitative questions. Conversely, qualitative data assists in explaining quantitively assessed practice. This was made possible through results data generated automatically from the LMS activity completion and from gradebook settings.

8.10.3 Recommendations from data generated from the learning management system

Use of normal distribution techniques to compare research samples, has been cited as beneficial in measuring course effectiveness (Mertler, 2016, p. 173). Repeated action-research cycles, using the same course and location, could produce interesting comparative results. Tracking 'graduates' after they complete the course or graduate from the programme may assist in maintaining longitudinal dialogue.

Recommended future studies could research statistical variations between the entire cohort and research group, for CAD activities measured against all module unit results. An

"independent measures t-test" may be the most useful statistical tool for achieving such. Were future research scaled to include additional campuses, "analysis of variance (ANOVA)" (Mertler, 2016, pp. 171, 176, 182) could be used. Both statistical tools provide a good measure of "correlation coefficients" (Mertler, 2016, p. 166) allowing understanding of the degree of similarity between variables.

The time taken to complete a CAD drawing, or design activity, provides an extra measure of competence. Recording of the time taken to complete CAD activities was not planned as part of this research, although some data from the peer assessment activity were accessible via the LMS. Measuring the time taken to complete activities from the LMS can be used as a form of triangulation of students' participation online compared with offline or face-to-face activities. Timed drawing activities, such as in exams, provide good comparative results for measuring higher-level CAD competency. Such can be achieved in a high school EGD course manual and CAD assessments, but not in higher-education end-user computing courses. If participatory action research includes online participation (Gerber *et al*., 2017), tools that assist in recording and monitoring such activities automatically should be valued as an alternative to taking class registers. Additionally, LMS analytics allow recording of lecturer hours setting up online learning and assessing work. This data is very valuable in identifying the hidden, and currently unacknowledged, workload involved in developing blended online learning. In summary, both quantitative and qualitative data accessed automatically from LMS analytics allow for pragmatic and realistic observation and interpretation of student and lecturer activity, both synchronously and asynchronously.

8.11 Conclusions from Qualitative Data Analysis and Discussion

"Everyone, irrespective of age, stage, context, or field of practice, has an influence, for better or worse, in their own lives and learning and that of others." (Whitehead, 2018, p. 1). Lecturers and students experienced something new in this research project. All were challenged to learn new skills and knowledge in a multimodal design and implementation of a blended online and offline course (Kress, 2010). This provided challenges in the resourcing of modes of delivery, monitoring and evaluation of student progress, and teaching and learning assessment. This situation reflected similar disruptions that other higher-education institutions experienced under forced or 'emergency' online learning precipitated by Covid-19 (Czerniewicz *et al*., 2020; Singh *et al*., 2020a). It also revealed the interconnectedness of pedagogical approach with technology integration in modern higher education (Fawns, 2022).

Students expressed a range of opinions about the online course, of learning CAD, and how they applied, or intended to apply, this knowledge and technological skill in teaching practice. Opinions were mixed and sometimes opposed. Their contributions to the CAD course ensured that it was delivered in an interesting and flexible manner, in that students supported various means of learning in their own way at their own pace. The retention and integration of face-to-face practical workshops was endorsed by those preferring more traditional contact learning, and the opportunity of having direct critique from lecturers. This hybrid blended online mode of learning later became a standard for non-ICT courses in the organisation, and in the higher-education diaspora (Dagman & Wärmefjord, 2022; Dhawan, 2020).

Lecturers appreciated collaboratively developing a unit of CAD work, in a critical manner. This was carried forward into alternative course analyses and redevelopment of the other courses in the ICT programme evident in the second cycle. Focus on the specific CAD unit implementation exposed wider socio-technical issues. Disruption caused by the new CAD unit content mirrored global changes to teaching both remotely and online, which coincided with this study (Dhawan, 2020; Singh *et al*., 2020b). This global shift to blended online learning, using pre-recorded material and live broadcast learning events, emerged from institutional change accelerated by the Covid-19 pandemic. Although research points towards blended, online hybrid modes of delivery as the way forward for higher education (Adeniji-Neill, *et al*., 2018), new pedagogies must still be tested against previously successful approaches before validating this further (Singh & Thurman, 2019). Likewise, this study showed that one or two cycles of implementation, with a limited sample, only begin to reveal the opportunities created by teaching CAD to primary school teachers.

If adopted and implemented in primary school education, CAD can help younger learners prepare for Industry 4.0, or 4th Industrial Revolution technologies (Bongomin, *et al*, 2020). CAD is a necessary design tool in development of robots, 3D printed products, smart devices, drones, intelligent buildings, renewable energy systems, and the plethora of interlinked systems that enable innovation within real-life, virtual, and biological spheres. Bongomin *et al*. highlight the need for higher-education institutions to educate graduates for this future vocational landscape (Bongomin *et al*., 2020, p. 8). These authors do not specify that this starts at a primary level; however, they do point to "Education 4.0" as a new view of education in

which technology inhabits all levels of education. Introduction of coding and robotics in South Africa as a primary school subject is likely to accelerate the need for teacher training in Industry 4.0 skills within the next few years.

Student participants were individually disrupted by learning CAD, although not overwhelmed by the experience of collaborating in the course implementation. Participants emerged with greater awareness of the benefits of using their own customised CAD resources for teaching and for learners' potential to integrate such into their technological schooling. Participants exhibited understanding of their own learning limitations, due to prior ICT schooling, but appreciated CAD's value in enabling smoother transition to secondary and tertiary technology disciplines. Finally, participants' experience of learning CAD, in this study, mirrored other students' experience of blended learning approaches used in other subjects (Czerniewicz *et al*., 2020; Serhan, 2020). Blended online learning is not for all; however, it does provide more differentiated learning for modern ICT-literate students.

8.12 Future Research in Computer-aided Design Education

Questions were raised by the study. These provide a springboard for further research in CAD teaching. This is expected in a CPAR process, in which researchers are unlikely to find all the answers, and may unearth more questions (Kemmis, 2014, pp. 187-189). Presenting new questions arising from the original research questions helps to prioritise these problems for future researchers and policymakers; and illustrates the dynamic nature of action research. The questions are first listed in Table 8.2 and later justified in relation to the study findings.

The first grouping relates to CAD pedagogy but draws on wider socio-technical systems issues. Teachers learn and reflect in different ways (Schön, 1987a). Making learning contextualised and relevant requires practical knowledge of a subject (PRAXIS) as well as contextual and theoretical understanding (Porras-Hernández & Salinas-Amescua, 2013). Grounding teaching in real-world contexts requires teachers to learn outside the narrow confines of the textbook, and to embrace the diverse society they live in (Petrina, 2003; Williams *et al*., 2018). Understanding that technology and pedagogy are entangled (Fawns, 2022) with blended online CAD teaching methodology dependent on technology, enables better appreciation of the need to provide a range of learning options which cater for a multicultural student cohort. The study has shown that one pedagogical approach does not fit all students in higher education (Dron, 2021) Realistically, the ideal approach to teaching CAD in a blended online space is likely to be expensive and resource intensive.

Table 8.2

Questions Arising from Research Questions as Opportunities for Future Study

Research Question	Question Grouping	Question Arising from Study
1	**Ideal CAD pedagogy**	Is a single ideal teaching and learning pedagogy an outdated concept for designing higher-education courses for technological specialisms such as CAD?
		How do we design better pedagogical systems for teaching technological subjects, such as CAD, to respond to wider human needs?
		How do we teach technology subjects to promote wider contexts and society's vocational and technological imperatives?
2	**Use of CAD on teaching practice (TPR)**	How can successful CAD teaching and learning pedagogies, used on campuses, assist with improving assessment of subject specialisms on teaching practice?
		How can portfolio assessment of technological subjects such as CAD improve students' application of skills on teaching practice?
		How should teaching practice (TPR) assessment models be designed to assess student teachers' ICT (and CAD) skills using e-portfolios, and in replacing outdated procedures?
		How can e-portfolios provide sufficient evidence of student teachers' practice of technology specialisms for meaningful assessment of classroom competence?
		What role should CAD, and other multimedia skills, play in primary school education?

The second grouping relates to students' use of resources on teaching practice (TPR) and its management by private HEIs. The study revealed students' willingness to use CAD when they recognised the value to them as individuals and as teachers. Student motivations varied from selfish − related to marks and personal achievement, to more altruistic – driven by a desire to improve life for others. Activities and assessments used in the ICT and CAD course have value in wider settings. The need to please teaching practice assessors, and specialist subject tutors, can provide confusion for student teachers unless departments collaborate. Assessing resources created in ICT courses, applied in school contexts, can help to better align TPR assessment. Student reluctance, or inability, to integrate CAD into teaching can be linked to technology subjects being undervalued and misunderstood in both schools and HEIs. Conducting practical design work is the best way of promoting better understanding of its value (Schön, 1987b). Sharing and critically appraising this work collaboratively is one way of improving CAD's integration into the curriculum (Brink *et al*., 2022; Petrina, 2003).

The above questions reveal that the research project does not have a clearly defined ending. By engaging in this process, a 'can of worms', or 'Pandora's box' (Czarniawska-Joerges, 1994, p. 97), has been opened. The end of the implemented CAD course's first cycle was clearly defined by student marks, course evaluations, and departmental reports. The process of integrating CAD into ICT courses, and empowering student teachers to teach it, has just begun. Extending CAD into various modules and programmes, to benefit more students' teaching practice, will require inter-departmental collaboration. CAD integration is part of a

continuum of continuous improvement initiatives (Yurkofsky *et al*., 2020) required if technology subjects are to achieve the recognition required in the schools and HEIs. The wider socio-political technical issues raised in the study have raised further questions, summarised in Table 8.3.

Table 8.3

Wider Socio-technical Systems Questions Arising from the Study.

Wider Research Question	Questions Arising from Study
Is there an ideal pedagogical approach for training educators to teach computer skills?	How should specialist primary school ICT educators be trained? What are ICT teachers currently working in primary schools being to do?
How should computer skills be taught at various phases of learners' education?	Why is there no formalised senior phase middle school (Grade 8 – 10) ICT course for high school learners when this is required for computer-integrated matric study?
How should schools be resourced to ensure that technological subjects are taught appropriately?	Where is existing classroom technology that has been supplied to schools going, if it is not being used by learners in classrooms; and why is it not being used by learners?
What is the best mode of study with which to train student teachers?	Are distance learning, and blended online, courses viable ways of training modern teachers in the South African context?
Where should computer technology education really fit into the curriculum?	Are computers necessary; or can students work effectively on mobile devices If coding and robotics will include digital skills, how much emphasis will be placed on CAD as a digital skill?

The questions arising from this study are not solely driven by the original focus of the research questions. Observing with a critical eye tends to expose more than what was initially identified as a thematic problem or concern (Zuber-Skerritt & Fletcher, 2007). CPAR projects can start by looking at the 'tip of the iceberg', and find huge issues buried beneath the surface. ICT and technology education in higher education are interrelated issues which should make fertile ground for future research.

8.12.1 Future community-based participatory research activities in schools to encourage students' application and teaching of CAD

Opportunities for further collaborative action research, as a university-school partnership, or as a self-study school CAD teaching implementation (Samaras, 2010), could extend knowledge of students' experience of teaching CAD software in schools, and assist in schools' curriculum design. Given the limitations of access to educational technology in many state schools, this would first require a wide survey of schools able to provide such an opportunity, or resourcing of host schools as a funded research project. The Curro private schools[xiii] group encourages learners' use of either tablet or laptop technology, at primary phases. A Curro schools' study may explore CAD application and teaching in spaces which already support such technology, for example, through their established primary school coding and robotics course.

Future collaborative research with teaching practice (TPR) departments could identify, record, and assess teaching of specialisms, such as CAD, in students' school lessons. Linking specialist assessors to teaching of specialist lessons is not difficult if the lesson taught is discussed with assessors in advance. Lecturer assessors should play a more explicit role in promoting use of technology in TPR. This could be promoted with focused training on what should be observed when CAD is taught.

Teaching CAD lessons within existing curriculum and school timetables, requires more research by students planning lessons. Using CAD as a tool to assist with design activities in technology lessons is an obvious starting point. Teaching learners to use CAD is not part of the formal primary school curriculum; however, it is part of the FET EGD curriculum. Giving learners a head start, by introducing basic CAD skills at primary level, will assist them with multidisciplinary design-related tasks throughout their schooling.

Should CAD pedagogies and contextual examples produced by learners, student teachers and lecturers, be critically appraised in online or offline research communities, this would help to "create an environment where participants and audiences listen to each other" (Mitchell *et al*., 2017, p. 12). Bringing the products of the implementation to the fore alongside the shared experience of the participants, working in different practice locations, may enable common ground to be established (Kemmis, McTaggart, *et al*., 2014, p. 75).

8.13 Limitations of the Study

Qualitative action-research studies can have "questions of legitimacy" levelled at them. (Kemmis, McTaggart, & Nixon, 2014, p. 39) When interpretation of data is based on participants' contributions in *WhatsApp* groups, interviews, observations and surveys, there is room for misinterpretation and contradiction. In this study, surveys and interview questions were scrutinised by supervisors at the ethical clearance stage of the research and by critical friends and participants prior to use. Member checking was used to validate transcribed interviews after completion. Interview question schedules were constructed and refined after scrutiny of survey responses, together with online interactions with participants, prior to terminal interviews. Qualitative findings and summaries from quantitative support statistics were also discussed with participants in the nominal group workshop. These processes helped to ensure trustworthiness and credibility of findings (Schwandt, Lincoln & Guba, 2007).

Additionally, quantitative data from the learning management system enabled cross-checking of students' use of CAD as evidence of learning and creation of initial resources. Quantitative data also indicated whether participants had achieved any advantage over non-participating students learning CAD in the study. Although these precautions were taken to normalise relationships, it is difficult to be totally sure whether all interview responses were what respondents really thought or believed. It is necessary to trust in the better side of human nature, and to assume that participants are sincere (Gerber *et al*., 2016, pp. 83-88).

As an HOD and participant, I questioned the power I projected as a participant and interviewer. Lecturers responded more readily to surveys than students; and this may have been

out of a sense of duty. Interviews felt relaxed and natural with students and lecturers. With hindsight, I reflected on whether individuals were saying what they thought I wanted to hear because I was enthusiastic about CAD. Repeated follow-up interviews with participants, after completion of teaching practice and module, may further reinforce validation of interview responses.

Because the study was linked to a single module, on a single programme, in a private higher-education institution, the results cannot be considered a microcosm of wider society. However, comparison of the sample group's quantitative and visual outcomes with cohort outcomes allowed for more pragmatic interpretation over the course of the research. Results may inform improved module practice and practice architectures, or identify research gaps, which may cover a greater sample size (Gerber *et al*., 2016, pp. 90-91), but may not dictate widescale programme change without repeating in different institutions or countries.

The campus-based and online aspects of the study were valuable to personalise participants' interactions, promote collaboration, and face-to-face communication. A larger longitudinal study, repeating cycles of implementation, may enable a teaching practice observation schedule to be negotiated with participants willing to use CAD in school practice. This would allow appreciation of how students' experience of learning and using CAD is translated into teaching CAD.

Promoting use and teaching of computer skills in schools raises questions about ICTs being prioritised over other forms of practical technological learning, when society has many skills and resource deficits (Francis & Webster, 2019). CAD can help bridge this deficit by

enabling practical technological design, while helping learners to explore wider ICT skills. There are also continuing concerns about the future we are creating by replacing human jobs with computers and robots (Rowe & Thompson, 1990; Willcocks & Mason, 1987), instead of using technology to enhance work and make it more rewarding (Takavarasha *et al*., 2018). Overemphasis on computerising the classroom can reduce the opportunities of learning and applying other equally important practical life skills.

8.14 Dissemination of Findings in the Institution and Wider Global Community

Participatory action research is an actively inclusive process in which participants' contributions should be acknowledged in any publication or findings (Koen, 2021). To share findings from this study in the host research institution, a research presentation abstract was submitted to the institution's research committee. The abstract title is *Reflections on intermediate-phase student teachers blended online learning and application of computer-aided design in practice* (Appendix 40: Dissemination – Abstracts, posters and conference presentations 2023). In September 2023, the presentation was formally accepted and presented in the 2023 institutional conference. The presentation was well received, and academic staff from various schools gave constructive feedback. Representatives from the School of Information Technology were particularly interested in collaborating on integration of CAD in their general end-user ICT courses, which are now provided for all schools.

To share findings with the South African academic diaspora, in October 2023, findings were presented in an academic poster presentation at HELTASA 2023 Conference, Northwest

University, Vanderbijlpark Campus, Gauteng; and in a verbal presentation at University of KwaZulu-Natal School of Education's post graduate conference. To share findings in the wider academic community, additional paper abstracts were developed for the *Africa Education Review* and the international academic journal: *International Journal of Technology and Design Education* (Appendix 40). To ensure that these outputs reach all participants, thesis presentation copies and final papers will be distributed via email. Sharing of findings is intended to firstly, publicly acknowledge contributions of participants in knowledge creation[xiv]; secondly, fulfil the obligations of the institutional gateway permission, and, finally, to address the academic imperative to share new knowledge in the wider global community.

8.15 Conclusion – Turning CAD Implementation in an ICT Module into CAD Integration into the Primary School Curriculum

The title of this chapter could be: '*Integrating Computer-aided Design Education in Primary Schools*'. This research reveals that little research has been conducted internationally in teaching CAD skills to primary school teachers, who in turn are unable to teach CAD in primary school settings, thus augmenting technology education or supporting teaching of design processes in coding and robotics. What emerges is that collaborative 'implementation' of new computer skills is not a straightforward process; and 'integration' is a more apt terminology to use in a CPAR process. Integration draws on the opinions and experience of various participants integrating their ideas (Lawrence & Tar, 2018). 'Implementation' can be a solo enterprise. 'Integration' implies collaboration across social, cultural, and technological

boundaries (Davies, 2011), justifying this with data viewed in a pragmatic manner from a wide range of sources (Tashakkori & Teddie, 2008). 'In Schools…' is ambiguous as it could be interpreted as simply using CAD to resource teaching or teaching learners to use CAD. Ideally, we should be aiming for the latter option; however, it depends on institutions' willingness and ability to resource such integration (Padayachee, 2017).

Introduction of new subjects and skills in a teaching curriculum is not implementation. Implementation implies that there is clear definition; and expediting such is like fitting the last piece of a jigsaw. Integration is more about introducing something in a manner acceptable to the society it is meant to benefit (Padayachee, 2017). Integration has a relationship in language with the South African struggle to liberate itself from the Apartheid regime's segregation of races (Sikakane, 1977). Integration is the opposite of segregation; and therefore the implication is that integration should be a negotiated process involving multiple stakeholders (Ramesh & Dibaba, 2017).

Much of this study has observed the minutiae of implementation. As the study concluded, the valuable findings pointed to the need for sequential integration of ICT skills into the primary school curriculum in South Africa (Padayachee, 2016). Integration of ideas; suggested improvements; and contributions from all participants, gave the implementation life. Without integration, the implementation could easily be dictated from above, mirroring technological changes coerced in the workplace. Integrating ideas has potential to unify communities and draw on the strengths of individuals that may otherwise be voiceless, or muffled by their institutional discourse (Kemmis, McTaggart, *et al*., 2014, p. 12). Encouraging

ICT integration in the teaching workplace can have a positive influence on a society which is still trying to fix the damage caused by forced segregation and separate schooling (Padayachee, 2017). Using the available technology to support this integration acknowledges that pedagogy and technology should be striving for compatibility instead of competing for bragging rights (Fawns, 2022).

Integration of new content into a course implies that existing content has its own merits. Change in practice, or practice architecture, should augment the existing course; however, participants must be prepared for change. Persuading lecturers, comfortable in teaching existing end-user ICT subjects, to implement CAD, required me to convince them that change was beneficial. Reconnaissance work was needed to make the change appear seamless, painless, and beneficial (Kemmis, 2014). This required sustained effort, willingness to collaborate, and acceptance of criticism with grace.

Persuading student teachers that learning CAD is relevant to their lives requires more than a well-organised blended online course. Students will extend themselves if they see the benefits. There are combined motivations of novelty, being the first to do something, and risk-taking, which appeal to young adults. Making something appear new and challenging requires imagination in the implementation. The contexts used to promote new ideas are important in stirring students' interest and in fitting their cultural experience. Incorporating content in online spaces is one way of encouraging and maintaining interest in computer-literate youth; nevertheless, content must be packaged into contextually and vocationally relevant morsels. Content, pedagogy, and technology must be orchestrated (Dron, 2021) in a manner which

directs student teachers to utilise their skills, firstly to resource with CAD; and ultimately, to teach CAD.

Persuading participants to change their practice, and practice architectures, in line with a new course, requires great effort if the implementer must work solo. The use of CPAR can spread the motivational load of implementation, and ease the integration by imparting a sense of shared achievement and pride in creating something new with participants (Zuber-Skerritt, Wood, & Dick, 2013). As lecturers are generally pragmatic, they need convincing that change is not only beneficial to students, but beneficial personally, without adding to workload. Organisational change in private higher education that increases workload without reward or benefits is not easy to promote or sustain. Learning management system analytics can help provide more accurate evidence of the hidden workload that lecturers, and some teachers, have absorbed in the move to blended online study.

Tracking students' CAD learning with their resourcing of teaching practice lessons requires cooperation with stakeholders both institutionally and in schools. At the school level, mentors and head teachers must be convinced of the value of technical changes against existing norms. At institutional level, teaching practice managers should be involved with CAD/ICT lecturers in developing tasks which ensure that students demonstrate specialist skills (Carl & Strydom, 2017).

Teaching design-related tools, such as CAD, can inspire participants to design and innovate, which gives them greater ownership of their teaching. Learning to use and apply CAD to produce resources is only the start. Teaching CAD to learners in primary schools is

the goal. This requires an extended ICT course and prolonged collaboration between stakeholders. Collaborating to create something new can be life-affirming. Ask new parents. Those who collaborated in this project all appreciated the teamwork.

Academically, following a design process in creating teaching resources is an invaluable form of experiential learning. Appropriate contextual design projects using ICT systems also encourage entrepreneurial practice, which can close the gender gap and attract more girls and young women into ICT and STEM careers, internationally (European Commission, 2020). Practising the task beforehand adds value to teaching tools which execute a technical skill. This is essential in teaching design-related subjects such as technology, engineering graphics and design, and applied arts. Developing and adapting resources collaboratively enhances the design process (Schön, 1988). Shared experience can provide nostalgic reflection which can maintain long-distance communities of practice, e.g., university alumni. Shared experience can also help to reinforce an implementation through group affirmation, and to build student teachers' confidence to teach CAD (Breckon, 2000). Online CAD software enables real-time collaborative design projects between schools nationally and across continents. The ability in this way to design and simulate ideas prior to manufacture also assists in improving the environmental footprint of new technologies. Experiencing such in schools enables much greater awareness of the environmental impact of engineering and design solutions.

Collaboration in integration of technology is not a new concept. Collaboration is cited as an indicator of higher-order thinking in the offline (Bloom, 1956) and modern digital world

(Churches, 2010). Working together across both online and offline spaces, adapting the technology available to sustain teaching and learning relationships, is essential in 21st century teaching (Dron, 2021; Gerber *et al*., 2016). Should educators be able to develop collaborative relationships using the technology available, they will remain relevant; more teaching and learning is delivered online and artificial intelligence (AI) is used in design education (Vartiainen & Tedre, 2023). Conducting participatory action research can develop productive relationships which "encourage and sustain collaborative working practices" and build efficient sustainable architectures (Wood, 2014, p. 663). Working collaboratively assists in creation of valid credible evidence to justify decision-making relating to digital competence; and encourages a human-centred approach to technology integration which is less likely to be harmful to humanity (European Commission, 2020, p. 8). Collaboration also stimulates innovation and promotes visual literacy which goes beyond basic ICT skills (Martín Erro & Nuere Menéndez-Pidal, 2024), extends beyond school curricula, and unites people across national borders. This collaborative attitude is essential if technological educational practice is to evolve with creative technologies such as computer-aided design meaningfully integrated.

END OF THESIS

References

Adams, C. (2020). TPACK's arc of technology transparency and teachers' ethical obligations: Understanding the digital as the new materia medica of pedagogy. Paper presented at the Society for Information Technology & Teacher Education International Conference.

Adegbenro, J. B., Gumbo, M. T., & Olakanmi, E. E. (2017). In-Service Secondary School Teachers' Technology Integration Needs in an ICT-Enhanced Classroom. *Turkish Online Journal of Educational Technology-TOJET, 16*(3), 79-87.

Adeniji-Neill, D., Weida, C. L., & Mungai, A. (2018). Hybrid, Hybrid Flexible and Fully Online Learning through Students' Eyes. *Journal of Social Sciences, 14*, 155-168.

African Union Commission. (2015). *Agenda 2063: the Africa we want*. Retrieved from http://archive. au. int/assets/images/agenda2063. pdf. Accessed: 18/03/2018.

Ainley, J., Schulz, W., & Fraillon, J. (2016). *A global measure of digital and ICT literacy skills*. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000245577

Al-Imarah, A. A., & Shields, R. (2019). MOOCs, disruptive innovation and the future of higher education: A conceptual analysis. *Innovations in Education and Teaching International, 56*(3), 258-269.

Al-Zahrani, A. (2015). Toward digital citizenship: examining factors affecting participation and involvement in the Internet society among higher education students. *International Education Studies, 8*(12), 203-217. doi:10.5539/ies.v8n12p203

Allan, D., Vettese, S., & Thompson, P. (2018). A study of children's relationship with making and use of CAD in collaborative, informal environments and the implications for institutional learning environments. *Design and Technology Education: An International Journal, 23*(3), 10-25.

Andrews, J. (1994). New Edge of the Anvil: A Resource Book for the Blacksmith: Skipjack Press.

Ardington, C., Wills, G., & Kotze, J. (2021). COVID-19 learning losses: Early grade reading in South Africa. *International Journal of Educational Development, 86*, 102480.

AutoDesk (Producer). (2022). TinkerCAD. [Schools software package] Retrieved from https://www.tinkercad.com/

Banks, F., & Barlex, D. (2020). Teaching STEM in the secondary school: Helping teachers meet the challenge: Routledge.

Bantwini, B. (2017). Analysis of teaching and learning of natural sciences and technology in selected Eastern Cape province primary schools, South Africa. *Journal of Education*(67), 39-64. doi:https://doi.org/10.17159/2520-9868/i67a02

Bao, W. (2020). COVID-19 and online teaching in higher education: A case study of Peking University. *Human Behavior and Emerging Technologies, 2*(2), 113-115. doi:https://10.1002/hbe2.191

Barlex, D. (2011). Teaching young people about the nature of technology. *PATT, 25*, 66-75.

Barlex, D. (2012). The Young Foresight Project: A UK initiative in design creativity involving mentors from business and industry *Bringing Communities Together* Brill. 113-125.

Barlex, D. (2015). *The future of technology education*. Dordrecht: Springer.

Barlex, D., & Miles-Pearson, S. (2008). Introducing CAD/CAM into primary schools, part 1 of a case study–developing the curriculum.

Bartlett, K. A. & Camba, J.D. (2024). "Generative Artificial Intelligence in Product Design Education: Navigating Concerns of Originality and Ethics", International Journal of Interactive Multimedia and Artificial Intelligence, vol. 8, issue Special issue on Generative Artificial Intelligence in Education, no. 5, pp. 55-64. https://doi.org/10.9781/ijimai.2024.02.006

Baxter, G., & Sommerville, I. (2011). Socio-technical systems: From design methods to systems engineering. *Interacting with computers, 23*(1), 4-17.

Bazeley, P., & Jackson, K. (2013). *Qualitative data analysis with Nvivo*. Sage Publications Limited.

Becker, K. H. (1988). Content and strategies for teaching computer aided drafting. Texas A&M University.

Beetham, H., & Sharpe, R. (2013). Rethinking pedagogy for a digital age: Designing for 21st century learning: routledge.

Benzer, A. I., & Yildiz, B. (2019). The Effect of Computeraided 3D Modeling Activities on Pre-Service Teachers' Spatial Abilities and Attitudes towards 3D Modeling. *Journal of Baltic Science Education, 18*(3), 335-348.

Bernabei, R., Cappellieri, A., Tenuta, L., & Yavuz, S. U. (2016). CAD/CAM and jewellery design education. *Making Futures 2015: Craft and the return of the maker in a post-global sustainably aware society, 4*, 1-8.

Bhaduri, S., Biddy, Q., Bush, J., Suresh, A., & Sumner, T. (2021). *3DnST: A Framework Towards Understanding Children's Interaction with Tinkercad and Enhancing Spatial Thinking Skills.* Paper presented at the Interaction Design and Children.

Bijker, W. E. (1987). The social construction of Bakelite: Toward a theory of invention: MIT press Cambridge, MA.

Bleakley, A. (2015). The Winston Churchill Memorial Trust of Australia.

Blewett, C. (2016). From Traditional Pedagogy to Digital Pedagogy *Disrupting Higher Education Curriculum*. Springer. 265-287:

Bloom, B. S. (1956). Taxonomy of educational objectives. Vol. 1: Cognitive domain. *New York: McKay*, 20-24.

Boelens, R., Voet, M., & De Wever, B. (2018). The design of blended learning in response to student diversity in higher education: Instructors' views and use of differentiated instruction in blended learning. *Computers & education, 120*, 197-212.

Bongomin, O., Gilibrays Ocen, G., Oyondi Nganyi, E., Musinguzi, A., & Omara, T. (2020). Exponential disruptive technologies and the required skills of industry 4.0. *Journal of Engineering, 2020*.

Borda, O. F. (1979). Investigating reality in order to transform it: The Colombian experience. *Dialectical anthropology, 4*(1), 33-55.

Botcherby, S., & Buckner, L. (2012). Women in Science, Technology, Engineering and Mathematics: from Classroom to Boardroom. *UK Statistics, London*.

Braundy, M. (2011). Men & women and tools: Bridging the divide: Fernwood Pub.

Breckon, A. (2000). DfEE/DATA CAD/CAM in Schools Initiative-A Success Story so Far. *Journal of Design & Technology Education, 5*(2).

Brink, H., Kilbrink, N., & Gericke, N. (2022). Teach to use CAD or through using CAD: An interview study with technology teachers. *International Journal of Technology and Design Education*, 1-23.

Bronfenbrenner, U. (1992). *Ecological systems theory*: Jessica Kingsley Publishers.

Brydon-Miller, M., & Greenwood, D. (2006). A re-examination of the relationship between action research and human subjects review processes. Action Research, 4(1), 117-128. doi:https://doi.org/10.1177%2F1476750306060582

Burnett, C., Davies, J., Merchant, G., & Rowsell, J. (2014). *New literacies around the globe: Policy and pedagogy*: Routledge.

Caena, F., & Redecker, C. (2019). Aligning teacher competence frameworks to 21st century challenges: The case for the European Digital Competence Framework for Educators (Digcompedu). *European Journal of Education, 54*(3), 356-369.

Callaghan, C. W. (2016). 'Critical theory and contemporary paradigm differentiation', in 'Critical Management Studies in the South African context'. *Acta Commercii, suppl. 1*(16(2)), 59-99.

Cambridge Dictionary. (2020). Cambridge Dictionary (online). Cambridge University Press https://dictionary.cambridge.org/dictionary/english/work-shadowing

Cansoy, R. (2017). Teachers' Professional Development: The Case of *WhatsApp*. *Journal of Education and Learning, 6*(4), 285-293.

Carl, A., & Strydom, S. (2017). e-Portfolio as reflection tool during teaching practice: The interplay between contextual and dispositional variables. *South African journal of education, 37*(1).

Carretero, S., Vuorikari, R., & Punie, Y. (2017). The digital competence framework for citizens. *Publications Office of the European Union*.

Chamane, N., Thompson, R. M., Goldstone, S., & Mashamba-Thompson, T. P. (2021). Designing and Piloting of a Mobile Learning Curriculum for Quality Point-Of-Care Diagnostics Services in Rural Clinics of KwaZulu-Natal, South Africa. *Frontiers in Reproductive Health, 3*. doi:DOI: 10.3389/frph.2021.728309

Cherns, A. (1976). The principles of sociotechnical design. *Human relations*, *29*(8), 783-792.

Cheryl, B.-K., Ng, B.-K., & Wong, C.-Y. (2021). Governing the progress of internet-of-things: Ambivalence in the quest of technology exploitation and user rights protection. *Technology in Society, 64*, 101-463.

Chisango, G., Marongwe, N., Mtsi, N., & Matyedi, T. E. (2020). Teachers' perceptions of adopting information and communication technologies in teaching and learning at rural secondary schools in eastern cape, South Africa. *Africa Education Review, 17*(2), 1-19.

Christensen, C. M., Horn, M. B., Caldera, L., & Soares, L. (2011). Disrupting College: How Disruptive Innovation Can Deliver Quality and Affordability to Postsecondary Education. *Innosight Institute*.

Churches, A. (2008). Bloom's taxonomy blooms digitally. *Tech & Learning*, *1*, 1-6.

Churchman, C. W. (1968). *The Systems Approach*. New York, U.S.A.: Dell Publishing Co. Inc.

Chytas, C., Tsilingiris, A., & Diethelm, I. (2019). *Exploring Computational Thinking Skills in 3D Printing: A Data Analysis of an Online Makerspace.* Paper presented at the 2019 IEEE Global Engineering Education Conference (EDUCON).

Clegg, C. W. (2000). Sociotechnical principles for system design. *Applied ergonomics*, *31*(5), 463-477.

Cohen, L. Manion, L. and Morrison, K. (2007). Research methods in education 6th edition. London: Routledge.

Collins, A., & Halverson, R. (2009). Rethinking education in the age of technology: The digital revolution and schooling in America: Teachers College Press.

Contact North. (2020). *A New Pedagogy is Emerging...and Online Learning Is a Key Contributing Factor*. Teachonline.ca. Contact North-Supporting Rural and Remote Ontario. Canada. Retrieved from https://teachonline.ca/tools-trends/how-teach-online-student-success/new-pedagogy-emerging-and-online-learning-key-contributing-factor

Corey, S. M. (1949). Curriculum development through action research. *Educational Leadership*, *7*(3), 147-153.

Corey, S. M. (1953). Action research to improve school practices.

Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., . . . Lam, S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. *Journal of Applied Learning and Teaching*, *3*(1).

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches: SAGE Publications.

Cronje, J., & Van Zyl, I. (2022). *WhatsApp* as a tool for Building a Learning Community. Electronic Journal of e-Learning, 20(3), pp296-312.

Czerniewicz, L., Agherdien, N., Badenhorst, J., Belluigi, D., Chambers, T., Chili, M., . . . Gokhale, C. (2020). A wake-up call: Equity, inequality and Covid-19 emergency remote teaching and learning. *Postdigital Science and Education*, *2*(3), 946-967.

Dagman, A., & Wärmefjord, K. (2022). An evidence-based study on teaching computer aided design in higher education during the COVID-19 pandemic. *Education Sciences*, *12*(1), 29.

Dasgupta, C., Magana, A., & Chao, J. (2017). *Investigating Teacher's Technological Pedagogical Content Knowledge in a CAD-enabled Learning Environment.* Paper presented at the Paper presented and published at the 124th ASEE Annual Conference & Exposition. Columbus, Ohio, 25-28 June 2017.

Davies, R. S. (2011). Understanding technology literacy: A framework for evaluating educational technology integration. *TechTrends*, *55*(5), 45.

De Bono, E. (2015). The Mechanism of Mind: Understand how your mind works to maximise memory and creative potential: Random House.

de Souza Almeida, M. V., Junior, A. B. A., Junior, E. S. C., da Silva, E. C. C., & de Mesquita, B. D. R. (2020). Educational Robotics as a Teaching Field and Technology Integration: Application of CAD, CAM and 3D printing in structural robot construction. Paper presented at the 2020 IEEE World Conference on Engineering Education (EDUNINE).

Delbecq, A. L., & Van de Ven, A. H. (1971). A group process model for problem identification and program planning. *The Journal of Applied Behavioral Science*, *7*(4), 466-492.

Department of Basic Education. (2011). *Curriculum and Assessment Policy Statement: Grades 10-12: Engineering Graphics and Design*. South Africa: Department of Basic Education Retrieved from https://www.education.gov.za/LinkClick.aspx?fileticket=pqcxCwUTO98%3D&tabid=570&portalid=0&mid=1558.

Department of Basic Education. (2015). *Action Plan to 2019:*

Towards the realisation of Schooling

2030 Pretoria, RSA: Department of Education Retrieved from https://www.education.gov.za/Portals/0/Documents/Publications/Action%20Plan%202019%20Final.pdf?ver=2016-01-20-155119-060.

Department of Basic Education. (2018). *Professional Development Framework for Digital Learning* Pretoria, RSA Retrieved from https://www.education.gov.za/Portals/0/Documents/Publications/Digital%20Learning%20Framework.pdf?ver=2018-07-09-101748-953.

Department of Basic Education. (2019). *National Education Infrastructure Management System (NEIMS) Standard Report*. South Africa: Department of Basic Education Retrieved from https:// www.education.gov.za/Portals/0/Documents.

Department of Basic Education. (2024). *Curriculum and Assessment Policy Statement: Grades R-3 Coding and Robotics*. South Africa: Department of Basic Education.

Department of Higher Education and Training. (2017). *Open learning policy framework for South African post-school education and training,*. South Africa, Retrieved from https://www.gov.za/documents/higher-education-act-open-learning-policy-framework-south-african-post-school-education.

Department of Telecommunications and Postal Services. (2016). *National Integrated ICT Policy White Paper*. South Africa: Department of Telecommunications and Postal Services. https://www.dtps.gov.za/images/phocagallery/Popular_Topic_Pictures/National_Integrated_ICT_Policy_White.pdf.

Dewey, J. (1900). The School and Society: Being three lectures. Chicago: University of Chicago Press.

Dewey, J. (1913). *Interest and effort in education*: Houghton Mifflin.

Dhawan, S. (2020). Online learning: A panacea in the time of COVID-19 crisis. *Journal of Educational Technology Systems, 49*(1), 5-22.

DHET. (2011). National qualifications framework act 67 of 2008: Policy on the minimum requirements for teacher education qualifications. South Africa Retrieved from https://www.dhet.gov.za.

Dockney, J., & Tomaselli, K. G. (2009). Fit for the small (er) screen: Films, mobile TV and the new individual television experience. *Journal of African Cinema, 1*(1), 126-132.

Dopp, K. E. (1902). *The place of industries in elementary education*: University of Chicago Press.

Downey, G. L. (1992). CAD/CAM saves the nation?: Toward an anthropology of technology. *Knowledge and Society, 9.* 143-168.

Downey, G. L. (1992). Human agency in CAD/CAM technology. *Anthropology Today, 8*(5), 2-6.

Downey, G. L. (2013). The machine in me: An anthropologist sits among computer engineers. New York: Routledge.

Downey, G. L. (2014). The machine in me: An anthropologist sits among computer engineers: Routledge.

Dron, J. (2022). Educational technology: what it is and how it works. *AI & SOCIETY, 37*(1), 155-166.

Eryilmaz, S., & Deniz, G. l. (2021). Effect of Tinkercad on Students' Computational Thinking Skills and Perceptions: A Case of Ankara Province. *Turkish Online Journal of Educational Technology-TOJET, 20*(1), 25-38.

Estelami, H. (2017). The pedagogical and institutional impact of disruptive innovations in distance business education. *American Journal of Business Education (AJBE), 10*(3), 97-108.

European Commission (2016): Digital Competence Framework for Citizens, https://ec.europa.eu/jrc/en/digcomp/digital-competence-framework.

European Commission (2016): ICT for work: Digital skills in the work place, https://ec.europa.eu/digital-single-market/en/news/ict-work-digital-skills-workplace.

European Commission (2017): Digital Competence Framework for Educators, https://ec.europa.eu/jrc/en/digcompedu.

European Commission. (2020). *Digital Education Action Plan (2021-2027)*. Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/33b83a7a-ddf9-11ed-a05c-01aa75ed71a1

Fares, K., Fowler, B., & Vegas, E. (2021). *How South Africa implemented its computer science education program*. Retrieved from Center for Universal Education at Brookings:

Fawns, T. (2019). Postdigital education in design and practice. *Postdigital Science and Education, 1*(1), 132-145.

Fawns, T. (2022). An entangled pedagogy: Looking beyond the pedagogy—technology dichotomy. *Postdigital Science and Education, 4*(3), 711-728.

Fawns, T., Aitken, G., & Jones, D. (2019). Online learning as embodied, socially meaningful experience. *Postdigital Science and Education, 1*, 293-297.

Feenberg, A. (1991). *Critical Theory of Technology*. New York: Oxford University Press.

Feenberg, A. (2005). Critical Theory of Technology: An Overview. *Tailoring Biotechnologies, 1*(1), 47-64.

Flinchum, R. (2000). Dreyfuss, design, and human factors. *Ergonomics in Design, 8*(1), 18-24.

Fraillon, J., Ainley, J., Schulz, W., Friedman, T., & Duckworth, D. (2019). Preparing for life in a digital world: IEA International Computer and Information Literacy Study 2018 International Report. Springer.

Francis, D., & Webster, E. (2019). Poverty and inequality in South Africa: critical reflections. *Development Southern Africa, 36*(6), 788-802.

Freire, P. (1972). *Pedagogy of the Oppressed* (6th ed.). Middlesex, England: Penguin Education.

Gale, N. K., Heath, G., Cameron, E., Rashid, S., & Redwood, S. (2013). Using the framework method for the analysis of qualitative data in multi-disciplinary health research. *BMC medical research methodology, 13*(1), 117.

Gerber, H. R., Abrams, S. S., Curwood, J. S., & Magnifico, A. M. (2016). *Conducting qualitative research of learning in online spaces*: SAGE Publications.

Goktas, Y., Yildirim, S., & Yildirim, Z. (2009). Main barriers and possible enablers of ICTs integration into pre-service teacher education programs. *Journal of Educational Technology & Society, 12*(1), 193.

Govender, R.G., & Khoza, S.B**.** (2024). First-hand user experience: Can Kaltura video come to the rescue of Moodle during/post COVID-19? *African Identities*, 22(3), 536-553. https://doi.org/10.1080/14725843.2022.2082376

Gracia-Ibáñez, V., & Vergara, M. (2016). Applying action research in CAD teaching to improve the learning experience and academic level. *International Journal of Educational Technology in Higher Education, 13*(1), 1-13.

Grassini, S. (2023). Shaping the future of education: exploring the potential and consequences of AI and ChatGPT in educational settings. *Education Sciences*, *13*(7),

692.

Green, J. C. (2007) Mixing Methods in Social Enquiry. San Francisco: Jossey-Bass.

Groover, M., & Zimmers, E. (1983). *CAD/CAM: computer-aided design and manufacturing*: Pearson Education.

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communication and Technology Journal*, *29*(1981), 75–91.

Gumbo, M. (2015). Indigenous technology in technology education curricula and teaching *The future of technology education*. Springer. 57-75.:

Gumbo, M., Du Toit, A., Maluleka, K., Mapotse, T., Ngetu, C., Sibanda, D., & Thompson, R. (2019). *Teaching Technology: Intermediate to Senior Phase* (M. Gumbo Ed.). South Africa: Oxford University Press.

Gumbo, M., Makgato, M., & Muller, H. (2012). The Impact of In-Service Technology Training Programmes on Technology Teachers. *Journal of Technology Studies*, *38*(1), 23-33.

Guo, R. X., Dobson, T., & Petrina, S. (2008). Digital natives, digital immigrants: An analysis of age and ICT competency in teacher education. *Journal of Educational Computing Research*, *38*(3), 235-254.

Guston, D. H. (2014). Understanding 'anticipatory governance'. *Social studies of science*, *44*(2), 218-242.

Habermas, J. (1984). *The Theory of Communicative action*, Thomas MacCarthy (Trans). Beacon press.

Habermas, J. (1987). The entwinement of myth and enlightenment: Max Horkheimer and Theodor Adorno. *The philosophical discourse of modernity*, 106-130.

Habernas, J. (1972). *Knowledge and human interests* (J. Shapiro, Trans.). London: Heinemann.

Ham, J. J., & Dawson, A. (2004). Managing digital resources for design education. Architecture in the Network Society, 443.

Haney, J. P. (1905). The teaching of applied design. *The Elementary School Teacher*, *6*(4), 179-191.

Hardman, J. D., R. Dumas, C. Lewis, A. Lilley, W. Madhav, N. Molotsi, A. Simelane-Mnisi, S.,. (2018). *Teaching with information and communication tecnology (ICT)* (J. Hardman Ed.). South Africa: Oxford Universtity Press South Africa,.

Hardy, A., & Davies, S. (2013). Using technology in design and technology. *Debates in design and technology education*, 125-138.

Hartley, D. (1990). Beyond Competency A Socio-Technical Approach to Continuing Professional Education. *Journal of In-Service Education, 16*(1), 66-70.

Hennessy, S., Harrison, D., & Wamakote, L. (2010). Teacher factors influencing classroom use of ICT in Sub-Saharan Africa. *Itupale online journal of African studies, 2*(1), 39-54.

Hervey, H. D. (1908). Manual Training. *Journal of Education, 67*(12), 328-329.

Horkheimer, M., Adorno, T. W., & Noeri, G. (2002). *Dialectic of enlightenment*: Stanford University Press.

Hramiak, A., & Boulton, H. (2013). Escalating the use of Web 2.0 Technology in Secondary Schools in the United Kingdom: Barriers and Enablers beyond Teacher Training. Electronic Journal of E-learning, *11*(2), 91-100.

Hu, M. (2019). BIM-enabled pedagogy approach: using BIM as an instructional tool in technology courses. *Journal of Professional Issues in Engineering Education and Practice, 145*(1).

Illich, I. (1976). *Deschooling society* (7th Edition ed.). London: Pelican.

Iyendo, O., & Halil, Z. (2015). Computer aided design (CAD) technology versus students' learning in architectural design pedagogy–a controversial topic review. *Int. J. Develop. Res., 5*(1), 3152-3158.

Jobson, I. (2006). The Unseen World of Transnational Corporations' Powers. *The Neumann Business Review, 1*, 23-30.

Joia, L. A., & Lorenzo, M. (2021). *Zoom* in, *Zoom* out: The impact of the COVID-19 pandemic in the classroom. *Sustainability, 13*(5), 2531.

Jones, A. J., Artikis, A., & Pitt, J. (2013). The design of intelligent socio-technical systems. *Artificial Intelligence Review, 39*(1), 5-20.

Jones, L. C. (2016). An investigation into the knowledge and skill requirements for effective teaching of technology in english secondary schools. Lewis Callum Reece Jones.

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for social work research. *Social sciences, 8*(9), 255.

Keirl, S. (2015). 'Seeing'and 'Interpreting' the Human-Technology Phenomenon *The future of technology education*. Springer. 13-34.:

Kemmis, S. (2009) Action Research as Practice-based practice. *Educational Action Research. 17*(3), 463-474

Kemmis, S., McTaggart, R., & Nixon, R. (2014). *The action research planner: Doing critical participatory action research*: Springer Science & Business Media.

Kemmis, S., Wilkinson, J., Edwards-Groves, C., Hardy, I., Grootenboer, P., & Bristol, L. (2014). *Changing practices, changing education*: Springer Science & Business Media.

Kessy, D., Kaemba, M., & Gachoka, M. (2006). *The reasons for under use of ICT in education: in the context of Kenya, Tanzania and Zambia.* Paper presented at the Fourth IEEE International Workshop on Technology for Education in Developing Countries (TEDC'06).

Kipchumba, S. K. (2019). African Perspective of the Challenges and Prospects of Massification of Higher Education. *Editon Consortium Journal of Curriculum and Educational Studies, 1*(3), 131-145.

Kirlidog, M., van der Vyver, C., Zeeman, M., & Coetzee, W. (2018). Unfulfilled need: reasons for insufficient ICT skills in South Africa. *Information Development, 34*(1), 5-19.

Khoza, S.B. (2020). Students' Habits Appear Captured by WhatsApp. *International Journal of Higher Education*, 9(6), 307-317. https://doi.org/10.5430/ijhe.v9n6p307

Koehler, M. J., Mishra, P., & Yahya, K. (2007). Tracing the development of teacher knowledge in a design seminar: Integrating content, pedagogy and technology. Computers & Education, 49(3), 740-762.

Koehler, M., & Mishra, P. (2009). What is technological pedagogical content knowledge (TPACK)? *Contemporary issues in technology and teacher education, 9*(1), 60-70.

Koen, M. (2021). Community-Based Research for Social Change. *Educational Research for Social Change, 10*, vii-xi. Retrieved from http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S2221-40702021000100001&nrm=iso

Kolb, D. A. (1984). Experience as the source of learning and development. *Upper Sadle River: Prentice Hall*.

Kress, G. R. (2010). Multimodality: A social semiotic approach to contemporary communication: Taylor & Francis.

Kurtuluş, A. (2019). Spatial visualization training using computer-aided cross sections of surfaces. *European Journal of Education Studies, 6*(4), 17. doi:10.5281/zenodo.3339227

Lacey, L. L., (2007). *Qualitative Data Analysis*. Yorkshire & the Humber: NHS.

Lareau, A. (2021). Listening to people: A practical guide to interviewing, participant observation, data analysis, and writing it all up. University of Chicago Press.

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*: Cambridge university press.

Lawrence, J. E., & Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in teaching/learning process. *Educational Media International, 55*(1), 79-105.

Lebbon, C., Davies, S., & Shippen, J. (2009). User centered research methods in postgraduate teaching. Paper presented at the DS 59: Proceedings of E&PDE 2009, the 11th Engineering and Product Design Education Conference-Creating a Better World, Brighton, U.K., 10-11 September. 2009.

Lewin, K. (1947). Frontiers in group dynamics: Concept, method and reality in social science; social equilibria and social change. Human relations, 1(1), 5-41.

Lipsey, M. W., Puzio, K., Yun, C., Hebert, M. A., Steinka-Fry, K., Cole, M. W. Busick, M. D. (2012). Translating the Statistical Representation of the Effects of Education Interventions into More Readily Interpretable Forms. National Center for Special Education Research.

Liu, H., Xu, S., & Liu, S. (2021). An online course mode based on microlecture videos: Using CAD geometric modeling course as an example. *Computer Applications in Engineering Education*, *29*(5), 1300-1311.

MacDowell, P. (2015). Empowering girls as change makers in maker culture: stories from a summer camp for girls in design, media & technology. University of British Columbia.

Majchrzak, A. (1990). Effect of CAD on the jobs of drafters and engineers: a quantitative case study. *International Journal of Man-Machine Studies*, *32*(3), 245-262.

Majchrzak, A., & Borys, B. (1998). Computer-aided technology and work: moving the field forward. *International review of industrial and organizational psychology*, *13*, 305-354.

Maphalala, M. C., & Adigun, O. T. (2021). Academics' Experience of Implementing E-Learning in a South African Higher Education Institution. *International Journal of Higher Education*, *10*(1), 1-13.

Mapotse, T. A. (2018). Development of a Technology Education Cascading Theory through community engagement site-based support. *International Journal of Technology and Design Education*, *28*(3), 685-699. doi:https://doi.org/10.1007/s10798-017-9411-6

Mapundu, M., & Musara, M. (2019). E-Portfolios as a tool to enhance student learning experience and entrepreneurial skills. *South African Journal of Higher Education*, *33*(6), 191-214.

Mark, E., Gross, M., & Goldschmidt, G. (2008). *A perspective on computer aided design after four decades.* Paper presented at the Architecture in Computro, Proceeding of the 26th eCAADe Conference.

Martín Erro, A., & Nuere Menéndez-Pidal, S. (2024). How visual literacy is developed through Engineering Graphics subjects. *Journal of Visual Literacy, 43*(1), 29–45. https://doi.org/10.1080/1051144X.2024.2315835

Martin, M., & Owen-Jackson, G. (2013). Is design and technology about making or knowing? *Debates in design and technology education* (pp. 82-91): Routledge.

Maslow, A. H. (1943). A theory of human motivation. *Psychological review, 50*(4), 370.

Mayer, R. E. (2017). Using multimedia for e-learning. *Journal of computer assisted learning, 33*(5), 403-423.

McLaren, S. V. (2008). Exploring perceptions and attitudes towards teaching and learning manual technical drawing in a digital age. *International Journal of Technology and Design Education, 18*(2), 167-188.

McNiff, J. (2005). Action research: Principles and practice: Routledge.

Merriam, S. B. (2009). Qualitative Design: A Guide to Design and Implementation, revised and expanded from,'Qualitative Research and Case Study Applications in Education': San Fransico: Jossey-Bass Publishers.

Mertens, D. M. (2007). Transformative paradigm: Mixed methods and social justice. *Journal of mixed methods research, 1*(3), 212-225.

Mertler, C. A. (2016). Action research: Improving schools and empowering educators: Sage Publications.

Miles, M. B., & Huberman, A. M. (1994). *Qualitative data analysis: An expanded sourcebook*. (2nd ed.): Sage.

Mishra, V., Aneja, U., & Evans, S. (2017). Empowering women in a digital age in South Africa: New York City: OECD. Also available at https://www. orfonline. org/research.

Mitchell, C., De Lange, N., & Moletsane, R. (2017). Participatory Visual Methodologies: Social Change, Community and Policy. SAGE.

Mo Ibrahim Foundation. (2016). *Index of African Governance*. Retrieved from http://mo.ibrahim.foundation/, Accessed: 25/02/2018

Mo Ibrahim Foundation. (2017). *Forum Report: Africa at a Tipping Point*. Retrieved from http://mo.ibrahim.foundation.

Moletsane, R., & Reddy, V. (2008). Report: An assessment of the participation of women in SET industry for Department of Science and Technology (5505). Retrieved from http://hdl.handle.net/20.500.11910/5187

Morgan, D. L. 2014a. Integrating Qualitative and Quantitative Methods: A Pragmatic Approach. Thousand Oaks: Sage.

Morgan, D. L. 2014b. Pragmatism as a paradigm for social research. Qualitative Inquiry 20: 1045–53.

Morse, J. M., Barrett, M., Mayan, M., Olson, K., & Spiers, J. (2002). Verification strategies for establishing reliability and validity in qualitative research. *International journal of qualitative methods, 1*(2), 13-22.

Moscoviz, L., & Evans, D. K. (2022). Learning loss and student dropouts during the covid-19 pandemic: A review of the evidence two years after schools shut down. *Center for Global Development, Working Paper, 609*.

Mumford, E. (1995). *Effective systems design and requirements analysis*: Macmillan International Higher Education.

Mumford, E. (2003). *Redesigning human systems*: IGI Global.

Mumtaz, S. (2000). Factors affecting teachers' use of information and communications technology: a review of the literature. *Journal of information technology for teacher education, 9*(3), 319-342.

Mzekandaba, S. (2021). Coding, robotics curriculum pilot to finally get going in 2021. *IT in Government*.

Ndovela, S., & Marimuthu, M. (2022). Prevalence of online cheating during the COVID-19 pandemic *Academic Voices.* Elsevier. 443-455.

Neill, A. S. (1915). *The Story of a Scottish teacher: A Dominie's Log* (H. Mackenzie Ed.). London: The Hogarth Press.

Nevid, J. (2012). *Psychology: Concepts and applications*: Nelson Education.

Nieusma, D. (2018). From Learning to CAD to CADing to Learn: Teaching the Command, Strate-gic, and Epistemic Dimensions of CAD Software. Rensselaer Polytechnic Institute.

Noble, D. (1984). Forces of Production: A Social History of Industrial Automation. New York: Oxford University Press.

Noffke, S. E., & Somekh, B. (2009). The SAGE handbook of educational action research: Sage.

Nordlöf, C., Höst, G., & Hallström, J. (2022). Technology teachers' talk about knowledge: from uncertainty to technology education competence. *Research in Science & Technological Education*, 1-21.

OECD (2019), TALIS 2018 Results (Volume I): Teachers and School Leaders as Lifelong Learners, TALIS, OECD Publishing, Paris. https://doi.org/10.1787/1d0bc92a-en

Odena, O. (2013). Using software to tell a trustworthy, convincing and useful story. *International journal of social research methodology, 16*(5), 355-372.

Onofrei, G., & Ferry, P. (2020). Reusable learning objects: a blended learning tool in teaching computer-aided design to engineering undergraduates. *International Journal of Educational Management, 34*(10), 1559-1575.

Onwuegbuzie, A. J., & Frels, R. K. (2013). Introduction: Toward a new research philosophy for addressing social justice issues: Critical dialectical pluralism 1.0: Taylor & Francis.

Oosthuizen, R., & Pretorius, L. (2016). Assessing the impact of new technology on complex sociotechnical systems. *South African Journal of Industrial Engineering, 27*, 15-29.

Open University (Producer). (2020, 14 November 2020). User research techniques. Retrieved from https://www.open.edu/openlearn/science-maths-technology/engineering-and-technology/design-and-innovation/design/people-centred-designing/content-section-9.1#:~:text=The%20essential%20idea%20of%20user,yourself%20a%20critical%20observant%20user.

Osborn, A. F. (1963). Applied Imagination: The principles and procedures of Creative Thinking. 1953. *New York: Charles Scribner's Sons*.

Padayachee, K. (2016). *A stepwise framework towards ICT integration in education: A South African perspective.* Paper presented at the 2016 International Conference on Advances in Computing and Communication Engineering (ICACCE).

Padayachee, K. (2017). A snapshot survey of ICT integration in South African schools. *South African Computer Journal*, *29*(2), 36-65.

Panday, S., Makiwane, M., Ranchod, C., & Letsoala, T. (2009). Teenage pregnancy in South Africa: with a specific focus on school-going learners.

Pannabecker, J. R. (1991). Technological impacts and determinism in technology education: Alternate metaphors from social constructivism. *3*(1). doi:doi:10.21061/jte.v3i1.a.4

Papert, S. (1987). Information technology and education: Computer criticism vs. technocentric thinking. *Educational researcher*, *16*(1), 22-30.

Papert, S. (1990). Children, computers and powerful ideas (2nd ed.): New York: Basic Books.

Papert, S. (1993). The children's machine: Rethinking school in the age of the computer: Basic Books, Inc.

Papert, S., Solomon, C., Soloway, E., & Spohrer, J. (1971). Twenty things to do with a computer. *Studying the novice programmer*, 3-28.

Parker, R., Morris, K., & Hofmeyr, J. (2020). Education, inequality and innovation in the time of COVID-19. *JET Education Services*.

Pegrum, M., & Oakley, G. (2017). The changing landscape of e-portfolios: Reflections on 5 years of implementing e-portfolios in pre-service teacher education *E-portfolios in higher education*. Springer. 21-34.

Peters, M. D., Godfrey, C. M., Khalil, H., McInerney, P., Parker, D., & Soares, C. B. (2015). Guidance for conducting systematic scoping reviews. JBI Evidence Implementation, 13(3), 141-146.

Petrina, S. (1998). Multidisciplinary technology education. *International Journal of Technology and Design Education, 8*(2), 103-138.

Petrina, S. (2000a). The political ecology of design and technology education: An inquiry into methods. *International Journal of Technology and Design Education, 10*(3), 207-237.

Petrina, S. (2000b). The politics of technological literacy. *International Journal of Technology and Design Education, 10*(2), 181-206. doi:https://doi.org/10.1023/A:1008919120846

Petrina, S. (2003). Two cultures of technical courses and discourses: The case of computer aided design. *International Journal of Technology and Design Education, 13*(1), 47-73.

Petrina, S. (2017). Critique of technology. *Critique in design and technology education.* Springer. 31-49.

Petrina, S. (2018). From Crit to Social Critique. *Handbook of Technology Education*, 39-50.

Porras-Hernández, L. H., & Salinas-Amescua, B. (2013). Strengthening TPACK: A broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research, 48*(2), 223-244.

Postholm, M. B., & Skrøvset, S. (2013). The researcher reflecting on her own role during action research. *Educational Action Research, 21*(4), 506-518.

Prensky, M. (2001). Digital natives, digital immigrants part 1. *On the horizon, 9*(5), 1-6.

Prensky, M. (2009). H. sapiens digital: From digital immigrants and digital natives to digital wisdom. *Innovate: journal of online education, 5*(3), 1.

Puentedura, R. R. (2014). SAMR and TPCK: A hands-on approach to classroom practice. *Hipassus*. Retrieved from http://www.hippasus.com/rrpweblog/archives/2012/09/03/BuildingUponSAMR.pdf.

Qualley, D. J., & Chiseri-Strater, E. (1994). Collaboration as Reflexive Dialogue: A Knowing" Deeper Than Reason". *Journal of Advanced Composition*, 111-130.

Rambe, P., & Moeti, M. (2017). Disrupting and democratising higher education provision or entrenching academic elitism: towards a model of MOOCs adoption at African universities. *Educational Technology Research and Development*, 65(3), 631-651.

Ramesh, B. P., & Dibaba, W. (2017). The role of effective integration of ICT in education, especially in primary and secondary education of remote settings. *International Journal of Advanced Research in Computer Science, 8*(9).

Redeker, C. (2018). Digital Competence Framework for Educators (DigCompEdu). https://ec.europa.eu/jrc/en/digcompedu.

Ritchie, J., & Spencer, l. (1994). Qualitative data analysis for applied policy research. In B. a. B. (Eds.) (Ed.), *Analysing Qualitative Data*. 173-194.

Roche, M. (2011). Creating a dialogical and critical classroom: Reflection and action to improve practice. *Educational Action Research, 19*(3), 327-343.

Rowe, C., & Thompson, J. (1990). People and chips: The human implications of information technology: London: Paradigm Publishing.

Rowsell, J. (2013). Working with multimodality. *Rethinking Literacy in a Digital Age*.

Saldaña, J. (2013). *The coding manual for qualitative researchers*. Thousand Oaks, C.A.: Sage.

Salzman, H. (1989). Computer-aided design: limitations in automating design and drafting. *IEEE Transactions on Engineering Management, 36*(4), 252-261.

Samaras, A. P. (2010). Self-study teacher research: Improving your practice through collaborative inquiry: Sage.

Sandholtz, J. H. (1997). Teaching with technology: Creating student-centered classrooms: ERIC.

Schatzki, T. R. (2002). The site of the social: A philosophical account of the constitution of social life and change. University Park, Pennsylvania: University of Pennsylvania Press.

Scheer, A., Noweski, C., & Meinel, C. (2012). Transforming constructivist learning into action: Design thinking in education. *Design and Technology Education: An International Journal, 17*(3).

Schon, D. A. (1983). The reflective practitioner: How professionals think in action (Vol. 5126). New York: Basic books.

Schön, D. A. (1984). The architectural studio as an exemplar of education for reflection-in-action. *Journal of Architectural Education, 38*(1), 2-9.

Schön, D. A. (1987). *Educating the reflective practitioner*. San Francisco: Jossey-Bass.

Schön, D. A. (1988). Designing: Rules, types and worlds. *Design studies, 9*(3), 181-190.

Schön, D. A. (1995). Knowing-in-action: The new scholarship requires a new epistemology. *Change: The Magazine of Higher Learning, 27*(6), 27-34.

Schubert, C., & Kolb, A. (2021). Designing Technology, Developing Theory: Toward a Symmetrical Approach. *Science, Technology, & Human Values, 46*(3), 528-554. doi:10.1177/0162243920941581

Schwandt, T. A., Lincoln, Y. S., & Guba, E. G. (2007). Judging interpretations: But is it rigorous? trustworthiness and authenticity in naturalistic evaluation. *New directions for evaluation, 2007*(114).

Seemann, K. (2015). Designing for Cultural Groups and Humanization: Two Ideas from Design Anthropology *Environment, ethics and cultures.* Brill Sense. 101-117.

Serhan, D. (2020). Transitioning from Face-to-Face to Remote Learning: Students' Attitudes and Perceptions of Using *Zoom* during COVID-19 Pandemic. *International Journal of Technology in Education and Science, 4*(4), 335-342.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational researcher, 15*(2), 4-14.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard educational review, 57*(1), 1-23.

Sikakane, J. (1977). *A window on Soweto*. International Defence and Aid Fund.

Singh-Pillay, A., & Sotsaka, D. S. (2016). Engineering graphics and design teachers' understanding and teaching of assembly drawing. *EURASIA Journal of Mathematics, Science and Technology Education, 13*(5), 1213-1228.

Singh, U., Proches, C. G., Leask, C., & Blewett, C. (2020b). *Emergency Online Learning (EOL) during the COVID-19 pandemic: Postgraduate students' perspectives.* Paper presented at the digiTAL 2020, University of KwaZulu Natal.

Singh, V., & Thurman, A. (2019). How many ways can we define online learning? A systematic literature review of definitions of online learning (1988-2018). *American Journal of Distance Education, 33*(4), 289-306.

Skinner, B. F. (1953). *Science and human behavior*: Simon and Schuster.

Snow, C. P. (1998). *The Two Cultures* (14th printing ed.). Cambridge, U.K.: Cambridge University Press.

Sobuwa, Y. (2020). Universities cancelling in-person classes due to coronavirus. *Sowetan Live.*

Soudien, C., Reddy, V., & Harvey, J. (2021). The impact of COVID-19 on a fragile education system: The case of south africa. In F. M. Reimers (Ed.), *Primary and Secondary Education During Covid-19: Disruptions to Educational Opportunity During a Pandemic.* Springer. 303-326.

South Africa Department of Basic Education. (1995). *White paper on education and training*. South Africa: Department of Education Retrieved from http://www.education.gov.za/Portals/0/Documents/Legislation/White%20paper/White%20paper%20on%20Education%20and%20Training%201995.pdf?ver=2008-03-05-111656-000.

South Africa Department of Education & Department of Labour. (2002). *Report of the study team on the implementation of the national qualifications framework*: Department of Education Pretoria.

Spaull, N. (2019). Equity: A price too high to pay? *South African schooling: The enigma of inequality*. Springer. 1-24.

Srivastava, A., & Thomson, S. B. (2009). Framework analysis: a qualitative methodology for applied policy research. *Journal of Administration and Governance,* 4 (2).

Stager, G. S. (2016). Seymour Papert (1928–2016). *Nature, 537*(7620), 308-308.

STATSSA. (2017). Vulnerable Groups Indicator, available from Statistics South Africa, accessed 17/03/2018. Retrieved from South Africa:

Stevens, A. (2006). Technology teacher education in South Africa *International handbook of technology education*. Brill Sense. 505-514.

Strauss, A., & Corbin, J. (1998). *Basics of qualitative research techniques*. Sage publications.

Swallow, V., Newton, J., & Van Lottum, C. (2003). How to manage and display qualitative data using 'Framework'and Microsoft® Excel. Journal of Clinical Nursing, 12(4), 610-612.

Taebi, B., Correlje, A., Cuppen, E., Dignum, M., & Pesch, U. (2014). Responsible innovation as an endorsement of public values: The need for interdisciplinary research. *Journal of Responsible Innovation, 1*(1), 118-124.

Takavarasha, S., Cilliers, L., & Chinyamurindi, W. (2018). Navigating the unbeaten track from digital literacy to digital citizenship: A case of university students in South Africa's Eastern Cape province. *Reading & Writing-Journal of the Reading Association of South Africa, 9*(1), 1-15. doi:https://doi.org/10.4102/rw.v9i1.187

Tashakkori, A., & Teddlie, C. (2008). *Mixed Methodology: Combining Qualitative and Quantitative Approaches*. Thousand Oaks: Sage Publications.

TechSoft. (2021). TechSoft *2D Design*. https://www.techsoft.co.uk/products/software/2ddesignv2

Thomas, M. (2011). Deconstructing digital natives: Young people, technology, and the new literacies: Taylor & Francis.

Thompson, R. & Alant, B. (2021). Finding and Defining Champions in a Rural Adult Education Intervention in Limpopo, South Africa. *Educational Research for Social Change, 10*(1), 33-51.

Thompson, R. M. (2016). Implementation of an Integrated ICT and BAE course for young mothers using CBPAR in Limpopo. *UKZN (MEd dissertation)*. Intervention in Limpopo, South Africa. *Educational Research for Social Change, 10 (1),* 33-51. doi:http://dx.doi.org/10.17159/2221-4070/2021/v10i1a3

Thorsteinsson, G., & Olafsson, B. (2017). Examining Teaching Practices in Design and Craft Education in Iceland. *Design and Technology Education, 22*(2), 83-103.

Tlali, N., Mukurunge, T., & Bhila, T. (2019). Examining the implications of massification of education on quality assurance and assessment in higher institutions in Lesotho. *Int J Trend Scic Res Develop, 3*(3), 1561-1568.

Tomblin, D., & Mogul, N. (2020). STS postures: responsible innovation and research in undergraduate STEM education. *Journal of Responsible Innovation, 7*(sup1), 117-127.

Tomei, L. A., & Nelson, D. (2019). The Impact of Online Teaching on Faculty Load–Revisited: Computing the Ideal Class Size for Traditional, Online, And Hybrid Courses. *International Journal of Online Pedagogy and Course Design (IJOPCD), 9*(3), 1-12.

Trist, E. L. (1978). On Socio-Technical systems. In J. Passmore & J. Sherwood (Eds.), *Sociotechnical systems: A sourcebook.* California: University Associates, LaJolla. 43-57.

Tynjälä, P., Pennanen, M., Markkanen, I., & Heikkinen, H. L. (2021). Finnish model of peer-group mentoring: review of research. *Annals of the New York Academy of Sciences, 1483*(1), 208-223.

Ueshiba, K., & Ueshiba, M. (1985). *Aikido*. Tokyo: Hozansha Publications

Valve, H., & McNally, R. (2013). Articulating scientific practice with PROTEE: STS, loyalties, and the limits of reflexivity. *Science, Technology, & Human Values, 3* (4), 470-491.

Van der Zwaan, A. (1975). The sociotechnical systems approach: A critical evaluation. *The International Journal of Production Research, 13*(2), 149-163.

van Dijk, E. E., van Tartwijk, J., van der Schaaf, M. F., & Kluijtmans, M. (2020). What makes an expert university teacher? A systematic review and synthesis of frameworks for teacher expertise in higher education. Educational Research Review, 31, 100-365.

Van Oudheusden, M. (2014). Where are the politics in responsible innovation? European governance, technology assessments, and beyond. *Journal of Responsible Innovation, 1*(1), 67-86.

Vartiainen, H., & Tedre, M. (2023). Using artificial intelligence in craft education: crafting with text-to-image generative models. *Digital Creativity, 34*(1), 1-21.

Voogt, J., Fisser, P., Pareja Roblin, N., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge–a review of the literature. *Journal of computer assisted learning, 29*(2), 109-121.

Vratulis, V., Clarke, T., Hoban, G., & Erickson, G. (2011). Additive and disruptive pedagogies: The use of slowmation as an example of digital technology implementation. *Teaching and Teacher Education, 27*(8), 1179-1188.

Wan, A., & Ivy, J. (2021). Providing access by integrating computer aided design in mathematics teacher education courses. *Journal of Digital Learning in Teacher Education, 37*(4), 234-246. doi:https://doi.org/10.1080/21532974.2021.1965506

Whitehead, J. (2018). *Living theory research as a way of life*: Brown Dog Books.

Whitehead, J., & McNiff, J. (2006). *Action research: Living theory*: Sage.

Willcocks, L., & Mason, D. (1987). Computerising work. *Paradigm, London.*

Williams, P. J. (2017). Critique as a disposition *Critique in design and technology education* Springer. 135-152.

Williams, P. J., Jones, A., & Buntting, C. (2015). *The future of technology education*: Springer.

Williams, P. J., Stables, K., De Vries, M. J., Petrina, S., Spendlove, D., Gumbo, M. T., . . . Ginestié, J. (2017). *Critique in design and technology education*: Springer.

Wood, L. (2014). Action research for the 21st century: Exploring new educational pathways. *South African journal of education, 28*(2), 662-674. doi: https://doi.org/10.20853/28-2-351

World Bank. (2016). *World Development Report 2016: Digital dividends*. New York. Retrieved from https://openknowledge.worldbank.org/.

Yeh, Y. F., Hsu, Y. S., Wu, H. K., Hwang, F. K., & Lin, T. C. (2014). Developing and validating technological pedagogical content knowledge-practical (TPACK-practical) through the D elphi survey technique. *British Journal of Educational Technology, 45*(4), 707-722.

Yurkofsky, M. M., Peterson, A. J., Mehta, J. D., Horwitz-Willis, R., & Frumin, K. M. (2020). Research on continuous improvement: Exploring the complexities of managing educational change. *Review of Research in Education, 44*(1), 403-433.

Zuber-Skerritt, O. (1992). Professional development in higher education: A theoretical framework for action research: Routledge.

Zuber-Skerritt, O. (2018). An educational framework for participatory action learning and action research (PALAR). *Educational Action Research, 26*(4), 513-532.

Zuber-Skerritt, O., Wood, L., & Dick, B. (2013). Action research for sustainable development in a turbulent world: Reflections and future perspectives. *ALAR: Action Learning and Action Research Journal, 18*(2), 184-203.

Zuber-Skerritt, O., & Fletcher, M. (2007). The quality of an action research thesis in the social sciences. *Quality Assurance in Education, 15*(4), 413-436. doi:10.1108/09684880710829983

Endnotes

[i] CASME – Centre for Advancement of Science and Mathematics Education, Pinetown, KwaZulu-Natal.

[ii] Source: Excel database of literature generated from EndNote references and notes (Appendix 43)

[iii] At the time of writing, the first foundation phase robotics and coding module CORO306, including CAD, was being finalised for release in 2024.

[iv] Department of Basic Education, South Africa, History of Coding and Robotics: DBE and partners' workshop Coding and Robotics Curriculum for the GET Band (education.gov.za)

[vi] The Council for Higher Education (CHE) is an independent statutory body as provided for by Section 4 of the Higher Education Act (Act No. 101 of 1997). It functions as the Quality Council for Higher Education in terms of the National Qualifications Framework Act (Act No 67 of 2008). The CHE promotes access to higher education for all, through research, policy review, reporting, national conferences and debates; and advises key stakeholders on quality assurance in higher education, and accreditation of programmes of higher education.

[vii] Gauteng is one of South Africa's nine (9) provinces; and is considered the commercial hub of the country as it has Johannesburg as its largest city (also the largest city in the country).

[viii] In this thesis, for participants' names I use pseudonyms. I critically reflect on the limits to anonymity later in the chapter, particularly as this is a CPAR of my own institution; the likelihood is high that people might be recognisable from their roles in the ICT and CAD courses and in this study.

[ix] DBE Curriculum and Assessment Policy Statement Grade 4-6 Coding and Robotics: Grades 4-6 Coding and Robotics Draft CAPS FINAL 19 March 2021.pdf (education.gov.za)

[x] CPT101 became a year-long module for HC students in 2020. It was renamed CPT100. The CPT101 semester module was migrated to the PGCE programme for graduates with no prior ICT qualification.

[xii] European Digital Education Hub facilitates online sharing of good practice, peer learning, and collaboration across training and education sectors, including practitioners from outside the European Union. Source: Digital education's collaborative community of practice - European Education Area (europa.eu)

[xiv] Kemmis (2014. p. 187) recommends acknowledging participants, with their permission, in a thesis, while using coding to retain anonymity in published articles. The underlining premise is that acknowledgement should be discussed not assumed.