

Teachers' Beliefs about the Use of Information and Communication Technology Simulations as a Form of Inquiry-Based Science Teaching

by

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ABSTRACT

This study examined teachers' beliefs regarding Inquiry-Based Science Teaching (IBST) and Information and Communication Technology (ICT) simulations, emphasizing the impact of these beliefs on teaching strategies in environments with limited resources. The literature recognizes IBST as a novel educational framework rooted in constructivist principles, fostering critical thinking, scientific understanding, and learner autonomy. ICT simulations are becoming more acknowledged as supportive tools in enhancing IBST by allowing dynamic, interactive, and inquiry-based exploration of scientific ideas. Nevertheless, in spite of these progressions, science teachers have faced significant systemic and personal barriers, such as rigid curricula, inadequate or even lack of technological infrastructure, and limited professional growth opportunities. This research seeks to address three critical questions: What are science teachers' beliefs about IBST and ICT simulations? How do science teachers' beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations? Why do science teachers' beliefs about the use of ICT simulations as a form of IBST influence their teaching in the manner that they do? Employing a qualitative interpretivist approach, the study gathered information from five purposively selected science teachers in Mozambique through semi-structured interviews, classroom observations, and document analysis. The generated data were analyzed using thematic and content analysis methods to uncover patterns and connections between beliefs, systemic barriers, and teaching practices. Results revealed that teachers' beliefs exist on a spectrum, influenced by systemic, cultural, and individual factors rather than falling neatly into 'traditional' or 'constructivist' categories. Teachers with formal ICT training demonstrated a higher alignment between constructivist beliefs and the integration of ICT simulations, fostering learner-centered inquiry and exploration. However, systemic barriers such as large class sizes, unreliable technology, and rigid curriculum frameworks often compelled teachers to adopt hybrid approaches, combining inquiry with teacher-directed instruction to navigate these constraints. These findings revealed the need for targeted professional development and systemic reforms to address the 'belief-practice gap' observed among science teachers. Tailored training programs that enhance teachers' technological pedagogical content knowledge (TPACK) and reflective practices are essential for equipping teachers to integrate ICT simulations effectively.

Additionally, the study highlighted the importance of flexible curriculum policies, equitable access to technological resources, and collaborative professional learning communities in fostering sustainable adoption of IBST. The implications reach beyond Mozambique context, providing significant perspectives for policymakers, curriculum designers, and educators worldwide, especially in resource-limited environments. This research helped advance inquiry-based, technology-enhanced science education by connecting teachers' constructivist goals with the practical realities of their teaching settings, preparing learners for the evolving demands of the 21st century.

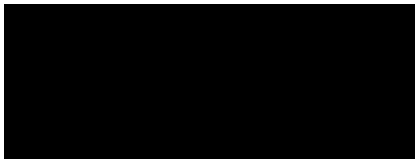
Keywords: Inquiry-Based Science Teaching (IBST), ICT simulations, Science Teachers' Beliefs, Mozambican Science Education, Qualitative Research, Technology Integration

DECLARATION

The research presented in this thesis was conducted in Mozambique as part of the academic requirements of the School of Education, Science, and Technology Education Cluster at the University of KwaZulu-Natal, under the supervision of Professor Nadaraj Govender. Ethical clearance for the study was obtained from the University of KwaZulu-Natal Research Office, with the Ethics Clearance Protocol Reference number HSSREC/00003719/2021.

This thesis is an original work by the author, except where explicitly stated otherwise. It has not been submitted, in whole or in part, for any other qualification at any tertiary institution. Contributions from other sources have been duly acknowledged throughout the text.

Signed



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LIST OF ACRONYMS

AR Augmented Reality

BIUT Beliefs Impacting the Usage of Technology

IBST Inquiry-Based Science Teaching

ICT Integration Information and Communication Technology Integration

ICTs Information and Communication Technologies

PD Professional Development

STEM Science, Technology, Engineering and Maths

TAM Technology Acceptance Model

TPACK Technological Pedagogical Content Knowledge

VR Virtual Reality

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CHAPTER 1

1.1 Introduction

In the science educational field, teacher practices and approaches have generally adopted a traditional approach, which puts emphasis on teacher explanations and learners' repetitive practice, as well as the constructivist approach that is regarded as an aspiring way of teaching and learning science as learners do not just passively take in information. The main focus of the constructivist approach is on the learners; it stimulates and enables learners to conduct their investigations. Teachers who rely more on traditional beliefs are more obliged to view teaching as a process of relaying knowledge to the learners and they tend to control the entire classroom environment right up to the learners' behaviour. The teachers in this scenario tend to act as the maximum authority in the classroom to assess the learners' learning outcomes. Education has shifted from the traditional, passive lecture teaching style to a more active learner-centered learning in which learners must self-regulate and manage their learning. There are several styles of active learner-centered science learning. Examples include inquiry-based learning, project-based learning, and discovery learning. As a result, Fullan (2013) coined the term "new pedagogy," which shifted the fundamental role of education from instructors to learning partners. According to Fullan (2013), this new approach to teaching and learning has the potential to be transformative due to technological advancements.

Studies of teachers' beliefs mostly describe these pedagogical beliefs as either constructivist or traditional. The constructivist teachers' beliefs are identified by their child-centeredness, with constructivism as their main theoretical foundation. The traditional teachers' beliefs, on the other hand, are characterized by teacher-centeredness, with their theoretical grounding being more linked with behaviorism (Chan & Elliott, 2004).

Evidence indicates that teachers with constructivist beliefs have incorporated Information and Communication Technology (ICT) as an aspect of technology in their classrooms (Fernandes et al., 2019). Researchers have also suggested that if any wants to see a change regarding teachers' technology use, there is a need to change the underlying teachers' pedagogical beliefs

that support and facilitate that practice (Huang et al., 2017; Tondeur et al., 2017). There has also recently been a growing trend in science teaching to incorporate Inquiry-Based Science Teaching (IBST) into science teaching. Although there are many definitions of IBST, the researcher will define IBST as a pedagogical tool that engages learners in investigating and questioning real-world problems and making action plans (Yesudhas et al., 2014). Yesudhas et al. (2014) say that IBST gives learners more freedom, and they benefit more in terms of deep concept learning and understanding through increased learner engagement as opposed to traditional teaching approaches.

As ICT simulation can play a significant role in the constructivist view of learning where IBST environments of learning are involved, there is a need for a deeper understanding of how teachers' beliefs impact their use in this environment (Hultén & Björkholm, 2016; Tondeur et al., 2017). Simulations, as a component of ICTs, can be an essential tool for helping high school learners enhance their knowledge. However, studies on using simulations in an IBST environment are still limited.

1.2 Background

The 21st century has been characterized by an increase in the use of technology in people's daily lives, especially in the education sector. Incorporating technology into the classroom is seen as a critical method for improving the effectiveness of the teaching and learning process (Apostolou & Koulaidis, 2010; Areepattamannil, 2012; Howard et al., 2000; Mirzajani et al., 2016). Some researchers believe ICT simulation can help learners understand complex concepts and foster cooperative learning in specific science content (Plass et al., 2012; Sarabando et al., 2014). However, it is also true that science teachers face some challenges in integrating ICT simulations within their teaching content in classrooms, as the use of simulations in teaching and learning requires a new, modified, or upgraded set of skills, attitudes, and development that align with this novel pedagogical approach (Mathevula & Uwizeyimana, 2014). However, science-inquiry teaching is lacking in many classrooms and needs to be implemented (Maigari Mohammed et al., 2020; Mugabo, 2012; Ssempala, 2017). The impact of numerous contextual and demographic factors on teachers' adoption and frequency of inquiry teaching has been studied all over the world in an attempt to explain and predict teachers' adoption and frequency of inquiry teaching (Ramnarain, 2016; Ramnarain & Hlatswayo, 2018; Tang et al., 2020). Some factors have proven to hinder inquiry teaching in some circumstances, but they have also had no effect in other circumstances.

IBST, with the aid of technology through interactive simulations, can promote at least three learning outcomes, as proven by evidence from research. IBST with simulations can promote learners' conceptual understanding (Thacker & Sinatra, 2019). According to Chiu et al. (2015), it can enhance learners' general inquiry skills and promote their science epistemic beliefs (Huang et al., 2017). Researchers also agree that learners using technology in their classes tend to make significant conceptual gains and integrate knowledge better than those relying solely on textbook use (Zacharia & Anderson, 2003). Although virtual educational environments can support highly interactive inquiry activities and are beginning to be used to deliver inquiry-based science curricula, several factors must be addressed to maximize their effectiveness (Albugarni & Ahmed, 2015; Thisgaard & Makransky, 2017). For example, implementing simulation

activities in a classroom can change the long-standing role of a teacher from being a transmitter of information to becoming a facilitator.

There is a traditional discussion among researchers and teachers concerning the relationship between teachers' beliefs and their instructional practices, with some arguing that beliefs strongly influence how teachers approach teaching, while others suggest contextual factors and external constraints may play a more significant role in shaping those practices (Levitt, 2002). When studying teachers' pedagogical practices, many researchers have realized the importance of their educational beliefs (Saadati et al., 2019; Stipek et al., 2001). Mumtaz (2000) emphasizes the role of teachers' beliefs in teaching and learning using ICT or their pedagogical-technological beliefs as a critical factor affecting the extent to which ICT simulation is integrated into their teaching practices in a classroom. Science teachers face several challenges that influence the implementation of ICT simulations in their classrooms. They may also encounter barriers that also hinder ICT simulation integration. Such barriers to ICT simulation integration are defined as "existing conditions that render the successful implementation of ICT in educational settings difficult to achieve" (Makki et al., 2018, p. 51). Several studies concluded that teachers' beliefs concerning ICT use within the classroom are among the most substantial barriers to ICT simulation integration (Blackwell et al., 2013; Ertmer et al., 2012; Shifflet & Weilbacher, 2015). (Ertmer et al., 2012) postulate that teachers' beliefs might impact their ability to overcome different barriers due to the relative weight on each barrier.

Despite overwhelming support for IBST to improve learner learning, contextual constraints that inhibit teachers from implementing IBST continue to cause divergence (Ramnarain & Hlatwayo, 2018). Researchers look at these difficulties from a technical, social, cultural, and political standpoint (Anderson, 2007; Wang & Zhao, 2016). The successful application of IBST is laden with obstacles in several countries, particularly South Africa. Obstacles to successful implementation include a need for laboratories, resources, teacher training, instructional materials, time to complete the curriculum, and manageable class sizes. These obstacles create uncertainty in teachers' motivation to implement inquiry (Ramnarain & Hlatwayo, 2018). In addition, teachers' limited understanding of scientific knowledge and beliefs about inquiry conceptions limit the implementation of IBST (Osborne, 2014; Wang & Zhao, 2016).

Although using digital technologies and tools offer potential affordances for more effective and efficient inquiry-based pedagogy in science classrooms, technical concerns such as limited/unavailable internet services and access to technology may hinder teachers' inquiry practice (Williams et al., 2017). Factors such as teachers' pedagogical content knowledge, personal characteristics, and beliefs about IBST must be considered in order to assist them develop and upgrade their beliefs about IBST (Council, 2000). While the elements that impact teachers' practices are complex and numerous, Harwood et al. (2006) and Harwood, Hansen, and Lotter et al. (2018) claim that teachers' beliefs have been found to influence their teaching practices, how they feel the pedagogical content should be delivered, and how they believe learners learn. As a result, whether teachers aim to carry out the practice of teaching science as inquiry is more likely to be influenced by their beliefs (Crawford, 2014). Teachers' beliefs about classroom management, teaching, and learning, according to Saad and BouJaoude (2012), are one of the biggest challenges to integrating inquiry approaches in science classrooms. Outside of South Africa, research has explored the correlation between teacher beliefs about inquiry-based approach and their teaching practices. Studies have shown that teachers' inquiry practices have been linked to their beliefs about inquiry. Haney et al. (1996) unearthed that teachers' beliefs significantly predicted their intentions to apply a reform-based pedagogy like IBST. While there is a positive attitude toward inquiry-based teaching and learning, there are significant differences in implementing inquiry-based teaching and learning methodologies in classrooms (Dorier & Maab, 2012).

The relationship between teachers' beliefs of IBST practice, technology adoption, and effective integration and how these beliefs influence the inquiry practice in the classroom is not clearly understood, particularly in Physical Sciences. Recent studies have concluded that teachers' classroom practices are highly influenced by their pedagogical beliefs (Peck & Herriot, 2014). Based on the results of previous studies (Ertmer, 2005; Hermans et al., 2008; Lin & Wang, 2012; Zhao & Frank, 2003), science teachers choose ICTs that align directly with their pedagogical teaching approaches and also align with their existing beliefs about which appropriate teaching methods to adopt. While resources such as technological devices, computers, tablets, or interactive whiteboards are necessary tools, they do not dictate one's pedagogical approach (Pellegrino et al., 2007); instead, each device enables the integration of a range of approaches to teaching and learning (Tondeur et al., 2012).

1.3 Motivation and Rationale

Science teachers employ direct rather than inquiry-based approaches when teaching science. Even when they involve learners in hands-on activities, it usually promotes conceptual comprehension or the acquisition of skills such as classifying items or making precise recordings and measurements. Teachers must be able to arrange, organize, and implement inquiry-based activities that facilitate learners' grasp of the intended information. Engaging learners in classroom inquiry-based learning does not guarantee the fulfilment of the above-listed aims (Harris & Rooks, 2010; Kock et al., 2015). IBST provides a suitable framework for increasing learners' general cognitive skills and grasp of science epistemology, in addition to promoting conceptual understanding and science process skills, a viewpoint shared by several academics (Alake-Tuenter et al., 2012; Kock et al., 2015). Harris and Rooks (2010) assert that an IBST approach integrates scientific knowledge and processes so that their interdependence is shown. Furthermore, research shows that IBST improves learners' academic progress in science and helps them build general thinking skills (Bybee, 2009). These potential IBST benefits align to cultivate a society with the learning, thinking, creative, and inventive skills that a knowledge-based society requires.

Abbitt (2011) investigated the connection between science teachers' knowledge, the use of technology, and their beliefs in the use of technology in teaching. He concluded that improving teachers' knowledge regarding teaching with technology may result in increased belief in their ability and confidence to teach more efficiently using technology. While most teachers are confident about teaching content, choosing the correct approach to deliver the content, and even selecting suitable ICT tools, the challenge lies in merging all three elements to teach effectively (Juggernath, 2017; Koehler et al., 2013). The beliefs also held by teachers influence their perceptions and judgement, which affects their choices of teaching strategies and their behavior in the classroom (Pajares, 1992). Both ICT efficacy and teachers' beliefs have influenced teachers' teaching practices. However, more studies are needed now that we have advanced technology resources, especially on using simulations, how they believe the content

should be taught, and how they think learners learn via ICT simulations. Three variables impact and develop beliefs: value judgment, reality judgement, and action judgement. Value judgments, such as those based on views about the importance of the teacher's position and ideas about the nature of education, impact on how teachers use ICTs in the classroom most. However, reality and action judgments are also influential to some extent. A study conducted by Juggernath and Govender (2020) concluded that in regards to ICT simulation use in schools, there is still a need for consistent assistance in fostering positive ICT simulation -related teacher beliefs, as well as more research into the inherent hurdles that arise in technology-rich environments (Juggernath & Govender, 2020).

Teachers' beliefs are a complicated phenomenon that is difficult to observe or define (Österholm, 2010). De Vries et al. (2014) state that knowledge and belief are closely linked: knowledge is the cognitive result of thought. It is schematically organized, whereas belief is the affective outcome with components of evaluation and judgment and a solid cognitive component. As a result, belief is seen as a "kind of knowing" (Pajares, 1992, p. 310). "The beliefs instructors have influence their perceptions and judgments, which, in turn, affect their behavior in the classroom" Pajares (1992, p. 307). He further points out that a teacher's actions can either strengthen or diminish the learner's basic ideas. As a result, the ideas and beliefs of teachers will have a significant influence on learners. To meet education challenges in South Africa, teachers must continually adapt and develop themselves professionally (Darling-Hammond et al., 2017; Steyn, 2008). They further say that teachers face new challenges that ICT integration poses when teaching from a constructivist framework using the IBST approach. Hence, it is essential to identify the factors behind teachers' decisions when integrating simulations (or not integrating them) in their classes. Ertmer (2005) points out that one of the factors might be the conflict between teachers' fundamental beliefs about simulation integration and the possibility of changing these beliefs.

Professional experience in physics education has provided exposure to various curricula and involvement in curriculum changes in countries such as Mozambique and South Africa. Observations of science education practices across various schools indicate that traditional teaching methods remain widely preferred among science teachers despite the increasing prominence of ICT simulation and modern pedagogies. Throughout my career, the researcher has

observed that despite the availability of technology, many science teachers still rely on traditional teaching methods, often due to their pedagogical beliefs and confidence in using ICT tools effectively. Witnessing how teachers adapted or struggled to adapt to these technological changes sparked my curiosity about the factors influencing their instructional decisions. I became particularly interested in how teachers' beliefs shape their willingness to incorporate interactive simulations as part of IBST, and how these beliefs could either facilitate or hinder the integration of ICT simulation in science classrooms. At the moment, amid the COVID-19 pandemic, where conventional face-to-face learning came to a halt at one-point, virtual laboratories have gained substantial popularity in science education. In this scenario, virtual laboratories are an effective tool that science teachers worldwide have used (Wen et al., 2020). First-hand observations of changes in how school teachers engage with learners and adapt to new technologies and teaching methods highlight the significance of teachers' beliefs in shaping their instructional approaches. There is a need to explore teachers' beliefs regarding IBST using interactive ICT simulation and how these beliefs influence their teaching practices. Studies have found that teachers' beliefs impact the successful implementation of technology in schools (Hennessy et al., 2005). However, the relationship between teachers' beliefs and technology use has not yet been thoroughly investigated on a qualitative basis, and the lack of research in this area significantly affects education programs. This study analyzed the relationship between science teachers' beliefs about using ICT simulations and the IBST approach.

1.4 Research Questions

The purpose of this study is to investigate teachers' beliefs regarding the integration of Information and Communication Technology (ICT) simulations within Inquiry-Based Science Teaching (IBST). It will also explore how these beliefs are related to teacher pedagogical teaching activities through various factors teachers consider when deciding whether to integrate technology into their pedagogy. These three areas of interest will guide this research, and it will be translated into the following specific research questions:

Research Question 1

What are science teachers' beliefs about IBST and ICT simulations?

Research Question 2

How do science teachers' beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations?

Research Question 3

Why do science teachers' beliefs about the use of ICT simulations as a form of IBST influence their teaching in the manner that they do?

This study, grounded in the pragmatism paradigm, adopted a multiple-case study design to investigate science teachers' beliefs about IBST and ICT simulations. The multiple-case study approach, which explores how individuals in a specific context make meaning of a phenomenon, was used to gather both numerical and textual data to address the research questions (Yin, 2018). This method was selected to provide a deeper understanding of teachers' behaviors and decision-making processes regarding the integration of ICT simulations in their teaching.

1.5 Significance

Taking into consideration the importance of understanding how intrinsic and extrinsic factors have been demonstrated to influence teachers' uses of technology including knowledge (Koehler et al., 2013), attitudes (Holden & Rada, 2011), and pedagogical beliefs (Ertmer, 2005), this study focused on the role of teachers' pedagogical beliefs on the use of interactive simulations as a form of IBST as these beliefs are one of the strongest predictors of teachers' technology use (Inan & Lowther, 2010). Hew and Brush (2007) have identified teachers' beliefs as barriers to using technology for instruction. Problems may surface when teachers' beliefs are ignored, as Cuban (2009) asserts that teachers' beliefs and values influence the choices they make in the classroom. Cuban (2009) further argues that beliefs influence how teachers choose to teach and what innovations they endorse or reject. Studies on high school teachers' beliefs in using ICT simulations as a form of IBST have not been conducted in Mozambique and are also limited worldwide. Context can also significantly impact teachers' beliefs (Altinsoy & Zuhail, 2017). In a review of the literature on the relationships between teachers' use of ICT and their pedagogical beliefs, Tondeur et al. (2017) highlight the significance of context-related factors,

such as a lack of time, curriculum, assessment, and professional learning and development, in forming teachers' beliefs and their practices: The relationship between teacher beliefs and educational innovations, such as ICT simulation integration, is complex, and therefore any outcomes from an identified context will be complex to generalize to all teachers.

Therefore, the present study's significance includes several beneficial aspects. Science teachers who had an opportunity to participate in the study gained much knowledge about their own beliefs about the use of ICT simulations and IBST. This study also gave teachers the chance to think critically about IBST, which would have improved their comprehension of IBST, self-assurance, and use of this pedagogical strategy in their future instruction. The design and execution of programs for enhancing IBST and the use of ICT simulations amongst science teachers are influenced by teachers' beliefs. Science teachers will hopefully continue using ICT simulations as an inquiry approach. Addressing the issue of science teachers' beliefs regarding the use of ICT simulations in IBST is crucial for building a community of teachers who are confident and skilled in integrating technology into their teaching practices. By identifying the barriers and enablers of ICT simulation adoption, this study expands the science education research field to science teachers and provides valuable insights that can inform professional development programs designed to meet the needs of science teachers. Furthermore, by equipping teachers with strategies to integrate technology meaningfully, this research supports the development of a more innovative and adaptive science education community, prepared to meet the demands of 21st-century learning environments.

1.6 Overview of Chapters

This research is organized in nine chapters. The current chapter introduced the study, presented the research goals, providing a summary of its context, justification, and the key research questions. It outlined the importance of the research in addressing the challenges faced by science teachers in integrating IBST and ICT simulations as well as how these teaching strategies could enhance learner engagement and critical reasoning.

Chapter 2 examined the relevant literature, beginning with the theoretical foundations of constructivism and its use in IBST. It investigated science teachers' beliefs on ICT simulations and their impact on teaching methods in the classroom. The chapter recognized barriers to ICT

integration, including infrastructural limitations and inflexible curricula, and emphasized the significance of professional development to address these challenges.

Chapter 3 focused on the conceptual framework employed in the research, integrating the Vickers Framework in examining teachers' beliefs, values, and decision-making, the Hew and Brush Framework for identifying barriers to ICT adoption, and the Beliefs Impacting the Use of Technology (BIUT) Framework. This chapter also presents the Extended BIUT Framework, integrating personal teacher beliefs with systemic elements for a comprehensive view.

Chapter 4 outlined the research methodology, introducing the qualitative interpretivist approach used for this investigation. It also outlined the research design, sampling approach, and methods for data generation, which consisted of interviews, observations in classrooms, and analysis of documents. Ethical considerations, reliability, and data analysis methods, such as thematic and content analysis, are also discussed.

Chapter 5 presented the findings from the interviews, offering insights into teachers' beliefs about IBST and ICT simulations. The chapter discusses the differences in these beliefs and their impact on teaching practices, highlighting the influence of training, professional development, and contextual factors.

Chapter 6 analyzed the data from classroom observations, examining how teachers' beliefs align with their implemented practices. The chapter emphasized the interplay between aspirational goals and practical realities, showing examples of hybrid teaching approaches combining inquiry and teacher-led instruction.

Chapter 7 examined how teachers' beliefs influence their use of IBST and ICT simulations. It explored how systemic barriers, curriculum constraints and resource limitations, influence teaching methods, providing a comparative analysis of teachers' pedagogical techniques.

Chapter 8 consolidated the results, examining the implications of teachers' beliefs, systemic barriers, and professional development for IBST and ICT integration. It provided perspectives on aligning teachers' beliefs with institutional goals to foster inquiry-based, technology-enhanced education.

Chapter 9 summed the study by summarizing important findings and addressing the research questions. It addressed the theoretical, practical, and policy implications, as well as limitations and suggestions for future studies. The chapter highlighted the necessity for comprehensive reforms and customized professional development to bridge the gap between teachers' beliefs and their teaching practices.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Chapter 2 provides a comprehensive review of the theoretical and empirical foundations underpinning this research, beginning with an exploration of constructivist learning theories that inform IBST. Rooted in the constructivist theory, the researcher adopts the theoretical perspective that learners actively build knowledge through engagement and critical inquiry, IBST emphasizes active participation, experimentation, and evidence-based reasoning to foster scientific literacy and deeper understanding (Amineh & Asl, 2015). This section focuses on how IBST aligns with constructivist principles, offering a pedagogical framework that not only engages learners but also promotes analytical skills and a collaborative learning environment. The chapter also investigates science teachers' pedagogical and epistemological beliefs, particularly regarding the integration of ICT simulations in IBST contexts. These beliefs are shown to exist on a spectrum, shaped by cultural, systemic, and personal factors, rather than adhering to traditional or constructivist categories (Tondeur, 2020).

To address the research questions, the study used the conceptual frameworks outlined in Chapter 3, which provide a comprehensive lens for understanding the relationships among systemic constraints, professional development, and teachers' beliefs. These frameworks delve into the multifaceted nature of challenges faced in integrating ICT simulations into IBST, such as infrastructure limitations and the rigidity of standardized curricula. By examining these barriers, the frameworks also propose practical strategies, including targeted professional development to enhance teachers' technological and pedagogical competencies, as well as equitable allocation of resources to create a supportive environment enabling the successful implementation of IBST practices enriched by ICT simulations, bridging the gap between theoretical potential and practical application.

2.2 Constructivism

In constructivist learning environments, predetermined answers are not required. Conversely, these environments permit learners to construct mental models of natural phenomena. Learners can select their preferred mode of information display on the computer monitor by employing a constructivist approach and utilizing a carefully crafted simulation. The process enables individuals to formulate hypotheses that align with their problem-solving approach. The fact that instructional approaches incorporating prescriptive methods still hold value and must be addressed. Engaging in unguided inquiry, particularly when utilizing ICT simulations, can result in a futile exercise for the learner.

Cirik et al. (2015) define constructivism as a learner-centered learning approach in which knowledge is subjectively constructed, construed, and reorganized by the learners. In other words, constructivism proposes that learners actively construct their understanding and knowledge through personal experiences; it prioritizes active learner participation in the knowledge construction process over passive listening. Thakur (2014) emphasizes that learners construct knowledge individually, drawing on their prior experiences. Collaborative construction with peers is another viable option. Therefore, learners actively construct their knowledge through experiences and interactions with the environment; Singh and Yaduvanshi (2015) argue that constructivism emphasizes the construction of knowledge rather than reproduction. Therefore, the constructivist learning model successfully provides meaningful learning experiences to children in the science classroom (Singh & Yaduvanshi, 2015). The constructivist approach benefits learners with more advanced motivations to comprehend the subject matter. Nevertheless, the unstructured characteristics of constructivist learning environments could also trigger frustration among them.

Utilizing a constructivist learning environment has been deemed beneficial in promoting learner engagement during educational pursuits. The learners are aided in constructing knowledge through its use. The acquisition of constructivist knowledge results from internal processes, and it is impossible to access external factors (Schunk & DiBenedetto, 2016). According to Boghossian (2006), knowledge and ideas are constructed internally by each mind, leading to variations in knowledge between individuals. He posits that one's viewpoint moulds

one's comprehension of the world. Wood (2010), emphasized that a person's pre-existing knowledge forms a schema for understanding internal phenomena. He further explained that the conflict between pre-existing knowledge and new knowledge exists in the schema. Since the children had gone through various stages of cognitive development, they were in equilibrium. A balanced form of conflicting knowledge is achieved by schema.

According to Kalina and Powell (2009), constructivism is categorized into two distinct sections: individual or cognitive and social. Therefore, the individual and the group can construct knowledge through constructivism. A cognitive psychologist, Piaget focuses on individual learners' efforts to comprehend their experiences. Piaget's perspective on learning emphasizes that the adaptive process involves assimilation and accommodation. The view is supported by Amineh and Asl (2015), Cakir (2008), and Kanselaar (2002). Thus, according to Sexton (2020) learners are active agents in constructing their understanding by integrating prior knowledge with new experiences. The process of assimilation involves integrating new experiences into a pre-existing framework (Cakir, 2008; Ültanir, 2012). Thus, a constructivist approach can enhance the learning experience by promoting learner-centered and interactive learning. Constructivist teaching is very challenging. Many teachers favor adopting constructivist instructional approaches; however, finding the starting point can be challenging (Gilakjani et al., 2013).

Piaget's theory of individual constructivism highlights how individuals cognitively construct their knowledge independently. This method is commonly referred to as an autonomous or individual learning approach. Vygotsky (1987) social interaction theory is also where social constructivism is uncovered. Vygotsky (1987) emphasizes the crucial impact of language and culture on an individual's cognitive development and construction of meaning. According to Amineh and Asl (2015), knowledge assimilation and implementation by individuals occur after it is first constructed in a social context. Therefore, social-cultural constructivists consider learning a collaborative and interactive process between individuals and their environment. According to its belief, the primary interaction elements, are language and society. The collaborative approach is widely recognized as the group work methodology within academic institutions.

Honebein (1996) categorized seven pedagogical goals of constructivist learning environments:

Cultivating learners' ability to construct knowledge by building upon their existing knowledge and promoting self-determination. Rewarding the exploration of alternative solutions by valuing diverse experiences and perspectives. Enhancing the learning process with authentic experiences through the incorporation of real-life assignments. Preserving learners' right to express their ideas during learner-centered learning. Incorporating education into collaborative group work using the collaborative method. Employing diverse media such as pictures, audio, and video enriches the learning experience. Helping learners understand the knowledge construction process through meta-cognition and reflection.(p. 96).

Researchers have investigated topics similar to those approached through constructivism. According to Tuwoso (2016), implementing a constructivist approach or learner-centered teaching leads to higher average learning outcomes among learners compared to a control group using teacher-centered methods. Ongowo et al. (2015) investigated teachers' perceptions of a genuine and preferred constructivist learning environment. According to Amineh and Asl (2015), a person's potential intellectual level is determined by their achievements under adult guidance or in collaboration with others. Therefore, social constructivists consider guided social interactions such as conversations, discussions, collaborations, and debates essential for learning.

Honebein (1996) highlighted several advantages of the constructivist learning environment. In the classroom, learners engage actively in participation. Their learning capacity learning also continuously expands. Optimal learning outcomes can also be achieved by prioritizing understanding and thinking processes over memorization. The constructivist approach emphasizes the cognitive processes of learners and how they can comprehend and reason. The constructivist learning approach enables learners to create principles they can implement in the classroom and beyond, as they are transferable characteristics. When learners autonomously conduct inquiries, explorations, and self-assessments, the knowledge they acquire during their studies will be ingrained in their memory for a long time.

A possible modification to the advantages discussed incorporates that in a constructivist classroom, learners can use various ways to assess their learning, such as creating physical models, writing research reports, making artistic representations, and keeping journals. These forms involve the ideas and personal investments of the learners. Engaging learners' creative instincts can enhance their ability to elaborate knowledge through various methods. Furthermore, the practical application of the newly acquired knowledge by learners in real-life scenarios will also be executed. Constructivism entails active learner participation in the learning process through an authentic and context-based instructional design. To clarify, learners can formulate inquiries and apply them in practical situations.

Moreover, learners can develop social skills through constructivism, enabling them to collaborate with peers in group projects and collectively find solutions while exchanging ideas. The training program includes participating in group discussions and enhancing communication skills. Engaging in a communal setting enables learners to establish social bonds and affiliations with their peers, ultimately fostering a feeling of inclusion and assistance.

2.2.1 Social Constructivism

Social Constructivism theory highlights the importance of culture and social environment for cognitive growth. Brown (2005) states that the construction of cognitive tools required for human growth occurs when individuals are engaged in shared practices. Knowledge acquisition of knowledge transforms into a predominantly cultural immersion process within a group with the same professional activities. Social factors and interpersonal exchanges facilitate developing and transmitting a common understanding among group members. Lev Vygotsky, the Russian-Soviet psychologist, was among the principal advocates of Social Constructivism. Timotheou et al. (2023) contested Jean Piaget's perspective, which emphasized cognitive growth as a solitary procedure rather than a collective endeavor. Vygotsky and Cole (1978) cognitive development ideas recognized the role of individual psychology and emphasized the importance of external factors intertwined with one's internal world.

In contrast, Piaget's theoretical framework was predominantly focused on the field of personal psychology. External influences play a critical role in molding human perspectives of the world. The process entails exposure to language and subsequent introspection prompted by

such exposure. According to Vygotsky (1987), learning cannot be fully comprehended by solely focusing on individual learning, as social interaction also plays a crucial role. The main emphasis of his research is on how social constructivism influences the acquisition and progression of language. The Zone of Proximal Development (ZPD) is arguably Vygotsky's most acclaimed idea. Timotheou et al. (2023) posited that the ZPD acknowledges the potential for individuals to demonstrate greater skill levels with the aid, motivation, and guidance of others. Individuals can enhance their proficiency to a more advanced level in any specific domain with the assistance of teachers, parents, and even peers with slightly higher expertise.

According to Kalina and Powell (2009), Vygotsky argues that social interaction enhances the effectiveness of internalization. In this scenario, ICTs can facilitate interaction, with the mediator or teacher providing guidance. The potential for learning development exists within this interaction. Vygotsky (1987) defined ZPD as the range of tasks a child can perform with guidance and instruction from a teacher or more knowledgeable peer in the classroom, leading to learning. As per Kalina and Powell (2009), this region denotes the space where a child is aided in comprehending a concept while present inside the classroom. According to Vygotsky in Vygotsky and Cole (1978), engaging in social interactions within this zone facilitates children's learning process. The establishment of the actual level of development occurs when the learner successfully attains the intended learning outcome. Attaining this phase is crucial to facilitate additional acquisition or development of understanding. Constructivists use the term scaffolding to describe the gradually structured knowledge in complexity implied by this concept. The involvement of the teacher and other individuals is crucial in facilitating the acquisition of new knowledge for the learner by serving as a mediator. Strategies are provided to support learners in connecting their existing knowledge with new information, ultimately facilitating the assimilation of novel concepts. Ultimately, the learner internalizes it while the teacher using conceptual language to help learners to establish these connections using multimodality affordance and adaptive media.

Vygotsky's theory of social constructivism emphasizes the significance of mediation in the learner's progress as they move from their independent capabilities (actual development level) to their potential abilities with the guidance of a more knowledgeable individual (ZPD). Moll (2001) highlights that Vygotsky's theory emphasises the significance of social interaction

and guidance in facilitating learning. The extent to which a learner can effortlessly operate within the confines of their acquired knowledge establishes their understanding of a concept at the current developmental level. Vygotsky's theory, in agreement with Piaget, posits that knowledge is not static. The construction of knowledge occurs through the interaction between the learner and mediator, although it is transmitted in this process. Different mediation tools are utilized by peers or teachers who can act as mediators. Utilizing ICT simulations during the mediation process enables teachers to evaluate their efficacy more accurately.

Vygotsky (1987) states that thought is not solely influenced by external factors or the assistance of others but rather is also shaped internally by meanings constructed through social interaction. The significance of ensuring that the teacher's instructional design supports easy comprehension is highlighted by Gagne (1975). The teacher's primary responsibility is establishing a conducive learning atmosphere that enables learners to comprehend and effectively use novel knowledge. According to Moll (2001), mediation tools encompass a range of practices, including procedures, cultural objects, thought methodologies that need to be adopted, and reasoning practices that have been developed and exercised through play or study. Using ICTs as mediating instruments facilitates the learners' capacity to comprehend and integrate novel knowledge or perspectives by reducing the distance between them and the information. The level of development or state of equilibrium can be easily attained even in complex tasks.

Vygotsky's concept has been expanded to acknowledge that learners' previous knowledge is pre-existing. As mentioned by Ripple and Rockcastle (1964), Piaget states that a learner's cognition reaches a state of equilibrium. Moll (2001, p. 114) reveals that "through this experience, scientific concepts become integrated into daily life with the intention of promoting conscious awareness and control." Learners become conscious and manage cognitive procedures regarding the depictions of the world that contribute to the formation of cognitive or thinking frameworks. A cognitive tool is the term used to describe the instrument utilized to acquire those abilities. If the integration of ICT simulation in pedagogy holds significance, teachers can utilize them as cognitive and mediation tools to enhance the current level of development. Implementing this measure will guarantee that learners possess the necessary internal preparation to face more complex scientific obstacles.

Kalina and Powell (2009) state that spoken language is crucial for mediation in a learning environment that follows social constructivist principles. During mediation, this is utilized as a means of communication for the interaction. Integrating digital technology or any teaching resource with language determines the value of the technology. The success of promoting meaning-making through explanation garnishment is contingent upon various factors. ICTs can enhance language's capability to link and demonstrate the arrangement of ideas through diverse modes.

Laurillard (2013) argues that the teacher is the crucial mediator in the learning development experience, as reinforced by Vygotsky's perspective. An example of how her emphasis is linked to Vygotsky's idea of language being used to make knowledge meaningful to learners is through the teacher's role in interpreting symbols used in the narrative. This study highlights that effective teachers explicitly fulfill this role. The interpreters of subject representations dutifully fulfill their role while acknowledging the value brought by ICT simulation affordances. The constructionist framework illustrates that the exchange between teacher and learner facilitates the learner's formation of novel comprehension. The upcoming section will discuss how cognitive constructivism elucidates how learners incorporate new information.

2.2.2 Cognitive Constructivism

Teachers may feel uncertain or confused when instructed to utilize instructional techniques that foster cognitive constructivism, as they may need clarification. After grasping the fundamental concepts and advantages, teachers might be more receptive to integrating them into their teaching methodologies. To truly comprehend the material, learners must obtain significant personal reflection on the content or subject matter. More than merely memorization of information should be required, as individuals should actively employ analytical and critical skills. It is necessary to offer classroom scenarios and exercises that facilitate personalised learning. The process was formulated by Jean Piaget, a renowned developmental psychologist from Switzerland, who extensively published books and articles on learning.

Piaget (1973) argues that active involvement in the learning process is necessary for a learner to acquire knowledge, as he initiates his discourse on cognitive constructivism. Piaget's

constructivist theory centres on how individuals construct knowledge. Piaget (1973) work was the direct source of cognitive constructivism. According to Piaget's cognitive developmental theory, individuals cannot receive information and instantly comprehend and apply it. Piaget (1973) states that humans are required to build knowledge. According to Kalina and Powell (2009), Piaget (1973) theory supports that equilibration happens when children transition between stages, resulting in a cognitive conflict and mental imbalance as they attempt to comprehend the information presented to them. The state of disequilibrium is characterized by discomfort that arises when an individual must modify their cognitive schema to resolve conflict and achieve a sense of comfort Kalina and Powell (2009). Piaget (1973) defined assimilation as the process by which children incorporate new information into their schemas. Children accommodate by modifying their schemas to incorporate new information or knowledge. The process of adjustment takes place during the learning phase. To ensure effective learning, instructors must assist and encourage this procedure within the educational setting.

Piaget (1973) argues that children build an internal schema by assimilating and accommodating information to clarify his perspective. The formation of children's schemas occurs through assimilation and accommodation processes. The schema gets disrupted when a stimulus or new knowledge is presented. Kalina and Powell (2009) described schema as the discomfort experienced when modifying one's thinking to resolve a conflict. The existing structure in the mind causes this discomfort due to its incompatibility. The learner gradually incorporates new knowledge into their existing understanding structure through assimilation, ultimately accommodating it as their own. Even though schema influences our understanding of new experiences and guides us towards specific sources of information (Winn et al., 2006), it presents a difficulty for teachers who aim to facilitate learners in acquiring precise worldviews. Laurillard (2007) emphasizes the significance of utilizing feedback to detect and correct misunderstandings resulting from schema's contextual nature and arranging meaningful material. Winn et al. (2006) found that presenting information in pictures and graphics facilitates recall by encoding it in both memory systems as propositions and images, while reading text only encodes information as propositions; this perspective is challenged by Hudgins (1977) and others subsequent research.

Piaget's developmental stages focus on how logical development enables learning at various ages during childhood. Piaget (1973) suggests that equilibration, assimilation, and accommodation are all processes through which children construct new knowledge individually within their cognitive stages and resolve conflicts. The teacher can better facilitate constructivist learning by acknowledging that this process happens at a unique pace for each learner. Piaget's cognitive constructivism theory emphasizes recognizing every individual's unique learning needs and pace of acquiring knowledge. The process requires a crucial step of closely monitoring and understanding the learners' difficulty level. According to Winn (2013), Piaget believed that involvement includes the interaction between learning and memory, and between the environment and knowledge. The environment serves as an external factor by presenting knowledge significantly.

Laurillard (2013) integrates the internal process highlighted by Piaget into the learning activity interaction. She illustrates the process of learners externalizing their thoughts by providing feedback to the teacher during learning activities. The teacher's feedback facilitates the reflection process, aiding the learner in adjusting the structure and acquiring new knowledge. Acknowledging Piaget's perspective on the individual formation of knowledge justifies utilizing various opportunities from multiple media to enhance discussions in academic settings. The improved process facilitates a deeper comprehension of the subject matter. The teacher's proficiency in establishing a conducive learning atmosphere that facilitates the delivery of significant content defines the instructional worth.

2.3 Teachers' Beliefs: Pedagogical and Epistemic Beliefs

The literature describes various terms connected to teachers' beliefs like opinions, attitudes, perceptions, conceptions, perspectives, confidence, motivation, self-concept (Pajares, 1992), knowledge, views, and principles (Milner et al., 2012). The classifications and definitions of teacher beliefs used in the literature are diverse and challenging to describe because beliefs are implicit, unobservable, and complex regarding what one knows and truly believes. Richardson (2003, p. 2) defines teacher's beliefs as "psychologically held understandings, premises or propositions about the world that are felt to be true." Generally, teachers' beliefs are often categorized as traditional or modern. Teachers' traditional and epistemological beliefs about

classroom practices are typically teacher-centred. In a learning environment, passive learners adapt knowledge from the teacher, who focuses on the content. On the other hand, teachers' modern and constructivist beliefs about classroom practices are learner-centred. Within the fashionable classroom, learners can participate, choose from different options, work more independently, and have meaningful topics (Markic & Eilks, 2012). Pajares (1992, p. 307) argues that "teachers' beliefs are vital to educational inquiry, as the ways teachers believe can help scholars understand their behavior better." However, teacher beliefs are challenging to define since "the construct of educational beliefs is itself broad" (Pajares, 1992, p. 315). Therefore, researchers need to be very clear about the specific teacher beliefs they will study.

Several sorts of teacher beliefs related to technology use have been discussed in previous studies. They include beliefs about the character of data, referred to as epistemological beliefs (Deng et al., 2014a); the worth placed on technology use (Mama & Hennessy, 2013); self-efficacy beliefs (Kreijns et al., 2013; Mei et al., 2018); and beliefs about teaching-and-learning or pedagogical beliefs (Ertmer et al., 2012; Gurcay et al., 2013). Teachers' pedagogical beliefs have also been identified as the main barriers to technology integration (Ertmer et al., 2012). For example, supported data from national surveys acknowledged that the external barriers to technology use had been "greatly reduced or maybe eliminated" (Ottenbreit-Leftwich, 2013, p. 424). The chronic ineffectiveness of technology integration indicated that a change in teachers' pedagogical beliefs – from traditional to constructivist – is necessary.

Similarly, Windschitl and Sahl (2002) found minimal positive influence of technology-rich environments on teachers who did not have constructivist pedagogical beliefs. Teachers' beliefs play an essential role in whether science teachers will or will not teach science as inquiry (Crawford, 2007). Saad and BouJaoude (2012) agree that one of the significant barriers that inhibit science teachers from implementing IBST in science classrooms is teachers' beliefs about teaching, learning, and classroom management. When considered collectively, the findings verify that pedagogical beliefs remain an obstacle to effective technology integration, even if external barriers like limited access to technology and technical support are further reduced.

Pedagogical beliefs encompass the use of ICT simulation for teaching and learning. In contrast, ICT simulation-related epistemic beliefs refer to individuals' viewpoints and

understanding of how information and communication technologies facilitate generating knowledge and acquiring new skills. The realm of epistemology is engaged when contemplating notions such as teacher-centric perspectives, learner-centered convictions, behaviorist instruction, or constructivist-influenced education. In other words, a teacher's epistemic worldview directs their instructional behaviors. This perspective comprises presuppositions regarding epistemology and the correlation between information and communication technologies and knowledge. Pajares (1992) proposed that conflicting beliefs could alter pedagogical beliefs and subsequently impact their implementation in practice.

Furthermore, contextual factors such as family expectations, standardized test demands, or relationships with school administration can influence the implementation of pedagogical beliefs into practical actions. The factors identified by Ertmer et al. (2015) and Windschitl and Sahl (2002) can significantly impact the implementation of teaching practices. The notion that pedagogical and epistemic beliefs are intricately connected governs our investigation.

2.3.1 Pedagogical Beliefs

According to Borg (2001), belief is a collection of fundamental beliefs subconsciously accepted by the individual as the 'truth' about the universe and are closely tied to their experiences. Pajares (1992) states that belief acts as a personal barometer that helps people define their ideas and behave consistently with them. According to some authors, beliefs are made up of a web of central and auxiliary values that are, respectively, deeply ingrained or sporadic in the subject's experience and identity (Ottenbreit-Leftwich et al., 2010). In this view, one's essential beliefs, which are influenced by culture, history, and tradition, make up their values. These beliefs demand a significant shift in thinking, which makes them more challenging to alter (though not impossible). In contrast, peripheral beliefs are created from subjective experience and are more adaptable to changing circumstances.

In teaching, beliefs connect teachers' perceptions and assessments of their behavior in connection to lesson plans, teaching strategies, relationships with learners, motivational techniques, educational objectives, and self-esteem (Hatlevik, 2017; Rohaan et al., 2012). Pedagogical ideas also address respect for others, competition, handling conflicts, parent-child interactions, autonomy, individuality, and group cohesion (Olsen, 2019). These ideas impact how

teachers organize and carry out their lessons and how they employ technology (Tondeur, 2020). The use of technology can also alter instructors' pedagogical views in a reciprocal and iterative process, according to studies (Ertmer, 2005; Santos & Pischetola, 2020; Tondeur et al., 2017). In agreement with Tondeur (2020), teachers' use of ICT simulation may be more successful if their educational views are better understood. Three areas of focus in research on ICT simulation integration in education have been identified by Tondeur et al. (2019) in a recent systematic review of the literature: (1) ICT simulation and teachers' attitudes (Holland & Piper, 2016; Mirzajani et al., 2016); (2) ICT simulation and self-efficacy (Compeau & Higgins, 1995; Scherer & Siddiq, 2015); and (3) ICT simulation competencies. The authors claim that because ICT simulation self-efficacy is linked to teachers' confidence levels in using ICT simulation, it can also help explain some of their attitudes and competencies. Therefore, the critical focus of future research into teachers' use of ICT simulation is self-efficacy.

2.3.2 Epistemic Beliefs

Epistemic beliefs are defined as those that concern how mental and intellectual processes relate to what can be referred to as the "sense of knowing". Epistemic beliefs explain queries like 'How would it be possible to know,' 'How does the learning process occur,' and 'Through what processes or tactics would it be feasible to know' (Pischetola et al., 2019). In education, epistemic beliefs concern how we can genuinely acquire knowledge. In other words, they represent the beliefs and expectations of both individuals and groups on what knowledge is, its boundaries, and how teaching and learning relate to the process of knowing. Thus, epistemic beliefs affect how people perceive, understand, and relate to the material presented, teach and learn the methodologies used in these processes, and critical and logical thinking in classroom teaching procedures. According to Erduran and Kaya (2019) and Maggioni and Parkinson (2008), such beliefs interfere with teachers' methodologies, theories, and pedagogical approaches adopted, materials used, and assessments. As a result, teachers' use of ICT simulations and epistemic beliefs are directly connected.

Three central beliefs prevalent in ICT simulation and education emerge through literature analysis. Firstly, an objectivist theoretical perspective views technology as a technical artifact and offers linear justifications for ICT simulation integration in education. Secondly, a social

constructivist approach that values learners' active use of ICT simulation and the dialogical aspects of teaching and learning. Thirdly, an ecological/systemic perspective that views technology as a cultural artifact and emphasizes the interaction between humans and non-humans. The present study aims to empirically demonstrate the connection between teachers' pedagogical and epistemic beliefs and ICT simulation use. In ICT simulation and education research, the first perspective, either objectivist or Cartesian, has a far greater representation. Even when it is indicated that a social constructivist perspective provides the framework for the study, the discussion of the findings and the final data interpretation are frequently linear and impartial. On the other hand, it is considerably more challenging to come across an ecological approach, which views technology as a cultural and material agent in the formation of knowledge (Pischetola et al., 2019).

2.4 Teachers' Beliefs about Inquiry-Based Science Teaching

In the school environment, IBST has been defined differently. Some researchers have defined IBST as “inquiry-based learning” (Moote, 2019, p. 71) or even as “inquiry teaching” (Jiang & McComas, 2015, p. 31), others have argued that IBST stands for “inquiry-based science teaching” (Fitzgerald et al., 2019, p. 59), some have a view that IBST is “inquiry-based science instruction” (Areepattamannil, 2012, p. 134), or even “science through inquiry” (Dudu & Vhurumuku, 2012, p. 581), “classroom inquiry” (Dudu & Vhurumuku, 2012, p. 150). Fitzgerald et al. (2019) describe four different definitions of inquiry in the context of science education:

- 1) Confirmation inquiry – learners know the question, procedure, and results.
- 2) Structured inquiry – learners know the question and procedure, but must explain the results.
- 3) Guided inquiry – learners know the question, but they have to design a procedure that generates explanations of the results.
- 4) Open inquiry – learners derive questions, design procedures, conduct investigations, and present explained results.

Definitions 3 and 4 are the most common in science classes (Fitzgerald et al., 2019) and are related to learning classroom activities such as ICT simulations.

In this study, the researcher adopted the fourth definition of inquiry, which emphasizes a learner-centred approach where learners actively derive their own research questions, design the investigative procedures, conduct experiments or simulations, and present their findings with detailed explanations. This definition aligned with the constructivist theory that encourages learners to take ownership of their learning by engaging in authentic scientific inquiry, fostering critical thinking and deeper conceptual understanding through hands-on exploration and reflection on their results.

Binns and Popp (2013) draw attention to the meaning of teacher beliefs by pointing out that educational background alone does not determine whether a teacher will use IBST. However, teachers' beliefs, values, and views regarding knowledge and how it is acquired are also important. According to Sikko et al. (2012), teachers' beliefs about science, teaching and learning, and IBST tend to influence science teachers' decisions and choices of pedagogical strategies in a classroom. If teachers' beliefs contradict their IBST practices, they may be a barrier to teachers in selecting or opting for IBST as a pedagogical tool (Binns & Popp, 2013). Becker and Riel (2000) state that teachers' beliefs usually are either traditional (teacher-centered) or constructivist (learner-centered). Several studies have informed researchers and practitioners alike on the influence of internal beliefs and external pressures in adopting inquiry pedagogy (Wallace & Loughran, 2012). Roehrig and Luft (2004) showed how new teachers' understanding of scientific inquiry, content knowledge, pedagogical content knowledge, teaching beliefs, and concerns about management and learners impacted how they adopted and facilitated inquiry in the classroom. In addition, Keys and Bryan (2001) suggest that knowledge of teachers' beliefs is instrumental in understanding how inquiry is implemented in the classroom. Choi and Ramsey (2009) have indicated that teachers' beliefs, attitudes, and practical knowledge are crucial factors in promoting a reform-based curriculum such as inquiry-based science instruction. To make science meaningful for all children, teachers must be capable of responding effectively to education reforms, including the incorporation of inquiry-based science lessons. Crawford

(2007) has conducted several studies on the influence of in-service teachers' views on inquiry and how that affects their classroom practices in inquiry science lessons. Findings reveal the complexity of negotiating tensions between existing beliefs and new ideas on inquiry while developing inquiry teaching practices (Crawford, 2007). Research conducted by Wallace and Kang (2004) found that high school teachers who believe in inquiry-based teaching and learning, especially in conceptual understanding, were most willing to integrate IBST activities into their science teaching.

Even though IBST has been shown to have advantages, its use is still restricted because of several obstacles. Teachers' attitudes are essential in deciding if and how they incorporate IBST in their classrooms. Constructivist beliefs support the adoption of IBST, while traditional beliefs frequently result in resistance, as teachers view the approach as either impractical or time-consuming (Boz & Cetin-Dindar, 2023). However, teachers in schools with limited resources may face obstacles in implementing IBST due to the substantial preparation and resources required. Lack of time and pressure from necessary tests make teachers reluctant to use inquiry-based approaches, as they focus on covering the curriculum instead of emphasizing learner-centered learning (Furtak et al., 2012). These challenges highlight the importance of systemic support, training opportunities, and policy changes to enable broader adoption of IBST.

2.5 Teachers' Beliefs about ICT Simulations

Teachers' beliefs about how simulations support learners in achieving success and how important it is to use ICTs to gain necessary knowledge reveal how technology integration relates to success in subject areas. According to the concept of Mindtools, technology serves as a means to facilitate learners in creating and deriving meaning instead of being a direct source of learning (Jonassen & Carr, 2020). Simulations can assist teachers in creating teaching activities that align with the constructivist learning paradigm. Using simulations by the constructivist approach in teaching can aid the development of advanced cognitive thinking skills. (Baylor & Ritchie, 2002). Many factors influence teachers' beliefs, including their personal experiences. These personal school experiences and experiences with formal knowledge influence teachers' formed beliefs (Forbes & Davis, 2010). Studies have found that teachers with constructivist beliefs use simulations to support a learner-centered approach, whereas teachers with traditional beliefs are more teacher-centered (Hermans et al., 2008).

Watson (2006) concluded that high school teachers' beliefs regarding using simulations in a classroom are entirely based on the assumption about whether the technology will help them reach the educational objectives. Cox (2003) follows an equivalent trend by exploring teachers' beliefs about the importance of simulations in a classroom. Cox focused on the distinction between using simulations to reinforce the standard practices that might enhance the classroom interactions between learners and, subsequently, the teacher. The findings of some studies highlight that teachers believe that simulations are only good as a reward tool (Palak & Walls, 2009), a tool that can only be used best in the early years and primary school classes (Hammond et al., 2011), or a tool that only serves to entertain the learners (Zhou et al., 2018). Using simulations among teachers is a time-consuming activity with minimal productivity (Reynolds et al., 2003). Some still suggest that these beliefs are directly linked to teachers' self-efficacy about their technology understanding (Bandura, 1997), and Karaseva et al. (2015) also indicate that teachers' beliefs and their use of simulations in the classroom are subject to the topic they teach and to school policy.

2.6 Science Teachers Beliefs about Integrating ICT Simulations in a Classroom

Fauzi et al. (2017) studied how teachers' beliefs are related to technology integration practices in a classroom. Their conclusions revealed that teachers' beliefs about the nature of knowledge and learning are directly correlated with beliefs about effective ways of teaching, and beliefs about effective ways of teaching are correlated with technology integration practices. Albugarni and Ahmed (2015) state that teachers' beliefs play a crucial role in shaping teachers' use of ICT simulations in teaching and learning. According to Wanjala (2016), integrating ICT simulations in the classroom depends on many factors, including teachers' beliefs, attitudes, confidence, and perceptions of the nature of mathematical knowledge and how it should be learned. Teachers' beliefs do influence their behavior. For this reason, researchers have widely argued that teachers' classroom practices with ICT simulations are directly influenced by their beliefs; according to Tondeur et al. (2017), science teachers tend to choose technology applications that align with their existing beliefs.

The literature presents the relationship between ICT simulation use and constructivist approaches as highly effective (Ertmer et al., 2012). Evidence also suggests that constructivist teachers tend to be highly active technology users (Ertmer, 2005). According to Becker (2000), these teachers use technology more frequently than teachers with teacher-centred beliefs and use technology more learner-centred. More specifically, teachers with constructivist beliefs have been observed using technology as an information tool (Tondeur et al., 2012) and helping learners develop higher-order thinking and problem-solving skills (Berg et al., 1998). According to Ananiadou and Claro (2009), teachers with constructivist beliefs use technology to support learners' capacity to "apply knowledge and skills in key subject areas and analyze, reason, and communicate effectively as they raise, solve, and interpret problems in a variety of situations." However, Ottenbreit-Leftwich et al. (2010) state that teachers' preference for using ICT simulations relies on their beliefs about technology, which helps or prevents them from achieving the pedagogical objectives.

Studies related to teachers' beliefs about technology integration identified two shortcomings. The first shortcoming, highlighted by Kim et al. (2013), is related to technology

integration, which confirms that there is less focus on teachers' beliefs and more on ICT simulation. While it is known that teachers hold beliefs about different issues, such as beliefs about knowledge, their learners, the environment in which they work, subject matter, as well as moral dilemmas and social issues that affect the teaching process (Priestley et al., 2015), most of the technology integration studies tend to draw the main focus on beliefs about technology's role in teaching and learning (Deng et al., 2014b). The second shortcoming, highlighted by Mansour (2008), is the formation of teachers' beliefs. In this regard, it holds that technology integration research tends to overlook its role. Plumb and Kautz (2016) state that recent studies on teachers' views on technology integration in education have been criticized for not considering the educational contexts and simply relying on theories and data collection tools. The relationship between teachers' pedagogical beliefs and technology integration is crucial (Miranda & Russell, 2012) because teachers' beliefs appear to be a primary predictor of technology use (Miranda & Russell, 2012). However, teachers' beliefs about technology integration can also be a barrier (Tondeur et al., 2017).

Literature has proven that teachers' beliefs about ICT simulation falls into four different categories:

- 1) Self-efficacy beliefs – teachers tend to choose not to use ICT if they are not confident in their ICT-skills (Ertmer & Ottenbreit-Leftwich, 2010).
- 2) Beliefs about teaching and learning – general beliefs about the role of teachers and learners in teaching and learning about how technology should be used (Tondeur et al., 2017).
- 3) Beliefs about the value of technology for teaching and learning – beliefs about how ICT simulations can help teachers achieve their educational objectives (Ertmer & Ottenbreit-Leftwich, 2010).
- 4) Beliefs about external factors – teachers' beliefs about their cultural and social context influence the use of ICT simulations (Ertmer & Ottenbreit-Leftwich, 2010).

Although these beliefs are not purely educational, they influence their teaching and learning are critical factors in how science teachers implement ICT simulations. High school

teachers' self-assessed technological skills, teacher training program experiences, and beliefs about the usefulness of technology in teaching and learning influence their choice of technology used in teaching (Chen, 2010). Abbitt (2011) acknowledged a correlation between teaching with technology and their beliefs in their ability to use technology in their teaching. Abbitt suggests that if teachers' knowledge regarding teaching with technology is developed and considered, it may exponentially increase their belief in their ability to teach using technology. Ertmer et al. (2012) also realized that most teachers who had successfully integrated technology into their teaching reported having an excellent passion for technology and having a problem-solving mentality, which are essential factors in shaping their practices and passion for using technology in a classroom. Based on the studies above, it is clear that teachers' beliefs in using simulations in a classroom are complex. Overall, teacher beliefs are key factors when considering technology integration in education (Ertmer et al., 2012).

2.7 The Impact of Teacher Beliefs on Educational Practices

As described in Section 2.2, teachers' beliefs include pedagogical beliefs (related to teaching and learning) and epistemic beliefs (related to knowledge) (Buehl & Fives, 2009). These beliefs become deeply rooted, originating in early life from personal learning experiences, mentor interactions, and professional growth. They represent beliefs about learning that influence teachers' choices, teaching strategies, and interactions with learners (Levin et al., 2012). Although teacher beliefs are stable, they can still change. They have the potential to grow through introspective learning, career growth, professional development, and exposure to new teaching methodologies. For example, participating in IBST or witnessing the advantages of active learning strategies can move teachers from traditional, instructor-focused perspectives to more constructivist, learner-centered approaches (Tondeur et al., 2017a). The significance of tackling teacher beliefs in education reform and enhancement highlights the potential for change.

2.7.1 Beliefs as Determinants of Classroom Practices

Teaching methods and interactions with learners are greatly affected by their beliefs. Those teachers with constructivist beliefs usually favor learner-centred approaches that encourage exploration, collaboration, and critical thinking (Ottenbreit-Leftwich et al., 2010). On the other hand, those who hold traditional beliefs tend to focus more on delivering content

material and using standardized assessments, showing a preference for memorization and teacher-driven strategies (Peck et al., 2015). Beliefs can also influence how learners perceive their abilities. According to Levin et al. (2012), teachers who believe that intelligence can be changed are more inclined to use methods that promote growth, such as providing scaffolding and personalized instruction. In contrast, those teachers who see intelligence as unchangeable may set lower standards, limiting learners' achievement. The different teaching methods and styles used in a classroom show how teachers' beliefs influencing learners' involvement, motivation, and academic success.

2.7.2 The Influence of Beliefs on Technology Integration

Teachers' beliefs are crucial in determining how technology is integrated into the classroom. Constructivists often view technology as a valuable resource for promoting active, inquiry-based learning, highlighting its ability to encourage collaboration, critical thinking, and deeper engagement by using interactive simulations, digital collaboration tools, and virtual labs (Ertmer et al., 2012; Tondeur et al., 2017). For example, ICT simulation can help learners visualize abstract scientific concepts, engage in collaborative problem-solving, or access real-time data for analysis. Nevertheless, traditional, teacher-centered beliefs often prefer to use technology more passively, like giving lectures via slides or giving out repetitive exercises, which complement their emphasis on delivering content and memorization (Kim et al., 2013). The difference between constructivist teachers and teachers with traditional, teacher-centered beliefs highlights how teachers' core beliefs influence the selection and implementation of technology, deciding whether it is used to improve involvement or support traditional methods.

Although ICT simulation can potentially transform teaching and learning, there is a gap between teachers' beliefs and classroom practices. Contextual barriers, such as lack of resources, inadequate training, or institutional pressures, can lead to a gap that hinders teachers from achieving their constructivist goals (Dexter et al., 1999). For example, teachers who value collaborative, inquiry-based teaching methods might have difficulty incorporating technology efficiently in a school with limited resources or strict curriculum requirements. Addressing these challenges requires professional development programs that build teachers' confidence, enhance teachers' skills and self-assurance in ICT simulation, and align with their educational beliefs.

Studies have indicated that these programs are most successful when they offer practical experience with technology, demonstrate its positive impact on learner results, and encourage a supportive environment for experimentation (Prestridge, 2019). Educational reforms can ensure that teachers' beliefs align with practical strategies and systemic support, ultimately closing the gap between beliefs and teaching practices and enhancing the effectiveness of technology in classrooms.

2.7.3 Contextual and Cultural Influences on Teacher Beliefs About ICT Simulation

Integration

Teachers' beliefs about integrating ICT simulations are not formed or developed independently. However, they are significantly influenced by their previous experiences and the broader institutional and cultural environment in which they work. Past experiences with ICT tools play an essential role in shaping these beliefs. Positive experiences, such as successfully using simulations to enhance learner understanding of complex concepts, often strengthen the perception that technology is an invaluable instructional tool. For instance, a teacher who observes learners grasping abstract concepts through interactive tools may become an enthusiastic advocate for ICT simulations. On the other hand, negative experiences, such as persistent technical failures, unreliable internet connections, or learner disengagement, can foster skepticism and reluctance to integrate technology into teaching practices (Ertmer et al., 2012).

Technology distracts from traditional teaching and learning methods in some educational contexts, focusing more on memorization and teacher-led teaching. Cultural expectations may influence teachers to adhere to traditional teaching practices, even if their personal beliefs align with constructivist, technology-enhanced, inquiry-driven learning approaches (Prestridge, 2017).

Recent studies have explored the integration of ICT simulations into IBST, using various instructional models to enhance learner engagement and understanding. For example, Graham et al. (2024) introduced the "Four Zones Model for the Integration of ICT in Schools," which categorizes the impact of ICT into context, school, classroom, and personal zones. This model emphasizes the importance of structured frameworks to ensure that ICT tools, such as interactive simulations, are effectively integrated into the teaching process. Furthermore, the transition from more complex models like the 7E framework (Elicit, Engage, Explore, Explain, Elaborate,

Evaluate, and Extend) to more concise frameworks like the 3E model (Engage, Explore, and Explain) highlights the adaptability of IBST approaches to meet various classroom needs and instructional objectives, facilitating scaffolded learning that encourages inquiry, critical thinking, and problem-solving.

Incorporating ICT simulations within these structured IBST models provides learners with dynamic platforms to explore scientific concepts, manipulate variables, and observe outcomes, thus supporting the construction of knowledge through inquiry-based activities. The 5E learning model is one of them, and many studies have been conducted in literature related to this model (Çakır, 2017). Watson (2019) investigated the use of the PhET pH Scale simulation within the 5E instructional model (Engage, Explore, Explain, Elaborate, Evaluate) to improve learners' understanding of pH in chemistry. The study found that virtual simulations allowed learners to interactively manipulate variables, observe real-time changes, and develop a deeper comprehension of acid-base solutions. Watson emphasized that simulations bridge the gap between abstract concepts and tangible experiences, making complex topics more accessible and engaging. This approach not only enhances conceptual understanding but also aligns with the goal of leveraging technology to foster inquiry-based learning and improve learner outcomes in science education.

2.7.4 Professional Development for Integrating ICT Simulations into Teaching

The integration of technology in education offers a chance to improve teaching and learning methods. Nevertheless, according to Lederman et al. (2014), ICT's role in education should function as a supportive tool rather than the main focus. Professional development programs must focus on leveraging ICT simulations to enhance teaching methods and consider the social, economic, and infrastructural factors affecting educational institutions. J Voogt et al. (2013) emphasize this concept, pointing out that ICT tools, while successful on their own, may not produce the same results in complex educational environments. This highlights the importance of creating professional development programs that position ICT simulations as a tool for creative teaching methods and adapt to the various challenges teachers face. A holistic approach is essential to incorporate ICT simulations effectively into education, involving different aspects and participants. This involves tackling the socio-economic inequalities

between schools and guaranteeing sufficient resources are accessible, as proposed by Meyer and Gent (2016). Professional development programs must align with education's systemic needs; encouraging collaboration among teachers, administrators, and policymakers is also crucial.

Despite substantial research on the components of effective professional development, challenges persist in evaluating its success. Guskey (2002) five-level framework provides a robust structure for assessing professional development initiatives, focusing on participants' reactions, learning outcomes, organizational changes, application of new knowledge, and learner performance. This comprehensive approach enables a deeper understanding of the impact and effectiveness of training programs, ensuring they align with teachers' needs and systemic goals.

However, implementing professional development programs often encounters barriers such as inadequate evaluation processes and a lack of sustained support for teachers. Guskey (2002) notes that shallow evaluations emphasizing documentation over meaningful outcomes can erode teachers' confidence in the relevance of professional development. To address these concerns, this research employs Guskey's framework to assess the suitability of Lesson Study as a professional development model for ICT simulation integration. By examining previous studies and teachers' experiences, this evaluation highlights how Lesson Study fosters collaboration, reflective practice, and the practical application of new knowledge. In later chapters, these insights guide discussions on how tailored professional development initiatives can empower teachers to integrate ICT simulations effectively, ultimately enhancing teaching and learning outcomes in diverse educational settings.

2.8 Challenges in Using ICT in Teaching and Learning

The use of ICT tools in schools faces numerous challenges, falling into two main categories: external and internal barriers. Extrinsic (external barriers) factors such as institutional leadership, timetabling, and resource availability are not viewed as significant barriers in environments that are both technology-rich and supportive of ICT simulations integration. However, intrinsic (internal barriers) factors remain critical challenges. These include teacher beliefs regarding the educational value of ICTs and their pedagogical applications, as well as their level of knowledge and proficiency in using these tools effectively. While external conditions may foster a favourable setting for technology use, the successful integration of ICT

often depends on addressing these internal factors, which influence teachers' willingness and ability to leverage technology in their teaching practices (Juggernath & Govender, 2020).

Moreover, teachers who are used to traditional teaching techniques may be hesitant to embrace change, concerned about losing authority in the classroom or viewing ICT simulation as a source of disruption. Cultural beliefs towards education, which prioritize memorization instead of interactive learning, continue to strengthen this opposition (Rafiq et al., 2021). This hesitation is further exacerbated by the lack of chances for professional growth, which are crucial for providing teachers with the essential abilities and self-assurance to adopt ICT simulations.

Dealing with these obstacles necessitates a diverse strategy. Governments and schools should allocate funds for infrastructure, such as up-to-date equipment, consistent internet connectivity, and dependable tech assistance. Customized professional development programs for teachers can assist in closing the skills gap and encouraging positive attitudes towards integrating ICT simulations. Additionally, fostering a positive school environment that highlights teamwork, creativity, and the educational advantages of technology can inspire teachers to adopt these resources. Effective integration of ICT simulations also relies on policy changes that offer teachers the needed time and resources for testing and adjusting, guaranteeing that technology progress leads to valuable educational results.

2.9 Barriers to ICT Simulation Integration in Education

The integration of Information and Communication Technologies (ICT) in education has great potential to change teaching and learning methods. However, its implementation often faces significant barriers, which vary based on contextual, institutional, and individual factors. According to Bingimlas (2009), teachers acknowledge the value of ICT simulations, they do face lots of challenges that hinder its successful implementation. These barriers can be classified into two categories: extrinsic and intrinsic. Understanding these barriers is critical for developing strategies that facilitate and support the integration of ICT tools in educational settings.

Extrinsic barriers refer to external factors, including infrastructure, resource availability, and institutional support. A lack of access to reliable internet, modern hardware, and quality software remains one of the most cited obstacles. Studies indicate that inadequate infrastructure

is particularly pronounced in under-resourced regions, where schools lack basic amenities to support ICT integration (Antoninis et al., 2023; Nikolopoulou & Gialamas, 2016). Even in technology-rich environments, issues such as inefficient timetabling and inadequate technical support persist, disrupting ICT use (Bogiannidis et al., 2023).

Institutional leadership also plays a vital role. Strategic planning, policy development, and continuous investment are necessary for successful integration of ICT. Schools led by forward-thinking leaders and strong policies are more capable of handling logistical challenges and fostering an atmosphere that promotes technological advancement (Scrimshaw, 2004). Recent research suggests that without systemic support, even resource-rich schools struggle to maintain consistency in ICT simulation adoption (Nelson & Hawk, 2020).

Intrinsic barriers are linked to individual attitudes, competencies, and pedagogical beliefs. Teachers' confidence and competence in using ICT tools significantly influence integration success. Bingimlas (2009) and Ottenbreit-Leftwich (2010) found that a lack of training in digital pedagogy often leads to apprehension and low self-efficacy among teachers. Resistance to change is another pervasive issue; teachers accustomed to traditional teaching methods may view ICT simulations as disruptive rather than transformative (Rafiq et al., 2021). These barriers are compounded by a lack of professional development tailored to teachers' needs. Generic training programs focusing solely on technical skills fail to address pedagogical integration, leaving teachers unprepared to implement ICT effectively in their classrooms (Pischetola et al., 2019). This gap highlights the need for continuous, context-specific training that aligns technological tools with curriculum objectives and teaching practices.

Beyond the dichotomy of extrinsic and intrinsic barriers, systemic challenges such as limited time, fragmented policies, and unequal resource distribution exacerbate ICT simulation integration difficulties. Teachers frequently cite insufficient time for planning and experimenting with ICT simulation-enhanced lessons as a critical constraint (Plumb & Kautz, 2016). Additionally, policy inconsistencies at the regional and national levels lead to fragmented implementations, resulting in uneven access to ICT simulation across schools (Scrimshaw, 2004). Technical issues such as malfunctioning equipment and delayed maintenance further hinder progress. Studies by Pelgrum (2001) and Kunnath and Kriek (2018) underscore the

importance of robust technical support to ensure that teachers can rely on ICT tools without disruptions. Without these systemic supports, even the most motivated teachers may struggle to integrate ICT simulations meaningfully. Educational institutions can unleash the transformative power of ICT simulations by recognizing and systematically overcoming these obstacles, ensuring every learner is ready to succeed in a more digital society. Future studies need to investigate scalable, contextually appropriate solutions that close the divide between the availability of technology and its utilization in educational settings

CHAPTER 3

CONCEPTUAL FRAMEWORK

3.1 Introduction

Chapter 2 presented an overview of the constructivist theoretical framework used in this study, covering the social and cognitive aspects of constructivism, and science teachers' beliefs about ICT simulations based on the literature review. ICT simulations are defined as interactive, computer-based tools that replicate real-world systems, environments, or processes to support learning and problem-solving in educational or professional contexts (Kuang et al., 2020). Science teachers hold the belief that these simulations use digital technologies to model dynamic phenomena, enabling learners to experiment, make decisions, and observe the outcomes in a controlled virtual setting, ICT simulations are particularly effective in promoting inquiry-based learning, as they allow learners to form and test hypotheses within safe and resource-efficient environments.

Chapter 2 also explored how teachers' beliefs about ICT simulations and IBST have been depicted in recent studies (Crawford et al., 2020; Furtak et al., 2012). IBST is a constructivist instructional approach that emphasizes active learner engagement in scientific processes such as questioning, hypothesizing, experimenting, and drawing evidence-based conclusions. This method fosters critical thinking and deepens scientific understanding by encouraging learners to explore and construct knowledge actively rather than passively receiving it. It integrates knowledge of scientific content with procedural and epistemic understanding, allowing learners to experience the practices and principles underlying scientific discovery (Kotsis, 2024).

Chapter 3 focuses on introducing the theoretical framework of IBST that serves as the foundation for this research. Following the approach of Areepattamannil et al. (2020), the conceptual framework in this study is used to analyse and interpret the data in order to conclude science teachers' beliefs about ICT simulations and IBST and how these beliefs influence their planned and implemented teaching. The chapter is presented in three sections. Section 3.1 introduces the IBST conceptual framework used in the study, linking it with constructivist learning theory to establish a foundation for understanding how IBST aligns with constructivist principles to support and enhance science learning (Schwarz et al., 2017). Section 3.2 introduces

the Vickers Framework, which explores the impact of teachers' beliefs on their IBST choices through Reality, Value, and Action Judgments. This methodical strategy will be demonstrated in a visual representation of the impact of these judgments on teaching. Section 3.3 discusses the Hew and Brush Framework, highlighting key factors and barriers that affect technology integration in IBST, such as teacher knowledge, resources, and technical support. This framework contextualizes the use of ICT simulations in science teaching. Section 3.4 covers the BIUT framework, which analyses factors impacting IBST, including obstacles, interventions, understanding, and technology. A visual representation will demonstrate these connections. Finally, in Section 3.5, the present study proposed the Extended BIUT Framework, which expands the original framework to address systemic factors like policy, curriculum flexibility, and professional development.

3.2 Linking IBST with Constructivist Learning Theory

IBST is an educational method that engages learners in active learning by encouraging questioning, exploration, and investigation, allowing them to take on a more active role in their learning. The foundation of IBST lies in the constructivist framework, which sees learning as the creation of understanding through experiences. It promotes scientific understanding by involving learners in activities that imitate the practices of scientists, like creating research inquiries, planning experiments, gathering and examining data, and making conclusions based on evidence. IBST shifts from traditional teacher-centred methods focusing on memorizing facts to a learner-approach where learners actively explore scientific concepts to develop critical thinking and problem-solving skills (Bybee, 2014). This method can be seen in different forms, from guided inquiry led by the teacher to self-directed inquiry by learners, showing different teaching and learning styles and enhancing conceptual understanding (Bell & Smetana, 2008).

When implementing IBST, the teacher shifts from being the primary source of knowledge to a facilitator who guides learners through the inquiry process, scaffolds their learning, and encourages autonomy. The role aligns with the ZPD, where teachers support learners in reaching higher levels of understanding through guided inquiry (Vygotsky & Cole, 1978). Studies indicate that IBST increases learners' understanding of content and promotes their scientific mindset and enthusiasm, viewing science as an evolving, question-based area rather

than a set of unchanging information (Crawford, 2014). IBST is increasingly integrated with technology in modern educational environments, utilizing digital tools such as simulations, data collection software, and virtual laboratories to support scientific investigations and collaborative learning (Kim, 2011). As a strategy, it promotes a culture of curiosity and continuous learning by developing learners' natural curiosity and providing them with the necessary tools.

The principal theory supporting this research study is the constructivism as learning theory, well known from Piaget's work. The study is articulated around two main theories, namely 'constructivism' and 'inquiry-based science teaching', as one of the teaching strategies designed to promote constructivist learning and science teachers' beliefs. IBST is based on constructivist learning theory, suggesting that learners develop knowledge through their experiences instead of passively receiving information. Key constructivist influencers, like John Dewey, Jerome Bruner, and Lev Vygotsky, highlight the importance of active, reflective, and social elements in learning (Kalina & Powell, 2009; Tamim & Grant, 2013). Dewey advocated for learning through inquiry, where learners engage in sustained questioning and problem-solving, while Bruner's discovery learning suggests that understanding is deeper when learners interact with their environment to find answers (Harris, 2016). Vygotsky's social constructivism adds that social interaction is essential for cognitive development, positioning inquiry-based learning as central to collaborative learning experiences (Liu & Zhang, 2024).

According to Fitzgerald et al. (2019), IBST can be structured at different levels, from *confirmation and structured inquiry* to *guided and open inquiry*, with increasing levels of learner autonomy. However, implementing higher levels like Open Inquiry can be challenging due to its complexity. The approach is rooted in constructivist learning theory, which advocates for active, reflective learning where learners build knowledge through experience (Tamim & Grant, 2013).

IBST aims to create engaging learning environments where learners connect science to real-world contexts, fostering critical thinking and problem-solving. While effective in promoting scientific literacy, practical challenges, such as curriculum constraints and assessment practices, can hinder its widespread adoption (Lehesvuori et al., 2018). Thus, successful IBST implementation requires addressing these barriers and aligning instructional strategies with inquiry principles.

3.3 Vickers Framework: Understanding Teacher Beliefs in IBST

Vickers framework offers a detailed approach to analysing teacher beliefs by categorising them into three specific types of assessments: reality judgments, value judgments, and action judgments. These categories are useful in understanding the complicated decision-making processes teachers undergo when incorporating technology in their classrooms (Burt & van der Heijden, 2024).

3.3.1 *Reality Judgments*

Reality judgements are the practical assessments teachers make about their current classroom environment. These judgments involve teachers' perceptions of what is actually happening day-to-day in their teaching space, including the abilities of their learners, the content they are expected to cover, and the logistical challenges of using technology. For instance, a teacher might recognize that their learners are technologically skilled, but the available ICT resources might be outdated or difficult to manage (Atman-Uslua, 2022; Ertmer et al., 2015). These reality judgments can significantly influence how comfortable or willing a teacher is to bring technology into the classroom.

3.3.2 *Value Judgments*

Value judgements represent teachers' personal beliefs about what they consider good teaching and learning should entail. Their educational methodologies and goals often shape and mould these beliefs, such as promoting critical thinking, creativity, or group work in their learners (Tondeur, 2020). A teacher who values a learner-centred teaching approach might be more prone to use ICT tools and technology that encourages exploration and problem-solving compared to a teacher who prioritizes structured learning, which might be more hesitant to integrate technology that requires a more open-ended, inquiry-based approach (Tondeur et al., 2017).

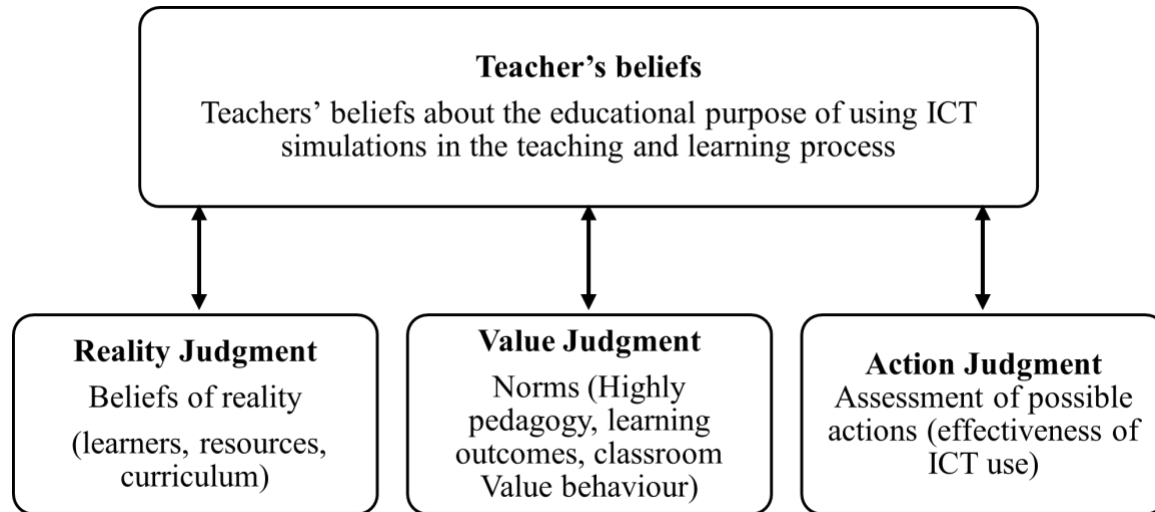
3.3.2 *Action Judgement*

Action judgments are where beliefs meet practice. These judgments concern teachers' ideas about how technology affects their teaching and learners' learning outcomes. Teachers who believe that ICT simulations enhances learner engagement or deepens understanding are more propelled to incorporate it into their lessons. On the contrary, if a teacher doubts the effectiveness of technology or is uncertain about its impact on learning, they may avoid using it, even if they have the resources and knowledge to do so (Chen et al., 2020). These action judgments influence the teacher's daily decisions about integrating digital tools into their classrooms, thereby shaping the practical implementation of technology in education.

Error! Reference source not found. Figure 3.1 illustrates Vickers Framework, which categorizes teacher beliefs into three types of judgments: reality, value and action judgments. Reality judgments reflect teachers' beliefs of the current teaching environment, such as available resources, learner capabilities, and curriculum constraints. Value judgments emphasize what teachers consider essential for effective teaching, such as prioritizing critical thinking or collaborative learning. Finally, action judgments represent the decisions teachers make about integrating ICT tools based on their beliefs about its impact on learner learning. This framework highlights the interconnectedness of these judgments, showing how they collectively shape teachers' approaches to using technology in the classroom.

Figure 3.1

Vickers Framework



Note. Adapted from “Modelling ICT Perceptions and Views of Urban Front-Liners,” by G. Cohen-Blankstain, P. Nijkamp, K. van Monfort, 2004, *Urban Studies*, 41(13), p. 2647–2667. <https://doi.org/10.1080/0042098042000294600>. Copyright 2004 by Sage Publications.

Vickers Framework provides a structured approach to understanding the interplay between teachers’ beliefs and their practices in implementing IBST with ICT simulations. The framework underscores how teachers’ views of their environment, such as the adequacy of ICT tools or learners’ readiness for inquiry, influence their pedagogical values and, ultimately, their decisions to implement or refrain from using IBST approaches. These judgments are iterative and interconnected, with reality shaping values, values guiding actions, and actions feeding back into revised realities and beliefs over time. Visually, the framework uses a flowchart to highlight the cyclical relationship between these components, with annotations contextualizing its application to IBST and ICT simulations. This model is crucial for analyzing teachers’ beliefs, as it reveals potential conflicts (e.g., valuing inquiry-based learning but perceiving limited resources), aligns with constructivist principles, and identifies intervention opportunities. By dissecting these decision-making layers, the framework not only clarifies how beliefs impact ICT

simulation integration but also provides a lens to design professional development programs that harmonize reality perceptions with constructivist teaching values, thus enhancing IBST adoption.

3.4 Integration Insights from the Hew and Brush Framework

The Hew and Brush framework offers valuable insight into teachers' challenges when integrating technology into their classrooms. These challenges may be external and internal barriers to ICT integration. However, external factors are not the primary issue in the present study. The present study is in a technology-rich environment where teachers can access essential tools, administrative support, and flexible structures. This setting eliminates many common external obstacles that could impede technological adoption in teaching.

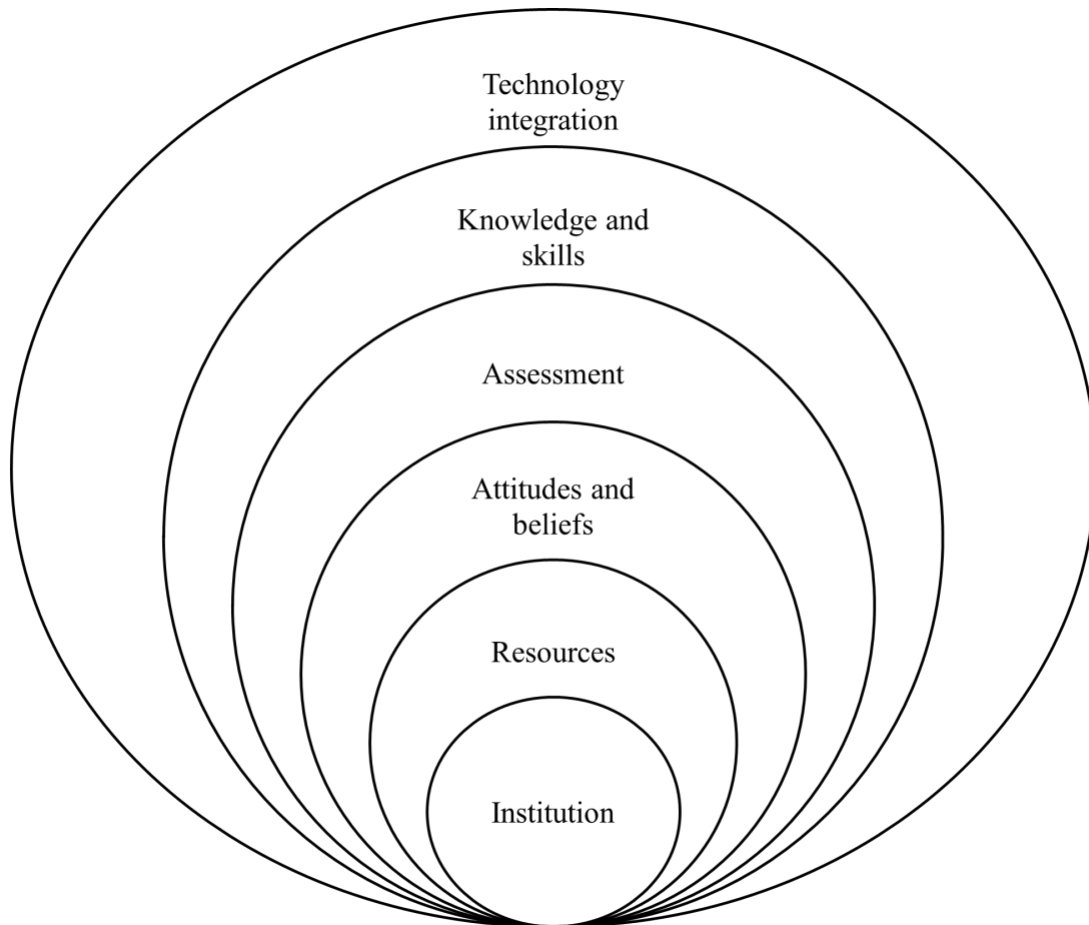
On the contrary, this study focuses on internal barriers, which, though less visible, can be equally or even more critical in shaping technology integration. Internal barriers primarily revolve around teachers' personal beliefs, knowledge, and confidence in using technology in classroom setups. Recent studies (Opre, 2021; Tondeur et al., 2017) indicate that teachers' beliefs about how vital ICT tools are in improving learning play a crucial role in their decision to use them successfully. If teachers perceive technology as a valuable tool for promoting inquiry and learner engagement and not as a distraction or simply an extra feature, the chances to use it are high.

The teacher's knowledge and proficiency with digital tools is another critical internal factor. Studies show that when teachers have strong ICT skills and feel confident using them, they are likelier to adopt technology in innovative and meaningful ways (Atman-Uslua, 2022; Inan & Lowther, 2010). However, even in technology-rich environments, gaps in knowledge or self-efficacy can limit how effectively these tools are used in the classroom. The present study zeroes in on these internal challenges, particularly teachers' beliefs about the role of technology and their skills in using ICT simulations. By exploring how these internal barriers influence their teaching practices, the research aims to shed light on the underlying dynamics that shape technology integration in education.

Figure 3.2

Figure 3.2

*Barriers to Technology
Integration*



Note. Adapted from “Integrating Technology into K-12 Education: Identifying Barriers and Their Solutions,” by K. Hew & T. Brush, 2007, *Educational Technology Research and Development*, 55(3), pp. 223-237. <https://doi.org/10.1007/s11423-006-9022-5>. Copyright 2007 by Springer.

Figure 3.2 illustrates the Hew and Brush Framework, which categorizes the barriers to technology integration into external factors and internal factors, providing a comprehensive lens for analyzing challenges in implementing ICT simulations in IBST.

The framework emphasizes that while external barriers often dominate discussions, internal barriers, such as a lack of constructivist beliefs or limited digital literacy, are equally if not more critical in determining whether and how teachers integrate ICT tools. This figure likely

employs an interlinked design, visually separating external and internal factors while illustrating their interdependencies, such as how internal beliefs about technology's educational value might exacerbate or mitigate external resource limitations. In this study, the framework's relevance lies in shifting the focus toward internal barriers in a technology-rich context where external challenges are minimized. It highlights how teachers' beliefs of ICT's role in fostering inquiry, their confidence in using simulations, and their pedagogical alignment with constructivist principles directly influence their adoption of IBST approaches. By identifying these barriers, the framework provides a basis for targeted interventions, such as professional development to enhance technical skills and reshape pedagogical beliefs, ultimately supporting deeper and more meaningful technology integration in inquiry-based science education.

3.5 Analysing Influencing Factors in IBST Through the BIUT Framework

The BIUT Framework used in the present study is based on constructivist principles, which suggests that teachers' beliefs about teaching, learning, and technology play a crucial role in determining their pedagogical practices. Teachers who hold constructivist beliefs tend to use inquiry-based methods and integrate technology to encourage active group work and learner-centred learning. The BIUT Framework highlights the critical role of understanding and addressing teachers' beliefs in implementing IBST and technology integration. Exploring the relationship between professional development (PD) and support systems with constructivist principles can create an environment where technology is used to engage learners in actively constructing knowledge rather than just delivering content. (Ottenbreit-Leftwich, 2013; Prestridge, 2017).

Teachers who hold a constructivist view see teaching and learning as an active and dynamic process that motivates learners to investigate, challenge their hypotheses, and build their knowledge. For these teachers, technology is used to help learners investigate, work together, and solve problems, following constructivist beliefs that emphasize learner empowerment and hands-on learning (Ertmer et al., 2012). Recent studies Chai et al. (2019); Lim et al. (2014) further emphasize that teachers' beliefs significantly impact how they integrate technology, often determining whether it is used to promote higher-order thinking or remains limited to traditional forms of instruction.

Professional development (PD) aligned with constructivist ideals is crucial for fostering these beliefs. Supporting teachers in developing constructivist approaches to technology use can create a learning environment where technology is more than a vehicle for delivering content it becomes an integral part of the knowledge construction process. According to Essalih et al. (2024), sustained PD that aligns with constructivist principles and addresses teachers' epistemological beliefs fosters deeper integration of technology into inquiry-based practices.

The BIUT Framework thus positions teachers' beliefs as a central element in the successful implementation of IBST and technology integration. By focusing on these beliefs, the framework suggests that PD should introduce new tools and address the underlying pedagogical approaches that influence how those tools are utilized (Essalih et al., 2024). Such an approach promotes a more meaningful integration of technology, supporting the active construction of knowledge, fostering inquiry, and cultivating an interactive, learner-centred learning environment.

Figure

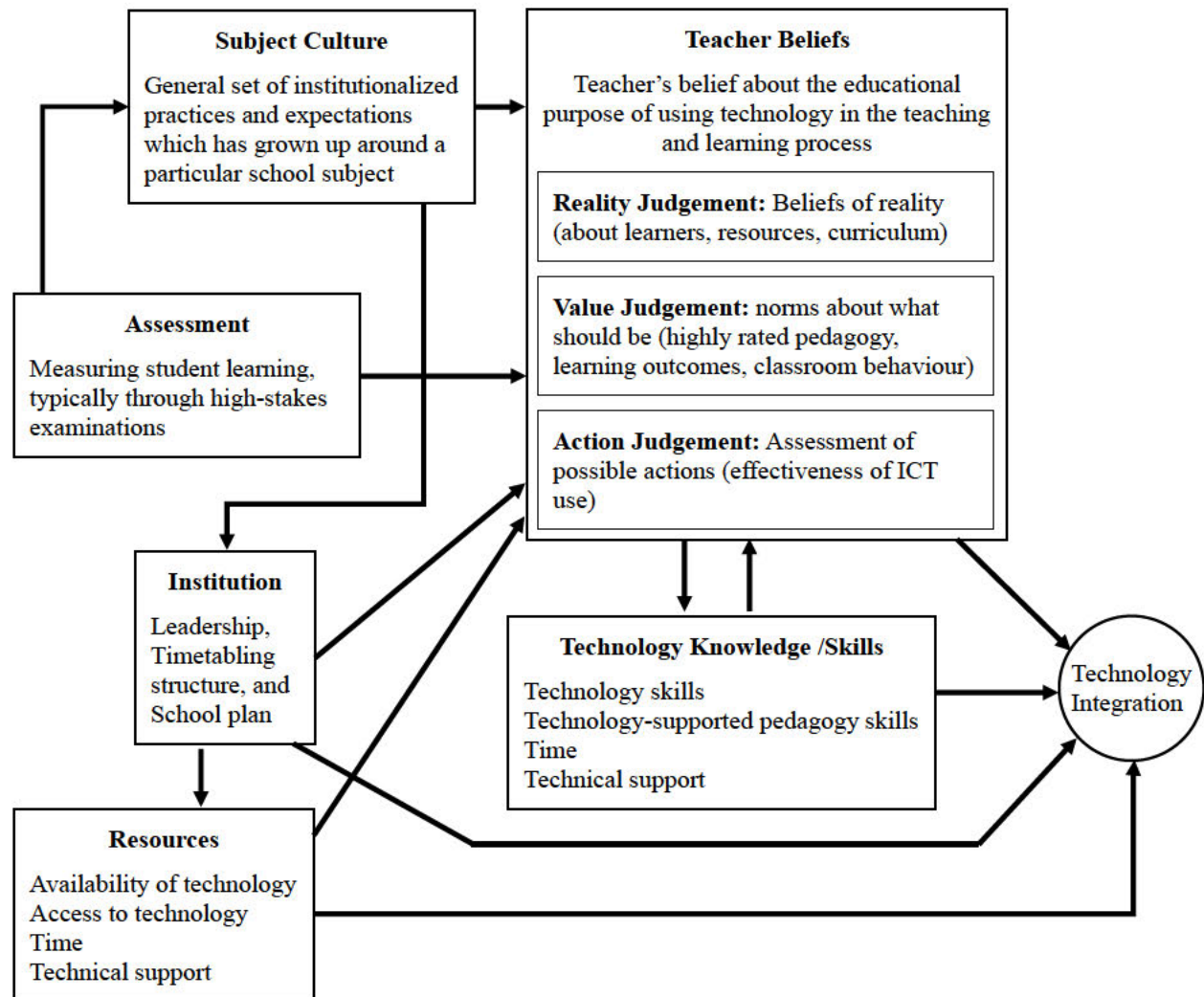
3.3

Beliefs Impacting the use of Technology (BIUT) Framework

explores how teachers' beliefs influence their adoption of technology by categorizing factors into barriers, interventions, understanding, and technology. It highlights the importance of teacher knowledge and support in fostering ICT simulations use aligned with inquiry-based teaching.

Figure 3.3

Beliefs Impacting the use of Technology (BIUT) Framework



Note. Adapted from “Natural Sciences Teachers’ Beliefs as Barriers for Integrating ICTs in a Technology-rich Context,” by A. Juggernath & N. Govender, 2020, *African Journal of Research in Mathematics, Science and Technology Education*, 24(1), p. 105–115.

<https://doi.org/10.1080/18117295.2020.1736854>. Copyright 2020 by Taylor & Francis.

The BIUT Framework synthesizes intrinsic and extrinsic factors influencing teachers' integration of ICT in teaching, with a focus on teacher beliefs as central barriers or enablers. The framework incorporates the Hew and Brush framework (external and internal barriers) and the Vickers Framework (types of judgments shaping beliefs). It highlights three key belief categories influencing ICT use: Reality Judgments (perceptions of classroom realities, such as resource management and learner abilities), Value Judgments (beliefs about effective teaching approaches and desired learning outcomes), and Action Judgments (beliefs about the impact of ICT simulations on learning outcomes and teacher efficacy).

In a technology-rich context, extrinsic barriers (e.g., lack of resources or institutional support) are minimized, leaving intrinsic factors especially beliefs as dominant influences. Teachers' judgments can act as barriers when they, for instance, perceive ICT simulations as making learners passive (action judgment) or believe that traditional methods are more effective for conceptual understanding (value judgment). Conversely, positive judgments about ICT's role in facilitating visual learning or collaboration can enhance its integration.

The BIUT Framework emphasizes the need for targeted professional development to reshape value and action judgments, promoting a shift toward learner-centred, inquiry-based uses of ICT. By addressing these belief-driven barriers, the framework offers a roadmap for transforming pedagogical practices in science education to integrate ICT meaningfully.

3.6 The Extended BIUT Framework

The Extended BIUT Framework (researchers' framework) is an expanded version of the original BIUT framework, designed to enhance the implementation of IBST by addressing a critical factor influencing its success. The original BIUT Framework primarily focused on the role of teachers' beliefs about teaching, learning, and technology, proposing that these beliefs significantly shape the extent to which technology is integrated into educational practices (Ottenbreit-Leftwich et al., 2010). The original BIUT Framework offered valuable insights by focusing on the connection between teachers' beliefs and technology usage, showing how teachers' epistemological orientations can impact technology-enhanced inquiry-based learning. The present study aligns closely with the BIUT Framework by focusing on the importance of beliefs in evaluating potential actions and decisions to incorporate ICT simulations in an IBST

approach. It builds on the original framework, which was developed to identify extrinsic factors (subject culture, assessments, institution, and recourses) and intrinsic factors (teachers' beliefs, teacher's knowledge, and skills) that impact the adoption and effectiveness of inquiry-based approaches in science education. This Extended BIUT Framework version builds upon these four pillars by incorporating additional layers of complexity that address the multifaceted nature of educational environments. It recognizes the connection between various educational factors, such as curriculum design, assessment practices, teacher beliefs, and PD.

For example, in the *Barriers* component, the framework expands beyond logistical and resource-based barriers to include cultural and systemic factors. These systemic barriers often manifest as rigid curricular standards, traditional assessment practices, or educational policies that do not align well with inquiry-based approaches (Levin et al., 2012).

Intervention within the Extended BIUT Framework takes a broader view, considering instructional strategies and some changes needed to foster a culture of inquiry in schools. The Extended BIUT Framework includes PD programs that equip science teachers with the skills and confidence necessary to facilitate and promote IBST and policy changes that allow for more flexible curricula within the schools.

Understanding goes beyond learners' grasp of scientific concepts to consider teachers' pedagogical content knowledge (PCK) and ability to guide learners through inquiry processes effectively. It emphasizes continuous teacher learning and adapting inquiry strategies to meet diverse learner needs. In the extended framework, *Technology* is viewed as an enabler of inquiry-based learning. Technology emphasizes the use of digital tools for conducting experiments, simulations, and for collaboration, communication, and the development of scientific literacy.

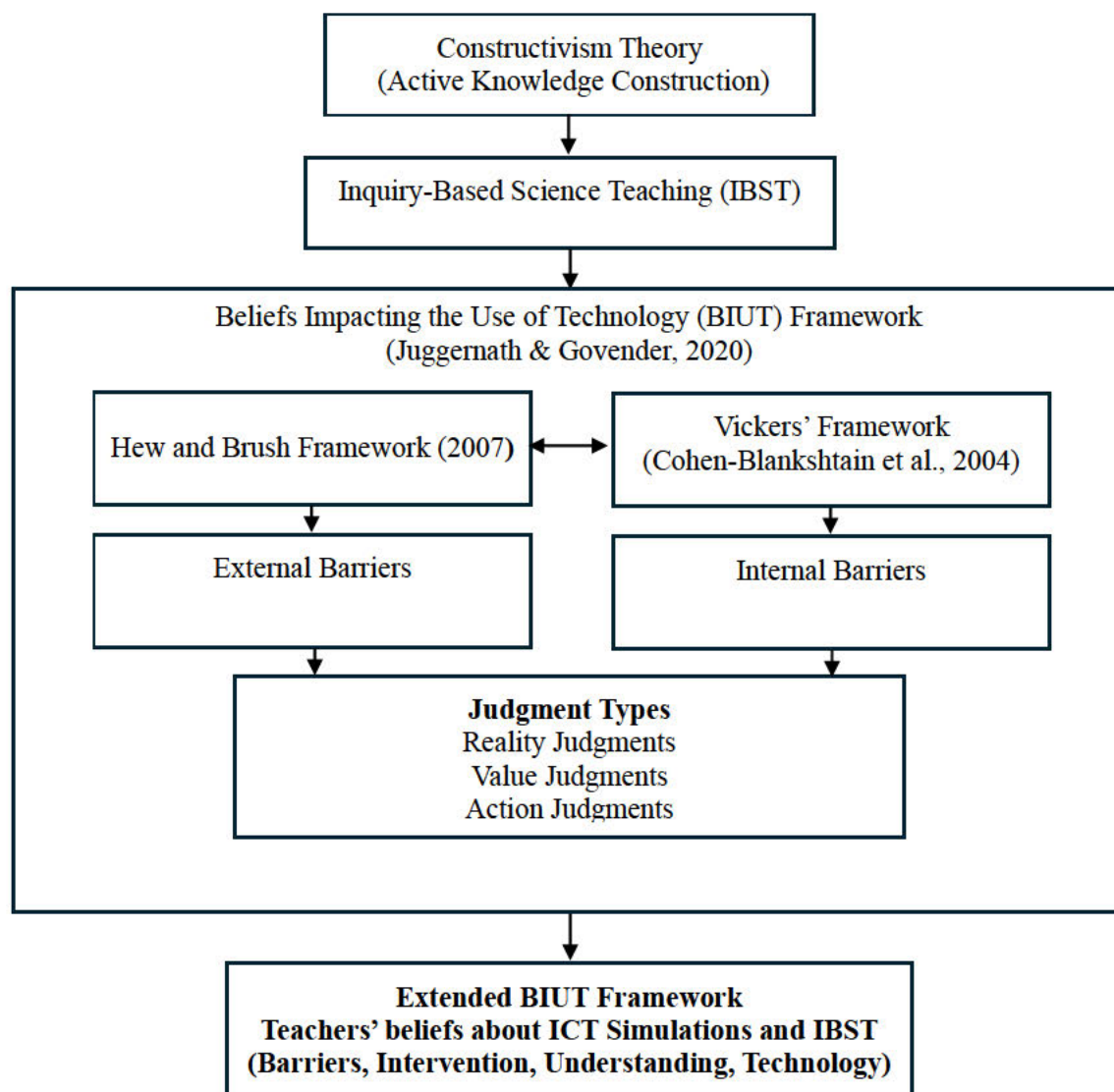
The Extended BIUT Framework aims to provide a more comprehensive and practical guide for teachers, policymakers, and researchers to support the implementation of IBST in diverse educational contexts by linking science teachers' beliefs with the use of ICT simulations and the implementation of IBST; it highlights the key aspects and barriers to successful technology adoption in science education. The Extended BIUT Framework, rooted in constructivist principles, focuses on building knowledge and recognizes how deeply teachers' beliefs shape their teaching practices. It also stresses the importance of addressing the complex

challenges within the education system while taking advantage of opportunities to make inquiry-based science education more impactful and sustainable.

Figure 3.4 illustrates the Extended BIUT Framework, a comprehensive model that integrates multiple theoretical perspectives, comprising constructivist learning theory, Hew and Brush Framework ((Hew & Brush, 2007), and Vickers Framework (Cohen-Blankshtain et al., 2004).

Figure 3.4

Beliefs Impacting the use of Technology Extended BIUT Framework



Note. Adapted from “Natural Sciences Teachers’ Beliefs as Barriers for Integrating ICTs in a Technology-rich Context,” by A. Juggernath & N. Govender, 2020, *African Journal of Research in Mathematics, Science and Technology Education*, 24(1), p. 105–115.

<https://doi.org/10.1080/18117295.2020.1736854>. Copyright 2020 by Routledge

Figure 3.4 represents the Extended BIUT Framework. Building on the original BIUT Framework, it incorporates additional layers of systemic complexity, such as curriculum design, assessment practices, policy constraints, and professional development (PD), alongside the foundational elements of barriers, intervention, understanding, and technology. This extended framework emphasizes the interconnectedness of intrinsic teacher beliefs with extrinsic institutional and cultural factors, illustrating how systemic challenges such as rigid curricula or traditional assessment frameworks interact with personal obstacles like teachers’ digital literacy and constructivist alignment. Likely depicted as a multi-tiered or networked framework, it highlights pathways for addressing barriers at both individual and systemic levels, with intervention points such as PD fostering both technical proficiency and constructivist teaching values. Central to the framework is its focus on aligning ICT simulation integration with inquiry principles, viewing technology as an enabler of collaboration, exploration, and critical thinking rather than merely a content delivery tool. By addressing the structural, cultural, and pedagogical dimensions of IBST, the Extended BIUT Framework offers a holistic roadmap for enhancing ICT simulations usage, ensuring alignment between teachers’ beliefs, institutional goals, and inquiry-based pedagogies. This framework serves as a key analytical tool in this research, revealing opportunities for systemic reform and personalized support to create sustainable and impactful IBST practices in science education.

3.7 Summary

In Chapter 3, the presented IBST conceptual framework aligns with constructivist learning theories. The aligned framework allowed examining the role of teachers' beliefs in successfully integrating ICT simulations into science education. The framework articulates that IBST is a pedagogical approach emphasising active, experiential learning where learners engage in scientific inquiry processes such as formulating questions, conducting investigations, and drawing evidence-based conclusions, fostering scientific literacy and critical thinking. The chapter integrates multiple theoretical perspectives, beginning with the Vickers Framework, which delineates the complex decision-making processes teachers undergo through three types of judgments: reality (perceptions of the classroom context), value (beliefs about effective teaching), and action (decisions about pedagogical practices). These judgments are connected, shaping how technology is incorporated into IBST and revealing the relationship between personal beliefs and practical limitations.

Chapter 3 also employed the Hew and Brush Framework to address barriers to technology adoption, distinguishing between external factors like resources and institutional support and internal barriers such as teachers' confidence, attitudes, and pedagogical content knowledge. In the context of the present study, where external barriers are minimized, the focus shifts to internal challenges, emphasizing how teachers' beliefs about the value of technology and their digital literacy impact its integration into learner-centred, inquiry-based practices.

Expanding the BIUT Framework situates teachers' constructivist beliefs at the core of successful IBST implementation, proposing that PD must enhance technical skills and reshape epistemological beliefs to support deeper learning and meaningful technology use. The Extended BIUT Framework (researchers' framework) broadens the scope by incorporating systemic factors such as curriculum rigidity, assessment practices, and policy considerations, recognizing that these elements can facilitate or hinder inquiry-based approaches. It calls for holistic interventions, including policy reform, flexible curricula, and ongoing PD, to address the educational environments' structural and cultural dimensions that impact IBST adoption. Chapter 3 underscored that teachers' pedagogical beliefs and values are critical determinants of how IBST and technology integration manifest in classrooms, advocating for a comprehensive

approach that addresses individual teacher beliefs and the broader educational system. This chapter using these frameworks within a constructivist paradigm, the chapter lays a theoretical foundation for examining teachers' beliefs about ICT simulation and how they relate to or influence their planned and implemented teaching using simulations. This foundation provides a multidimensional framework to guide future research and practice in advancing science education.

CHAPTER 4

METHODOLOGY

4.1 Introduction

In Chapter Three, the researcher presented the conceptual frameworks that support this study, establishing a basis for analysing science teachers' beliefs regarding ICT simulations in IBST. Chapter 4 describes the comprehensive methodology used to conduct an in-depth multiple-case study, to offer insights into science teachers' perspectives on ICT simulations in enhancing IBST and how their views influence instructional choices when using these resources. Essential parts of this chapter cover the study's overall methodological design, techniques for data gathering, analytical approaches, and reflections on dependability and possible constraints. The following research questions guided the study:

Research Question 1

What are science teachers' beliefs about IBST and ICT simulations?

Research Question 2

How do science teachers' beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations?

Research Question 3

Why do science teachers' beliefs about the use of ICT simulations as a form of IBST influence their teaching in the manner that they do?

4.2 Research Paradigm

Pragmatism emphasizes practical results, concentrating on “what is effective” in actual situations instead of pursuing a definitive depiction of truth or reality (Goldkuhl, 2012; Ivankova & Stick, 2007). Pragmatism acknowledges that reality is objectively existing and socially created, adjusting according to contextual needs (Cohen et al., 2017a). Knowledge is esteemed for its ability to solve problems, with theories evaluated according to their effectiveness in tackling real issues in educational practice (Essalih et al., 2024).

Pragmatism, as a worldview, blends well with qualitative research approaches because it is concerned with practical application, solving problems, and responding to the needs of participants, which is central to interpretive inquiry. “Both qualitative interpretive approaches and pragmatism share a focus on context, action, and the belief that understanding comes from the interactions between people and their environment.” Pragmatism does not propose one correct interpretation, and this parallels the flexibility of qualitative interpretivism in the interpretation of data (Creswell & Poth, 2017, p. 42).

Qualitative interpretive approaches align closely with pragmatism since it allows researchers to understand the personal experiences of science teachers in their actual environments (Merriam & Tisdell, 2015; Patton, 2014). “Pragmatic epistemology supports qualitative research because it allows for multiple perspectives. Interpretive research, with its emphasis on meaning-making, aligns with pragmatism’s flexibility and focus on the process of inquiry rather than rigidly defined outcomes” (Creswell & Poth, 2017, p. 38).

This interpretive approach is especially suited to examining teachers’ beliefs about ICT simulations and IBST, providing deep insights into their instructional choices and the contextual factors influencing technology use in the classroom. An interpretive lens complements pragmatism by emphasizing an understanding of individuals’ perspectives within specific, localized settings, essential when investigating personal beliefs and teaching practices (Cohen et al., 2017a; Creswell & Creswell, 2017).

Pragmatism was used in this study because it prioritizes practical outcomes and real-world applications over rigid theoretical constructs, making it particularly suited for investigating

teachers' beliefs about ICT and IBST. Since pragmatism acknowledges that reality is both objectively existing and socially constructed, it allows for a detailed exploration of how teachers navigate technology integration within their unique educational contexts (Cohen et al., 2017a). This paradigm aligns well with qualitative interpretive approaches, emphasizing meaning-making through interactions between individuals and their environments (Creswell & Poth, 2017). By adopting a pragmatic perspective, the study was able to explore the practical implications of ICT use in science teaching, focusing on how teachers' beliefs and contextual factors influence their instructional decisions. The flexibility of pragmatism supports the study's interpretive lens, allowing for multiple perspectives and a richer understanding of teachers' experiences with technology in inquiry-based learning (Merriam & Tisdell, 2015; Patton, 2014).

This research adopted a pragmatic approach and uses a multiple-case study method to explore beliefs and experiences of teachers' regarding ICT simulations and IBST. This approach addresses different philosophical dimensions: ontological (recognizing how the realities of classrooms influence teachers' beliefs), epistemological (investigating the essence of knowledge and reasons behind teachers' beliefs), and methodological (emphasizing teachers' beliefs as demonstrated through their teaching choices) (Ponelis, 2015). This method allows for creating detailed, contextual insights crucial for understanding the complexities of teachers' practices (Creswell & Clark, 2017). The advocacy of methodological pluralism by pragmatism aids this research, permitting the incorporation of various methods specifically designed to tackle the research questions instead of rigidly following only one tradition (Johnson & Onwuegbuzie, 2004; Teddlie & Tashakkori, 2011).

Further, by adopting a flexible approach that integrates both interpretivist and pragmatic principles, this study accounts for diverse realities, allowing for multiple valid interpretations of teachers' beliefs and practices (Hess et al., 2011). This approach allows the study to explore how teachers' beliefs shape their curriculum design, risk assessment regarding ICT simulations, and constructivist approaches within the specific contexts of their classrooms. The researcher hopes this combination of interpretive and pragmatic approaches will provide rich, context-specific insights to inform future educational practice and policy regarding IBST and ICT simulation integration. Pragmatic approach in qualitative research prioritize the exploration of

individuals' experiences as they unfold naturally, a focus well-supported by interpretive methodologies (Merriam & Tisdell, 2015; Patton, 2014).

In sum, the combination of pragmatic and interpretive approaches allows the researcher to explore not only what teachers believe and do regarding ICT simulations and IBST but also why they make certain instructional decisions within the complex realities of their classrooms. This flexible, context-sensitive approach fosters a comprehensive understanding of the teachers' beliefs and constraints that shape science teaching in technology-enhanced learning environments.

4.3 Research Design

This qualitative research used a multiple-case approach, which is well suited for examining phenomena in their natural settings (Yin, 2018). Multiple cases are studied together to investigate a phenomenon, population, or general condition, which was critical in understanding the shared and distinct experiences of science teachers integrating ICT simulations and it allows the researcher to explore differences within and between cases, which helps to gain a deeper understanding of the phenomenon and enhances the reliability of the findings (Creswell & Creswell, 2017).

According to Yin (2018), case studies are valuable in investigating 'how' and 'why' research questions, mainly when the distinction between the phenomenon and its context is unclear, and the researcher's influence over events is restricted. A multiple-case study, according to (Yin, 2018), is appropriate when the researcher seeks to understand a complex phenomenon within its real-life context, making this methodology ideal for examining the dynamic interplay between teachers' beliefs, pedagogical strategies, and systemic. This multiple-case study focused on specific science teachers to explore teachers' beliefs and actions towards ICT simulations and IBST, examining how these beliefs influence their teaching pedagogies and styles (Baxter & Jack, 2008; Hennessy et al., 2010).

Therefore, the multiple-case study method is suitable for this research as it allows a thorough investigation and detailed understanding of how science teachers' beliefs about ICT simulations and IBST influence their planning, implementation, and use of simulations in

teaching through various data sources like lesson plans, interviews, and classroom observations. This method allowed for a thorough grasp of the reasons behind teachers' integration of ICT simulations in IBST, and the particular obstacles encountered in their diverse teaching environments. Different data generation techniques enabled *crystallization*, a concept introduced in 'Writing as a Method of Inquiry' to qualitative research (Richardson & St. Pierre, 2005). Richardson conceptualized *crystallization* as a way for qualitative researchers to transcend conventional genre constraints, allowing for more flexible and creative approaches to presenting research findings:

The scholar draws freely on his or her productions from literary, artistic, and scientific genres, often breaking the boundaries of each of those as well. In these productions, the scholar might have different 'takes' on the same topic, what I think of as a postmodernist deconstruction of triangulation... In postmodernist mixed-genre texts, we do not crystallize, we crystallize... I propose that the central image for 'dependability' for postmodern texts is not the triangle a rigid, fixed, two-dimensional object. Rather, the central imaginary is the crystal, which combines symmetry and substance with an infinite variety of shapes, substances, transmutations, multi-dimensionality, and angles of approach... Crystallization provides us with a deepened, complex, thoroughly partial, understanding of the topic. Paradoxically, we know more and doubt what we know. Ingeniously, we know there is always more to know. (Richardson & St. Pierre, 2005, p. 93).

This technique complements rather than conflicts with other qualitative methodologies, bridging traditional qualitative analysis and creative genres. It encourages researchers to blend scientific rigor to achieve multiple goals: (a) exploring innovative ways to represent experiences, (b) broadening analytical perspectives, (c) critically reflecting on the researcher's positionality and influence in the field, and (d) thoughtfully considering how participants' voices are authentically represented (Ellingson, 2009). In addition to enhancing the trustworthiness of results and providing varied insights into science teachers' beliefs about ICT simulations and IBST, these technique also helped to validate and extend conceptually, the existing framework for IBST which is a combination of the Hew and Brush framework, Vickers framework, and BUIT. In line with the pragmatic paradigm, this research design was chosen to effectively

address the research questions, prioritizing practical applications of results over strict adherence to a specific methodology (Creswell & Clark, 2017; Creswell & Creswell, 2017). This study examines the beliefs and practices of science teachers to understand how they integrate ICT simulations as a form of IBST, as well as the intrinsic and extrinsic barriers they face. The findings could help improve education by guiding specific interventions to assist science teachers in using ICT resources in inquiry science-based teaching methods (Kim et al., 2013; Tondeur et al., 2017).

4.3.1 Research Strategy

This qualitative research, conducted at a School in Mozambique, employed a multiple-case study approach rooted in a pragmatic paradigm to explore three central research questions. The study focused on understanding teachers' beliefs about ICT simulations as a form of IBST. This approach provided a holistic view, allowing for an in-depth exploration of each case within its natural context (Yin, 2018).

The analysis relied exclusively on qualitative data generated through semi-structured interviews, classroom observations, and document analysis. This qualitative design is appropriate for interpreting complex social phenomena, capturing the contextualized and evolving nature of teachers' beliefs and practices. As Stake et al. (1998) noted, qualitative methods allow researchers to delve deeply into the meanings participants attribute to their experiences, which is essential for understanding the realities of ICT simulation integration in educational settings.

The thematic analysis method was employed to organize and interpret the qualitative data, providing a structured way to identify patterns, themes, and categories aligned with the research questions (Ketelhut et al., 2010). This method involves coding data and generating themes, which allows for the systematic synthesis of rich, descriptive insights (Cohen et al., 2017b). As Miles et al. (2014) outlined, qualitative data analysis involves three concurrent flows of activity: data reduction, data display, and conclusion drawing. This strategy enables researchers to distil large amounts of qualitative data generated in the field into manageable segments, display the data to highlight relationships and draw conclusions based on identified patterns.

Using these qualitative techniques within a multiple-case study allowed for understanding the ICT simulation adoption process. This approach highlighted the individual experiences of teachers at School and allowed for cross-case analysis, identifying common themes and contextual factors influencing the integration of ICT simulations in teaching practices.

4.3.2 *The Research Site*

The research was conducted at a private school in Maputo, a middle-income suburb in Mozambique. The school is a well-resourced high school accommodating approximately 1000 learners from Grade R to Grade 12. The school had established a fair ICT infrastructure, including Wi-Fi and internet access available to learners and teachers. Additionally, learners from Grade 8 to Grade 12 were required to have electronic devices for accessing educational materials through the school's learning management system, which uses Google Classroom. Most classrooms were equipped with digital projectors, but the school unfortunately did not have a dedicated IT manager to oversee the ICT systems and provide technical support as teachers needed.

The research specifically involved Grades 10, 11, and 12, as these senior grades required more advanced instructional strategies and greater engagement with ICT for learning. Given that learners in these grades were allowed to use electronic devices for accessing educational materials, the study aimed to explore how science teachers integrated ICT within their teaching practices. These grades were also crucial for examining the effectiveness of the school's blended learning approach in preparing students for higher education and future careers, where digital literacy plays a significant role.

In line with the school's ICT policy, science teachers were encouraged to adopt a blended learning approach, which combines traditional teaching methods with digital and online resources. Traditional methods typically include chalkboards, whiteboards, printed materials, and physical textbooks, while digital resources integrated mostly computers, cell phones, tablets, and data projectors all integrated to enhance the ICT simulations learning experience. Despite this ICT simulations setup, teachers' use of ICT resources remained limited. According to an anonymous survey conducted by the school's Head of Digital Learning, a primary reason cited

for this limited use of technology is the lack of professional development focused on effective ICT simulation integration in teaching practices.

4.3.3 *The Participants*

Selecting a suitable population and sample is crucial for any research endeavour. This choice significantly affects how well the study's findings' generalizability, accuracy, and usefulness. The population for this research study comprised teachers actively engaged in teaching responsibilities within educational institutions. This diverse group included teachers from various backgrounds, specialties, and levels of expertise. The decision to concentrate on teachers was influenced by the assumption that they are the primary agents promoting technology integration in the classroom. Their attitudes, practices, challenges, and visions influence how technology is integrated into educational processes, impacting learners' learning outcomes and experiences (Mukherjee, 2019). However, although the population offered a large canvas, focusing on a representative sample was critical.

Given the qualitative nature of the study, a purposive sampling strategy was used. This non-randomized sampling technique guaranteed that participants were selected based on specified criteria that matched the aims and questions of the research (Quinlan, 2011). The following were among the selection criteria:

Minimum teaching experience: A minimum of three years of teaching experience helps ensure they have substantial classroom experience and established pedagogical practices, allowing them to offer relevant views on ICT simulations integration in IBST.

Experience with ICT in teaching: Science teachers who had experience in using ICT tools or simulations as part of their science teaching and those who integrated technology into their pedagogical practices, either as main tools or supplementary resources, is crucial as the study focused on the application and beliefs of ICT simulations within IBST.

Willingness to participate in reflective practices: Science teachers had to be open to engaging in reflective practices such as interviews, lesson observations, and discussions. These reflective practices were essential for understanding their beliefs and instructional decisions about ICT simulations use in the classroom.

Familiarity with IBST: Preference was given to teachers familiar with or actively engaging in IBST practices. Since the study examines how IBST and ICT simulations relate to their planned and implemented teaching using simulations, teachers with a background in inquiry-based methods are more likely to provide relevant insights.

Open minded to new educational technologies: Science teachers had to be positive or open toward new educational technologies. Open minded teachers towards technology and inquiry can contribute with valid views into the challenges and opportunities associated with ICT simulations in IBST.

Once these criteria were established, determining the sample size was the next task. In qualitative research, the emphasis is on depth, richness, and the capacity to attain saturation - at which no new themes or insights emerge from the data (Pandey & Pandey, 2021). A *sample of five teachers* was chosen based on this framework and the feasibility of conducting in-depth interviews, classroom observations, and document analysis. This amount permits a thorough investigation while ensuring the study remains manageable. However, it is critical to recognize the potential limitations of purposive sampling. Considering the non-random nature, biases may arise, potentially marginalizing certain voices or viewpoints. Transparency of the sampling criteria and logic ensured minimal sources of bias. Furthermore, as Greening (2019) suggests, the findings were constantly contrasted with the broader literature to ensure they resonated with larger patterns and trends.

Another critical part was ensuring sample diversity. While experience and technology usage were the primary criteria, efforts were taken to ensure that the sample represented diversity in gender, age, teaching disciplines, and institutional affiliations. Such diversity diversified the data, giving varied views and lowering the likelihood of biased or restricted viewpoints (Mishra & Alok, 2022). This sampling procedure aligned well with the research methods employed. For instance, semi-structured interviews gained greater relevance when participants shared narratives, comments, and reflections from their diverse experiences. Similarly, classroom observations benefited from diverse teachers' educational methods and technology integrations (Snyder, 2019).

4.3.3.1 Demographic Considering the demographic characteristics of the science teachers in the study helped the researcher understand the insights better. These demographics offered a comprehensive background to the participants, allowing a deeper understanding of their perspectives and views. Table 4.1 shows the age distribution of science teachers.

Table 4.1

Age of Science Teachers

Age	n	%
25-30	2	40
31-35	1	20
36-40	1	20
41-45	1	20
Total	5	100

Table 4.2 shows that a significant proportion of science teachers (40 %) fall in the age group of 25-30, indicating that many of the participants are relatively early in their teaching careers. This lack of experience may impact their propensity and adaptability towards technology.

Table 4.2 shows the teaching experience distribution of science teachers.

Table 4.2

Years of Teaching Experience

Experience (years)	n	%
3-5	3	60%
6-10	1	20%
11-15	1	20%
Total	5	100%

Table 4.3 presents the academic qualifications of the five science teachers and the respective grades they teach. Understanding teachers' educational backgrounds provides insight into their pedagogical approaches and potential influences on their instructional decisions. The

table highlights the diversity in qualifications, ranging from diploma-level training to master's degrees, which may impact their use of ICT simulations and inquiry-based science teaching (IBST) methodologies.

Table 4.3

Academic Qualifications and Grades Taught by Science Teachers

Academic Qualification	n	Grades Taught
BSc in Science Education	2	10, 11
BEd in Science Teaching	1	10, 11, 12
MSc in Science Education	1	10, 11, 12
Diploma in Science Teaching	1	8, 9, 10
Total	5	

Table 4.4 shows that the majority of science teachers (60%) have 3-5 years of teaching experience. This data aligns with the age distribution, where a sizable portion of science teachers are in the younger age group. **Error! Reference source not found.** It shows the training status of science teachers.

Table 4.4

Training in Educational Technology

Training status	n	%
Formal training	2	40%
Self-taught	3	60%
Total	5	100%

Interestingly, a significant proportion of the science teachers (60%) are self-taught in terms of educational technology, implying a proactive approach towards integrating technology in their classrooms. All teachers in the sample specialized in Physical Sciences.

The demographic data contextualizes the insights and experiences of the Science teachers. The age and experience distribution indicates that most science teachers in the sample are relatively young and early in their teaching careers. Their approach to training, particularly

the high percentage of self-taught individuals, reflects an evolving landscape where science teachers are proactively managing their professional development.

4.4 Data Generating Tools

In a multiple-case study design, using multiple data sources and methods enables a comprehensive exploration of the phenomenon being studied by capturing various perspectives and ensuring data crystallization (Cohen et al., 2017b; Yin, 2018). This approach typically includes diverse methods, such as semi-structured interviews, document analysis, and observations (Merriam & Tisdell, 2015; Yin, 2018). The present study used semi-structured individual interviews alongside lesson plans, school policy documents, and classroom observations to address the research questions. Drawing on findings from previous research, which emphasized the effectiveness of these methods in understanding teachers' beliefs and instructional practices using ICT simulations in IBST, the study's data generation strategy was designed to capture the complexities of teachers' experiences, teachers beliefs, and their practices (Chabalengula & Mumba, 2012). Data were gathered through the described methods, followed by a post-lesson discussion to provide in-depth, reflective insights into teachers' pedagogical decisions and beliefs on ICT simulations as a form of IBST. This study investigated science teachers' beliefs of ICT simulation to enhance IBST and how technology is incorporated into education, using a comprehensive and reflective analysis approach to reveal both general themes and complex details (Kumar, 2018).

4.4.1 Interviews

As a qualitative data-gathering method, a semi-structured interview can facilitate for a critical examination individual experiences, opinions, beliefs, and emotions. A semi-structured interview instrument, embedded within the wider matrix of qualitative research, is distinguished by its flexibility, enabling both the interviewer and interviewee a degree of freedom and spontaneity while being tied to established topics as proposed by (Kumar, 2018).

Semi-structured interviews provided an in-depth, flexible way to explore teachers' beliefs, attitudes, and experiences with ICT simulations in IBST, "through interviews, researchers are able to explore complex phenomena, uncovering meanings, beliefs, and

interpretations that cannot easily be accessed through other methods... Through interviews, researchers are able to explore complex phenomena, uncovering meanings, beliefs, and interpretations that cannot easily be accessed through other methods” (Creswell & Creswell, 2017, p. 176). This method allowed for an open-ended dialogue where science teachers could express their views in their own words while also enabling the researcher to probe specific areas relevant to the research questions.

The semi-structured interview questions were developed based on the study’s objectives and previous findings from the literature (see Appendix C 1). Key aspects of IBST and ICT integration guided the structure, ensuring alignment with relevant theoretical frameworks (Hew & Brush, 2007; Tondeur et al., 2017). To enhance reliability and validity, the questions were reviewed by experts in science education and technology integration, ensuring they effectively captured teachers’ beliefs and experiences. A pilot study was conducted with two teachers to refine the questions for clarity and relevance, leading to adjustments in wording and question sequencing

Questions were open-ended to allow for detailed responses, while follow-up questions were prepared to probe deeper into critical areas, such as teachers’ beliefs about IBST and ICT’s role (Cohen et al., 2017a). “A qualitative interview occurs when researchers ask one or more participants general, open-ended questions and record their answers, this allows the participants to best voice their experiences unconstrained by any perspectives of the researcher or past research findings” (Creswell & Poth, 2017, p. 164). According to Creswell and Creswell (2017), “qualitative interviews are particularly valuable when the researcher aims to understand the context and depth of participants’ experiences, providing an opportunity to ask clarifying questions and probe deeper into responses (p. 178).” Each teacher was briefed on the purpose of the interview, assuring them of confidentiality and emphasizing the importance of honesty and openness. Teachers were given an overview of the questions to help them feel prepared and comfortable during the interview. Interviews were conducted individually and allowed teachers to discuss their experiences in depth while minimizing external influences.

Teachers were asked to describe their understanding and views of IBST and how they perceived ICT simulations as a support for inquiry-based methods. Teachers discussed their

specific strategies for integrating ICT simulations, how these aligned with inquiry-based methods, and any adjustments they made to accommodate learners' needs. Teachers shared insights into the barriers and enablers they encountered, such as resource availability, learner engagement, or institutional support. During interviews, the researcher remained flexible, allowing teachers to expand on topics of particular importance, creating a richer and more nuanced dataset. After each interview, participants were allowed to clarify or expand on their responses, especially if any points required further elaboration. This process encouraged a more thorough understanding of the teachers' perspectives, supporting the study's objectives. Interview transcripts were then analysed using thematic coding, with themes representing recurring ideas, attitudes, and experiences shared by participants. These themes were cross-referenced with observation data to crystallize insights into teachers' practices and beliefs.

4.4.2 Lesson Observations

Classroom observation was a critical method to gain direct insights into the teaching and learning process as teachers integrated ICT simulations within IBST. This approach offered a structured way to examine real-time classroom dynamics, instructional techniques, and the role of technology in facilitating inquiry-based learning. Observing in the natural classroom environment, the researcher captured nuances that may not emerge in self-reported data such as interviews.

The researcher provided an overview to each participating teacher, detailing the observation's main objectives and the specific classroom aspects that would be monitored. Various aspects were taken into account during classroom observations which included classroom dynamics, teacher-learner interactions, instructional techniques, and ICT simulation use. Teachers were informed about the observation protocol, which aligned with Mukherjee's (2019) guidelines for structured observation, thus setting clear expectations for both the observer and participants. The researcher was not allowed to record during classroom observations, which presented challenges in capturing the full scope of classroom interactions and instructional details. To address this, the researcher relied on meticulous, real-time notetaking, which required heightened attention and careful planning to ensure that all relevant aspects of the classroom environment were documented accurately.

An initial observation session was conducted to familiarize teachers with the observer's presence ensuring that their teaching practices were not significantly influenced by the observation itself. This step was crucial to minimize the Hawthorne effect where teachers or learners may alter their behaviour due to awareness of being observed (Greening, 2019). The familiarization period helped create a comfortable atmosphere, allowing teachers to conduct their instructional activities as naturally as possible. Once the teachers became comfortable with the observation process, structured observations were conducted using a detailed protocol (see Appendix C2).

After each observation, the researcher engaged in reflective discussions with the teachers, allowing them to share insights on what went well, any instructional challenges encountered, and their overall impressions of ICT integration in the lesson. This reflective phase was invaluable for gaining additional context and understanding any deviations from planned instruction, allowing teachers to discuss practical difficulties and successes. To ensure accuracy, reflective discussions were audio-recorded (with participants' consent), transcribed, and analyzed thematically alongside observation notes. In cases where audio recording was not feasible, field notes were taken, documenting teachers' responses and key insights. This systematic approach to observation and reflection allowed for a comprehensive understanding of how teachers implemented IBST strategies, their challenges, and their evolving beliefs about technology integration.

At least two observation sessions were conducted for each teacher, enabling the researcher to validate initial findings and observe any evolution in teaching strategies over time. Repeat observations allowed for consistency checks and captured adjustments that teachers made to improve the effectiveness of their IBST practices. Observation data was analysed alongside semi-structured interview responses and lesson plans to verify patterns across data sources. This crystallization helped reinforce the credibility of findings by confirming observed behaviours against teachers' reported practices and lesson objectives.

4.4.3 Document Analysis

Document analysis is a fundamental approach in qualitative research involving a methodical review of written materials to gain in-depth insights into non-reactively and

unobtrusive events, drawing from a broad spectrum of sources, including reports, minutes of meetings, transcripts, newspapers, and diaries. The success of this technique is dependent on its capacity to provide a historical and contextual perspective, allowing for a more in-depth knowledge of the research issue (Mishra & Alok, 2022).

Document analysis systematically examines teachers' lesson plans, instructional materials, and other relevant documents. This method provided contextual insights into the structured aspects of teaching practice, revealing how teachers planned to integrate ICT simulations and how these plans aligned with IBST principles. Teachers provided lesson plans and instructional documents related to the observed lessons. These included lesson objectives, planned activities, resources, curriculum guidelines, and assessment strategies. Each document was reviewed for information to shed light on the teacher's planning process, particularly regarding technology integration.

4.5 Procedures

Upon receiving ethical clearance from the University of KwaZulu-Natal (see Appendix A 1), an application letter was submitted to the school's general director, where the research was intended to be conducted (see Appendix B 2). Following approval, a preliminary meeting was scheduled with the school's principal to discuss the study's objectives, schedule, and logistics. Permission from the university to conduct research was previously granted as it was essential for ethical compliance, as stipulated by the ethical clearance certificate guidelines (Creswell & Poth, 2017; Patton, 2014).

During the meeting, the school's principal agreed to support the study, recognizing its potential value for teacher development. However, they established certain conditions: the study should not interfere with teachers' instructional duties during school hours, and teachers would retain the right to withdraw if participation affected their job performance (McMillan & Schumacher, 2010; Merriam & Tisdell, 2015). This agreement revealed the importance of accommodating teachers' responsibilities, consistent with ethical research standards (Hess et al., 2011). A session was arranged with the pedagogical director of the school, where a presentation was given to outline the study's main goals, particularly the classroom observation process and

the central role of participants. Due to the specific participant selection criteria, only five science teachers met the criteria.

The school allocated a date for a presentation to all the interested teachers, where the researcher was given time to outline the study's main goal; the presentation was done in PowerPoint. The presentation contextualized the study, highlighted its relevance for teacher development, and explained the specific procedures involved. All participants responded positively, with all of them expressing interest in participation. Only five science teachers could be selected based on the selection criteria, but one additional teacher was selected to be part of the pilot study.

One teacher participated in an initial lesson study process and served as the pilot study, essential for refining the research instruments and processes before the main study commenced (Teddle & Tashakkori, 2011). This pilot phase provided a valuable opportunity to test the logistics and ensure that the lesson study framework was suitable for the research objectives.

This phase, guided by both pragmatic and interpretive paradigms, ensured ethical adherence, contextual relevance, and participant engagement, which is critical for generating rich, contextually grounded insights into teachers' beliefs about ICT simulation integration and IBST in their classrooms (McChesney & Aldridge, 2019).

4.6 The Pilot Study

This pilot study was conducted to explore science teachers' beliefs regarding the use of ICT simulations as a form of IBST. The purpose was to trial the study's procedures and refine them before the main study. This section outlines the stages of the pilot study, reflections on each phase, and revisions made based on the findings. At the initial meeting, the participant was introduced to the study's objectives and his role, including the support of an IT team designated to provide technical assistance with ICT simulation integration. The roles of the volunteering teacher and researcher were clarified, creating a collaborative environment. A schedule of meetings was established according to the teacher's availability to coordinate the interview and classroom observation lesson session.

4.6.1 Stage 1: The Introductory Session

The pilot study started with an introductory session to give the teacher research guidelines where the researcher discussed the schedule and the plan with the teacher. Guidelines for the study were provided to the teacher to deepen his understanding, and he also had the opportunity to ask questions throughout the session. The researcher and the teacher discussed and established norms for behaviour inside the classroom, emphasising equal participation. The planning process began with the teacher working collaboratively and drafting initial lesson plans using a standardized lesson planning template. Although he spent about two hours planning the lesson, the initial lesson plan was found to lack sufficient detail. The lesson plan had a vague description, leading to a decision to revise the planning template for subsequent stages.

4.6.2 Stage 2: Implementation and Observation

The next phase involved lesson observations. The researcher selected a lesson, incorporating ICT resources as prescribed by the Lesson plan. Phet simulation was to be used in the lesson. The classroom required functional ICT tools, and recording the lessons was not allowed, so arrangements were made to ensure proper setup. Teachers could engage in post-lesson reflection with the researcher without leaving his classroom, which minimized classroom disruption and facilitated richer data generation. After the lesson, the researcher and the teacher reviewed and discussed the lesson observed. The teacher and the researcher reflected on ICT simulations use and IBST, lesson content integration, and suggestions for improvement, capturing reflections on individual and group experiences.

4.6.3 Stage 3: Reflection and Revision

The reflective phase was structured around a lesson plan document, encouraging the teacher to think deeply about his instructional practices, particularly his application of ICT simulation as a form of IBST highlighting areas of success and improvement, leading to the revision of lesson plans based on the feedback. During the discussion, he highlighted the need

for more comprehensive lesson planning. Thus, a revised lesson planning template was developed to capture detailed instructional strategies, specific ICT simulations usage, and a reflective component on pedagogical choices. This structured format aimed to help him articulate his lesson objectives and teaching approaches clearly, ensuring better consistency and depth in lesson planning.

4.6.4 Stage 4: Teachers' Interview Process

The pilot study included a test phase for the teacher interview process, aiming to refine questions and assess their effectiveness in eliciting in-depth responses about teachers' beliefs regarding ICT integration in IBST. The interview questions initially focused on broad themes, such as teachers' general views on the advantages and challenges of Lesson Study, which led to responses that were often off-topic or unrelated to ICT simulations use.

The interview guide was revised to adopt a more conversational tone, beginning with questions that allowed the teacher to share his opinion on the lesson plan process and gradually moving into more specific questions about ICT simulation integration in science teaching. Terms like 'phenomenon' were clarified or replaced with simpler language to reduce ambiguity and ensure that the teacher understood each question clearly.

Additionally, questions were rephrased and removed to directly focus on using ICT simulations in facilitating IBST in the classroom, thus ensuring that responses were relevant to the study's objectives. This iterative adjustment to the interview protocol allowed the researcher to capture more precise insights into teachers' beliefs, experiences, and the perceived impact of ICT simulations on their instructional practices in IBST.

4.6.5 Stage 5: Lessons Learnt from the Pilot Study

4.6.5.1 Enhanced Planning Template

Based on the observed lack of detail in initial lesson plans, the template was revised to require more explicit information on ICT simulation integration, pedagogical strategies, and content connections. Reflective questions were added, such as "Why was this topic selected?"

and “How did the class discuss and link this topic to the educational goals?” This structured format facilitated more thorough planning and alignment with IBST principles.

4.6.5.2 Revised Interview Structure

Post-lesson interviews were adjusted based on pilot feedback. The initial interviews were formal, and the teacher struggled with ambiguous terms, such as “phenomenon,” when asked to describe their experiences. Rephrasing questions or removing some of them to use more conversational language allowed the discussion to flow more naturally and ensured better alignment with the study’s objectives on ICT integration.

4.6.5.3 Reflective Process

The reflection in the revised template helped the teacher articulate his beliefs, instructional decisions, and views on ICT simulations more clearly. This process revealed that the participant needed guidance to connect his reflections directly to IBST principles and the specific advantages of ICT tools in engaging learners.

This process provided clarity and consistency, ensuring the research study could effectively capture data on teachers’ beliefs, instructional approaches, and reflections on ICT simulation integration in inquiry-based science teaching (see Appendix C3). This pilot study tested the research instruments and methods and generated preliminary insights into teachers’ beliefs, collaborative practices, and challenges in using ICT simulations within IBST. The reflections and modifications derived from this pilot study were essential in refining the approach and enhancing the credibility and relevance of the upcoming main study.

4.7 The Study

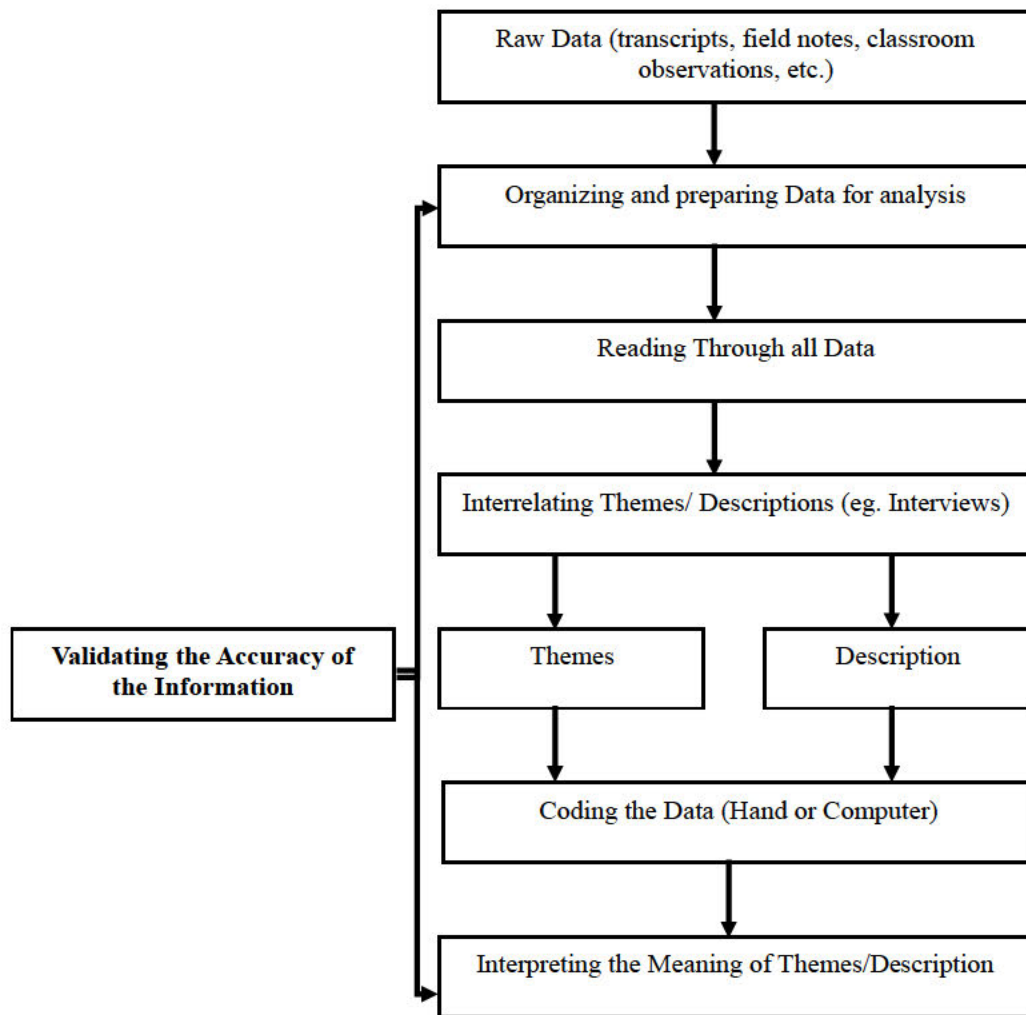
Due to the complexity of the data generated, a comprehensive and systematic approach was essential to ensure its organized and impartial analysis. The initial phase consisted of organizing and familiarizing with the collected data. This phase involved transcribing the

interviews, documenting classroom observations, and gathering relevant documents, followed by an immersion phase. Throughout this period, initial analyses of the data collected started, taking preliminary notes and highlighting repeated phrases, concepts, or keywords (Quinlan, 2011). This phase was crucial in connecting with the data, allowing the researcher to grasp its intricacies and range.

Subsequently, a coding procedure was initiated, which, according to Pandey and Pandey (2021), involves the organised classification of data into manageable and significant segments. All data were structured by combining predefined codes aligned with the research aims and new codes from the data. Newman and Gough (2020) described the qualitative analysis technique as robust and focused on identifying, analysing, and interpreting patterns in the gathered data. The next phase included grouping the coded data to form potential themes. Themes go beyond single codes; they capture key patterns summarizing the main ideas across larger data sections. This process involved repeatedly reviewing the data, adjusting the theme definitions, and ensuring they reflected the full depth and complexity. At this stage, Mukherjee (2019) highlights the importance of dependability checks. To ensure the emergent themes accurately represented the data, they were continually cross-referenced with raw data excerpts. This crystallization strengthens the study's dependability, ensuring the interpretations are based on participants' perspectives. The literature review guided the data generation methods, highlighting effective strategies used by previous researchers to understand the phenomenon. Data for this study were generated through classroom observations, additionally, a semi-structured interview, teachers' lesson plans, and other relevant school documents were used to view participants' beliefs and experiences comprehensively. Figure 4.1 represents the data generation procedures employed to analyse the qualitative case study data.

Figure 4.1

A summary of the process of the analysis of data generated



Note. Source: Author's own creation, 2024.8 Data Analysis

The present study used qualitative data analysis to address the three research questions, framed within a pragmatic paradigm and employing a multiple multiple-case study approach.

The analysis focused on qualitative data from semi-structured interviews, classroom observations, and document reviews. Each data source was first analysed independently to provide a comprehensive understanding of individual insights before being integrated for a holistic interpretation.

A crystallization strategy was used Creswell and Creswell (2017), in which qualitative data were collected and analysed simultaneously. This approach enabled comparisons across data types to identify convergent themes and patterns while addressing emerging disparities.

The semi-structured interviews were analysed using thematic coding, categories and themes to capture themes of teachers' beliefs, instructional approaches, and reflections on their experiences with ICT simulation integration. During classroom observations, the researcher tried identifying behaviours and instructional methods that aligned with or contradicted the teachers' reported beliefs and teaching practices. Document analysis further corroborated these findings by revealing insights from lesson plans, instructional documents, and curriculum guidelines, adding depth to the understanding of the teachers' classroom approaches.

The crystallization strategy provided well-substantiated findings, as data from interviews, observations, and document analysis were crystallized in the analyses and discussion section to produce a comprehensive result. Although crystallization also presents challenges, such as sorting out discrepancies among data sources, this design was optimal for this study. A concurrent crystallization strategy was employed to merge the insights from all three methods, creating a comprehensive view of the teachers' experiences and addressing potential biases within any data source (Creswell & Creswell, 2017). This approach allowed for cross-verification of findings, enhancing the credibility and depth of the study by ensuring that observations, statements, and recorded plans aligned to create a fuller understanding of teachers' experiences integrating ICT in IBST.

4.9 Qualitative Data Analysis

Data were analysed using thematic analysis, which helped uncover critical patterns and themes by organizing data into categories that responded directly to the research questions (Braun et al., 2016). This approach is effective for studies that aim to capture detailed, real-world

insights, as it helps highlight the different views of participants (Cohen et al., 2017b). The analysis followed the structure suggested by Miles et al. (2014), involving coding the data, organizing it into visual formats such as tables, and drawing systematic conclusions. This approach allowed for a clear, organized view of the data, making interpreting teachers' insights and experiences easier.

Data generation relied on semi-structured interviews, classroom observations, and document analysis. In this analysis, data were reduced, displayed, and organized for synthesis, following the structure proposed by Miles et al. (2014), which recommends reducing data through coding, displaying it in matrices or other visual forms, and drawing conclusions systematically. This iterative process allowed for deep reflection on each aspect of the data while ensuring accuracy and thoroughness.

Coding involved systematically labelling text segments from interviews, observational notes, and documents to identify recurring themes and ideas. This initial coding phase used both inductive and deductive approaches. Inductively, codes emerged organically from the data, capturing the nuances in teachers' descriptions and experiences with ICT simulation integration in their teaching contexts. Deductively, the research questions and existing frameworks on ICT simulation integration and lesson study practices informed specific codes, providing a structure for analysis (Vaismoradi et al., 2016).

Caulfield (2019) framed the thematic analysis as three key stages: noticing, collecting, and thinking about the data. The noticing stage involved identifying recurring patterns and specific terms that signalled significant insights. Data were then organized into themes that encapsulated major topics and viewpoints within each participant's responses. Each observation or interview was summarized to highlight the most relevant data points, allowing themes to emerge representing common issues across cases.

To ensure credibility multiple forms of data were used for crystallization, comparing data from semi-structured interviews, observations, and document analysis. This method verified the consistency of findings across sources, strengthening credibility (Creswell & Creswell, 2017). Consistency in coding was also verified by comparing codes with a colleague, with discrepancies discussed until a consensus was reached (Yin, 2009). Data were then displayed and organized

into charts or narrative summaries, facilitating an in-depth analysis of each case individually, and cross-case comparisons. Conclusions were drawn by revisiting codes and themes, ensuring they aligned with the present study's objectives and reflected teachers' authentic experiences (Miles et al., 2014).

4.10 Ethical Considerations

Research ethics have become necessary, especially in qualitative research, where participants' beliefs, experiences, and personal stories are deeply involved. As Kumar (2018) points out, ethics goes beyond just following rules. It includes a strong commitment to respecting and protecting participants' dignity, rights, and well-being. From the beginning of this research, it was clear that teachers, their practices, and their perspectives on technology in classrooms would be closely examined. It was imperative to scrutinize it with the utmost respect and integrity. Quinlan (2011) emphasizes that ensuring ethical rigour extends beyond mere adherence to predetermined rules and involves adopting an attitude of respect and understanding towards participants.

4.10. 1 *Informed Consent*

The researcher distributed consent forms to potential participants before the commencement of the research. These forms align with the recommendations of Pandey and Pandey (2021), explicitly outlining the study's goals, the nature of involvement, potential risks, and benefits. Participants were explicitly informed that participation was voluntary and that they could exit at any moment without encountering any consequences.

4.10.2 *Anonymity and Confidentiality*

Due to the personal nature of the interviews, concerns arose regarding the potential implications of public disclosures. Participants' identities were meticulously masked to mitigate disclosure concerns in any publication or presentation related to the study. Pseudonyms replaced actual names, and any identifiable details were omitted or altered (Mishra & Alok, 2022).

Additionally, all collected data, such as audio recordings, notes, or transcriptions, were stored in a safe place that only the researcher could access.

4.10.3 Prevention of Harm

A core principle of research ethics, as emphasized by Newman and Gough (2020), is the obligation to cause no harm. Even though the subject was not especially delicate, measures were implemented to prevent the conversations from turning awkward; the topic diverged when participants showed distress or discomfort. Their well-being was paramount.

4.10.4 Transparency

During each stage of the research, openness and transparency were maintained. Participants were provided with frequent updates on the study's advancement and were presented with preliminary findings to verify and validate the research interpretations, a process known as member checking (Mukherjee, 2019). This strategy enhanced the research's credibility and ensured that participants took center-stage in shaping their narratives.

4.10.5 Handling of Data

Data management received special attention. Electronic data was encrypted and stored on secure servers, while physical data was locked away. As Greening (2019) suggests, data access, storage, and eventual disposal protocols were established at the onset to minimize potential breaches or misuses.

4.10.6 Reciprocity

Ethical considerations also encompass the reciprocity aspect of research. As Snyder (2019) posits, participants give their time, insights, and experiences to the study. It is only fair that they gain something in return. Although the primary objective was not to offer direct benefits, participants received a summary of the findings. In addition, it could benefit their professional trajectories by offering insights into prevailing trends and practices.

4.10.7 Dealing with Unforeseen Issues

Researchers cannot predict ethical dilemmas with precision in qualitative research. The research adopted a flexible and responsive approach, promptly addressing unforeseen ethical issues while keeping participants' interests. Regular debriefing sessions with the research team ensured that any emerging ethical concerns were promptly addressed in line with Quinlan (2011)

4.10.8 Cultural and Contextual Sensitivity

The educational settings in the present study were diverse and, therefore, sensitivity to cultural and contextual nuances was crucial. The research actively aimed to avoid diluting the participants' perspectives, ensuring the participants' viewpoints were genuinely understood and represented authentically within their unique contexts. For that, the research team refrained from imposing preconceived notions or biases.

The present study's ethical considerations prioritized respect, transparency, and protection of participants' rights, mainly due to the personal nature of qualitative research involving teachers' beliefs and classroom practices. Following guidelines from Kumar (2018) and Quinlan (2011), the researcher secured informed consent, ensured anonymity through pseudonyms, and protected data with secure storage practices (Mishra & Alok, 2022; Pandey & Pandey, 2021) & Alok, 2022). Participants received regular updates, and member-checking validated preliminary findings, reinforcing credibility (Mukherjee, 2019). Attention was also given to cultural sensitivity, ethical flexibility in unforeseen situations, and reciprocity, honouring the participants' contributions by offering summaries of study results that could benefit their professional growth (Newman & Gough, 2020; Snyder, 2019).

4.11 Trustworthiness

To ensure that the data gathered meets the study objectives, careful alignment between data generation methods and research goals is crucial, particularly in exploring science teachers' beliefs about ICT simulations in IBST. A multi-faceted approach involving semi-structured interviews, classroom observations, and document analysis captured varied aspects of teachers' instructional beliefs and practices using ICT simulations. These methods provided comprehensive insights, allowing data crystallization that strengthened the study's credibility and ensured alignment with the study's objectives (Yin, 2018). Moreover, the Extended BIUT

and Vickers frameworks were integrated into data analysis to systematically categorize teachers' beliefs and instructional judgments about ICT simulation use. This alignment helped ensure that each data source specifically addressed what are the teachers' beliefs about ICT simulations and how these beliefs influence the implementation of IBST in the classroom while also accounting for potential barriers and facilitators of ICT simulation integration (Cohen-Blankshtain et al., 2004; Juggernath & Govender, 2020).

In qualitative research, trustworthiness means how accurate and reliable the study's findings are (Kumar, 2018). It ensures that the results are dependable and accurately reflect the participants' experiences. Establishing trustworthiness is imperative, particularly in complex and multifaceted fields like technology in education, where participants' perspectives are highly significant.

While some debates exist among researchers about quality assurance strategies within knowledge-based research, four primary criteria are widely recognized for ensuring trustworthiness in qualitative research findings: *Credibility*, *Dependability*, *Transferability*, and *Confirmability* (Korstjens & Moser, 2018). These criteria are fundamental for evaluating the rigour of qualitative studies, and each addresses a distinct aspect of research quality.

4.11.1 Dependability

Dependability in this study was ensured through participant involvement at various stages, which provided consistency and trustworthiness in how data were collected, stored, and analysed. Participants were given opportunities to verify that the findings represented the data they provided, promoting transparency and participant validation as critical dependability strategies (Creswell & Poth, 2017; Nowell et al., 2017). Copies of transcripts were shared with each participant for verification to ensure that responses were interpreted correctly, and field notes were also made accessible for participant review. These practices allowed participants to confirm or clarify the data, enhancing dependability by aligning the researcher's findings with participants' responses or views. For data security and accessibility, all data from each participant were stored in separate, locked files, with restricted access to each participant's file only. This systematic organization, alongside an audit trail containing raw data and field notes, supported transparency and credibility. Further strengthening dependability, peer debriefing was

employed: a colleague with a Masters in Education and experience in computer sciences and an independent researcher with a PhD in Educational Research and expertise in qualitative data analysis participated in the verification process. Both researchers were informed of the confidentiality protocols, and participants were made aware that external reviewers would assist in ensuring accuracy and reliability. Their role was to cross-check the thematic analysis, thereby maintaining ethical standards. The verification process involved reviewing coded themes, ensuring consistency in interpretations, and confirming that findings accurately reflected participants' views, reducing the likelihood of researcher bias and contributing to data stability (Bowen, 2009; Shenton, 2004).

4.11.2 Credibility

Credibility was carefully established to verify that the findings represented the participants' perspectives and experiences. Prolonged engagement, lasting seven months, allowed the researcher to build trust with participants and to conduct persistent observation in the school setting. This long-term interaction with the participants increased the trust and depth of understanding of participants' behaviours and viewpoints, an essential aspect of credibility in qualitative research (Birt et al., 2016). The participants in each Lesson Study group served as additional observers, which provided crystallization by combining multiple perspectives and reducing potential biases (Shenton, 2004). Each participant was also given access to transcripts of their interviews and group discussions, which allowed them to confirm that the data accurately reflected their views, reinforcing both credibility and participant validation.

Crystallization played a significant role in supporting credibility, as data were gathered through various methods, including lesson observations, interviews, and document analyses. This method helped reduce bias by providing a comprehensive view of the phenomena studied (Nowell et al., 2017). Participants reviewed the notes from lesson observations and interview transcripts to verify accuracy, promoting confidence that the data collected was a faithful representation of their input. The overall process ensured that participants were actively involved in validating the data generation and analysis stages, solidifying credibility and dependability in alignment with qualitative research standards (Creswell & Creswell, 2017).

4.11.3 Transferability

In qualitative research, transferability addresses the extent to which findings can be applied in other contexts, emphasizing the researcher's responsibility to provide a rich, detailed account of the study's setting, methods, and participant experiences (Korstjens & Moser, 2018). For this study on science teachers' beliefs about ICT simulation as a form of IBST, transferability was supported through comprehensive descriptions of the research context, which included a well-resourced educational environment with access to ICT tools. Detailed school documents used, data generation processes, and participant interactions were provided to enable future researchers to determine the applicability of these findings to similar settings. However, the transferability of these findings may be limited in less-resourced schools where technology access and support differ significantly. The potential variation in results across different educational environments suggests that additional studies in under-resourced settings are necessary to explore how resource limitations might impact ICT simulation adoption and IBST implementation (Morse, 2015).

4.11.4 Confirmability

Confirmability in qualitative research ensures that the findings are not figments of the researcher's imagination or shaped by the researcher's biases or interpretations but genuinely represent the participants' perspectives (Tobin & Begley, 2004). The present study used multiple strategies to achieve confirmability, including audit trails, peer review, and the code-recode strategy. Two science teachers from a different school, who were not part of the present study, reviewed the coding process by independently coding selected transcripts, with the identity of the participants anonymized to avoid bias. They were competent in qualitative analysis, having received training in data validation. While their familiarity with teaching practices was acknowledged, ethical considerations were upheld by ensuring they had no direct connection to the participants. This minimized potential bias and maintained confidentiality throughout the verification process. Where discrepancies arose, the science teachers engaged in discussions with the researcher to understand and sort out these differences, strengthening the credibility of the coding process. Regular consultations with a colleague provided opportunities to challenge

assumptions, examine potential biases, and refine interpretations (Nowell et al., 2017). This collaborative approach facilitated a more objective analysis, ensuring that the study's findings and interpretations authentically represented science teachers' beliefs and practices regarding ICT integration in IBST.

4.11.5 Reflexivity

Reflexivity played a crucial role in qualitative research, highlighting the importance of researchers considering their positioning, biases, assumptions, and impact on the research process (Korstjens & Moser, 2018). In the present research, reflexivity required continuous self-assessment to ensure that all interpretations are based on data and not influenced by personal biases or researcher-established definitions. Self-assessment required a relationship between the researcher and participants, recognizing how the relationship could impact participants' answers.

The researcher used crystallization as a methodological approach to enrich the analysis and to enhance reflexivity in the study. This approach was proposed by (Richardson & St. Pierre, 2005) and later developed by Ellingson (2009). The concept of crystallization goes beyond traditional methods by incorporating various data sources and viewpoints to comprehend better the subject being studied. Unlike triangulation, which seeks convergence of findings, crystallization embraces multiple facets of the data to highlight complexities, contradictions, and diverse interpretations (Ellingson, 2009).

All data generated from semi-structured interviews, lesson planning, classroom observations, and document analyses were used in the study to aid the crystallization process. Every data source used provided a distinct perspective on teachers' views and their methodology regarding ICT simulations and IBST. For example, interviews showed teachers' beliefs and understandings of ICT simulations and IBST, while classroom observations demonstrated how these beliefs were implemented, sometimes uncovering inconsistencies. Analyses of documents such as lesson plans, school policies, and curriculum guidelines provided insight into how teachers incorporated ICT tools in their instructional planning. These various data sources offered a diverse comprehension that went beyond a singular viewpoint.

Reflexive notes were consistently kept during the research phase to record emerging observations, assumptions, and insights. This method allowed the researcher to assess their impact on the research and recognize possible biases affecting data interpretation. Reflexivity played a crucial role in the crystallization phase by avoiding the imposition of alignment on diverse data sources and acknowledging their distinct contributions to the narrative (Ellingson, 2009).

Feedback from participants was also crucial in improving reflexivity. By member-checking protocols, participants were offered chances to examine their interview transcripts and initial findings. This procedure guaranteed that the interpretations reflected the participants' views and motivated them to enhance or elaborate on their responses. Through actively engaging participants in shaping the research, the study elevated their voices as a priority and reduced the influence of researcher bias.

Ultimately, the researcher effectively managed the relational dynamics with the participants to create a trustworthy environment. Participants were encouraged to openly communicate and be transparent, creating a safe environment for sharing their experiences without any fear of judgment or misrepresentation.

Merging reflexive methods with crystallization enabled the researcher to examine the phenomenon from various perspectives, enhancing the analysis and emphasizing the relationship between teachers' beliefs of ICT simulations and IBST, teaching methods, and the environment. This varied method ensured that the results were believable and intricately detailed, aiding in a more thorough grasp of the utilization of ICT simulations in IBST (Ellingson, 2009; Korstjens & Moser, 2018).

4.12 Role of The Researcher

In qualitative research, the researcher has an important and multifaceted role; the researcher acts as a facilitator and an instrument of data collection and interpretation. Initially, the researcher was responsible for designing, testing, and refining all supporting documents for the study, a process involving multiple iterations. The pilot phase informed subsequent adjustments to these documents to ensure they effectively met the study's objectives and

participants' needs. This adaptability aligns with the iterative nature of action research, where continuous refinement is crucial to respond dynamically to insights gained in real-time (Creswell & Creswell, 2017).

Additionally, the researcher piloted the interview protocols and classroom observation guidelines, refining questions to align with the study's goals based on feedback from preliminary trials. This process showed the researcher's role as an instrument of data generation, with active engagement necessary to shape and adapt tools to capture authentic participant insights. When data generation was completed, the researcher facilitated comprehensive analyses by interpreting qualitative data collected from interviews and lesson observations.

During the lesson observation sessions, the researcher acted as a spectator, observing the participants, introducing the lesson study model, and guiding the learners through the initial stages. In the first cycle, the researcher did not play an active role, allowed the participant introduce content and set up the ICT tools, and conduct the lesson. This teaching approach encouraged participants to assume greater responsibility, fostering collaborative learning and empowering teachers to engage more independently (Darling-Hammond et al., 2017). By acting like that, the researcher contributed to the study's framework and fostered a reflective, iterative environment, reinforcing the principles of collaborative, participant-driven inquiry essential to action research.

4.13 Limitations

In examining the limitations of this study, several constraints emerged that influenced the findings and their generalizability. First, the small sample size typical in qualitative research may limit the generalisation of results across broader populations. This constraint is often inherent in in-depth qualitative studies focused on gaining detailed insights from specific contexts (Creswell & Poth, 2017). While a limited sample allows for richer data generation, it can also restrict the study's applicability beyond the immediate research setting. Additionally, researcher involvement in data generation, analysis, and facilitation can introduce subjectivity, potentially impacting findings and interpretations. While this involvement can help build rapport and gain insights, it can also risk researcher bias despite efforts to minimize it through reflective practices and member-checking (Patton, 2014). An audit trail was used to maintain transparency and

mitigate risks, though the interpretation of data remains a limitation in any researcher-centred study.

Time constraints presented another challenge: prolonged engagement is essential for credibility but was limited by practical considerations. Extended field time would allow for more robust relationship-building and nuanced understanding of participant responses. However, limitations on time may have restricted the depth of participant observation and follow-up. Moreover, the reliance on participant self-reporting in interviews and surveys can introduce response bias, as participants may alter responses based on perceived expectations or social desirability (Alshenqeeti, 2014). Response bias is a recognized limitation in educational research where teachers may consciously or unconsciously align their responses with normative expectations.

Finally, the specific educational context and cultural setting in which the study was conducted may limit its transferability to other regions or educational frameworks. As educational practices and policies vary widely, findings from this study may be more applicable in contexts with similar educational structures and cultural norms (Yin, 2018). Efforts to generalize findings should consider these contextual limitations to provide a more accurate interpretation of the study's relevance.

4.14 Summary

The present study aimed to explore teachers' beliefs about ICT simulations as a form of IBST in their teaching. The research employed an interpretive paradigm; to align with the study's goal of understanding and describing teachers' beliefs and experiences. Qualitative data collection maximized credibility and dependability. This method allowed for crystallization, enhancing the credibility and depth of the findings (Creswell & Poth, 2017). The present study employed a multiple-case study design that enabled in-depth analysis of teachers' experiences across a single educational context. The study was conducted over seven months in a Mozambican high school, involving five science teachers; teaching different grades. This multiple-case study approach supported the collection of detailed and context-rich data (Yin, 2018).

Data were collected through semi-structured interviews, classroom observations and document analysis, integrating qualitative insights. Qualitative data were coded and categorized into themes. Integrating the results from qualitative data allowed for a comprehensive understanding of teachers' beliefs about ICT simulations and IBST and also their experiences with ICT simulations integration.

The present study's findings, discussed in the next chapter, are based on rigorous data analysis and are expected to contribute valuable insights into effective ICT simulations integration in teaching as a form of IBST.

CHAPTER 5

TEACHERS' PERSPECTIVES AND PRACTICAL EXPERIENCES

5.1 Introduction

Chapter 5 presents an in-depth analysis of science teachers' beliefs, practices, and challenges in integrating IBST with ICT simulations in the classroom. By exploring the responses from semi-structured interviews with five teachers, this chapter highlights their perspectives on the role and impact of ICT simulations in enhancing inquiry-based learning and learner engagement. The chapter addresses each teacher's experience with various ICT tools, such as smartphones, laptops, and simulations, and examines how these tools influence their instructional approaches.

This chapter is framed around key themes, including *teachers' beliefs about the value of ICT for learner engagement, the perceived benefits and barriers of using technology, and practical judgments about its integration in diverse classroom contexts*. The interviews revealed the complexities science teachers face when balancing technological integration with instructional goals and curriculum requirements, and the infrastructural limitations that impact their teaching practices. Using a structured approach that categorizes responses into *reality, value, action judgments, and barriers*, this chapter provides insights into how ICT simulations and IBST are implemented in science education, grounded in each teacher's context and instructional philosophy.

In section 5.2, the researcher discussed teacher's Antonio's responses followed by the other four teachers' responses to the interviews conducted. Confirmability was ensured through detailed documentation of data generated procedures, including semi-structured interviews. Transcriptions were meticulously and repeatedly verified against audio recordings to ensure accuracy. To reduce researcher bias, participant responses were coded and categorized based on emerging themes, independent of preconceived notions. Peer debriefing was employed, where colleagues reviewed the coding process and interpretations to ensure they accurately reflected the participants' responses. Additionally, participants were given the opportunity to review and validate their interview summaries, codes and themes generated ensuring that their views were authentically captured.

5.2 Teacher Response - António

The following sections will explore each aspect of António's approach, highlighting his use of ICT tools, beliefs about their benefits, and the challenges he faced. António (teacher) used various ICT tools: *I use smartphones, laptops, a microscope and a projector in the classroom but the smartphone is used the most.* He also highlighted the role of these tools in enhancing teacher-directed strategies, providing detailed explanations and visual aids to strengthen learners' understanding of the subject matter: *ICT tools serve as visual aids in helping children learn and learners can understand better because ICT tools help them to visualize the concept.* António mentioned the importance of ICT tools in our daily lives; he also encouraged learners by saying that *"learners should be prepared for the modern world and the 4th Industrial Revolution and technology-rich learning environments facilitate better understanding of scientific concepts and rules and improve learners' grades."*

During his interview, António shared some challenges that hinder the smooth integration of technology into his lesson; despite his enthusiasm and excitement for using ICT tools, these barriers pose significant disruptions to the teaching process and, overall, to his lesson delivery.

António explained that one of the biggest challenges he had during his lesson was the time spent setting up all the computers and data projector before class time: *Setting up all the equipment before class time takes a lot of time, and I end up using the time I should be teaching.* He expressed frustration that this preparation takes away his valued limited instructional time with his learners. For António, in addition to the time required to set up the equipment, time is also used to get all the resources from the school's administration and ensuring everything runs smoothly during the lesson: *It's not just using the tools; it's also about finding the right resources and making sure everything is ready. This part can be really time-consuming, especially when you're trying to make the lesson flow smoothly.*

António is skilled in using multiple ICT tools, but he also noted that it is challenging to stay updated with constantly evolving technology: *Keeping up with all the new technology is challenging. I try to learn as much as I can, but with my teaching schedule, it's hard to find the time for proper training.*

The same feeling is shared among science teachers, where the speed at which ICT tools change requires continuous learning and adaptation from the teachers, something that can be difficult for some to manage alongside a full teaching load: *You can't just pick up a new ICT tool and use it right away. It takes time to understand how to integrate it effectively, and that's something I struggle with balancing along with my other teaching duties.* His background highlights the importance of having professional growth opportunities that fit within the realities of a teacher's schedule.

António also faces a significant obstacle with the inconsistent internet connection at his school. He described the impact on his lesson plans: *The internet connection is sometimes very unstable, and when it goes down, it disrupts the entire lesson plan. It's frustrating because the learners lose focus, and it's hard to get them back on track. It is not so easy when the learners become distracted to make them regain their attention.*

He emphasized that connectivity issues represent a significant barrier to integrating technology effectively: *We rely a lot on the internet for simulations and resources, so when it's not working, it really sets us back.*

Connectivity issues aggravate unreliable internet at school due to frequent disruptive power outages: *Electricity is another big issue. There are times when the power just goes out, and then we can't use any of the electronic devices. I have to be prepared with a backup plan, which is not always as effective.* These power outages limit the availability of technology and force teachers like António to constantly develop alternative plans that may not engage learners effectively: *Frequent power cuts mean I always have to think of alternative ways to deliver the lesson, which sometimes affects the quality of teaching. Thus, power cuts present a consistent challenge, impacting lesson planning and execution.*

António also expressed concerns about the damage to ICT equipment due to power fluctuations. He described past experiences where sudden power surges had caused extensive damage to critical equipment: *Power fluctuations have damaged some of our equipment before, and it's expensive to repair or replace them. This makes me cautious about using the tools too much, but at the same time, I know they are essential for teaching.* This risk of damaging equipment creates ongoing tension for António, as he must weigh the benefits of using

technology against the potential costs of its fragility in an unstable environment: *There's always a risk with the technology here; one bad power surge and you could lose a projector or a laptop. It's a real concern that we have to constantly think about.* Highlighting a significant infrastructural barrier that supports effective technology integration in his classroom. Table 5.1 shows a summary the responses from António's interview and captures key insights into the use of ICT tools in science education, based on his classroom experiences. The Table 5.1 organizes responses into four different categories comprising *reality judgment, value judgment, action judgment, and barriers*, providing a holistic view of António's practices and beliefs about technology integration.

Table 5.1
António's Interview Response

Category	Observed instances
Reality judgement	António uses various ICT tools, including smartphones, laptops, and projectors, to enhance his teaching.
Value judgement	António sees ICT tools as crucial visual aids that enhance learners' understanding of scientific concepts and prepare them for the modern world. He believes that using technology-rich environments in teaching leads to better comprehension and improved academic performance among learners.
Action judgement	António integrates smartphones, laptops, projectors, and microscopes into his teaching despite difficulties with setup time and connectivity issues. He prepares alternative lesson plans to address power outages and connectivity problems, though these backups are often less effective than his ICT-enhanced lessons.
Barriers	The setup and resource preparation for ICT tools significantly reduces instructional time, making the integration of technology challenging and overwhelming. António finds it difficult to keep up with new technologies due to limited time for proper training amid his demanding teaching schedule. Although proficient, António struggles to stay updated with fast-paced technological changes due to limited time and a heavy teaching workload. Frequent internet and power disruptions at the school make it difficult for António to consistently integrate ICT tools, leading to interruptions in lesson delivery and learner engagement. António worries about the potential damage to expensive ICT equipment from power fluctuations, which constrains his ability to use these tools frequently.

Table 5.1 presents António's perspectives on IBST with ICT simulations, showing his practical use of ICT tools like smartphones and laptops to enhance lesson delivery and learner engagement. António values ICT's role in deepening learners' understanding of scientific

concepts, reflecting a belief in the educational benefits of technology-rich environments. Despite challenges like setup time and connectivity issues, his commitment to using ICT tools demonstrates resilience and adaptability. However, he also faces significant barriers, including time constraints, infrastructure issues, and concerns over equipment damage, highlighting common obstacles in technology integration within educational settings.

5.2.1 *Reality judgement*

António uses different ICT tools, like smartphones, laptops, and projectors, to enhance his teaching practice. This enhanced teaching practice reflects teachers' practical approach to using technology to improve content delivery and engagement in the educational process. Using these tools suggests that the teacher is familiar with ICT tools and believes in their benefits, supporting the work of Ottenbreit-Leftwich (2010), which focuses on the importance of technological proficiency in modern education. António's choice to use of ICT tools like smartphones and laptops demonstrated a reality judgment that values these tools as essential components of the teaching process. Harris (2016) supports the incorporation of ICT tools and technology in education, emphasizing the significance of integrating technological pedagogical content knowledge (TPACK).

5.2.2 *Value judgement*

António considers ICT tools and technology crucial visual aids that enhance learners' understanding of scientific concepts and help them be better prepared for the modern world. This statement is supported by Koehler et al. (2013), who believe that technology-rich environments provide multiple ways to present information, catering to various learning styles and improving comprehension. António also believes that using ICT tools and technology leads to better comprehension of the content and academic performance among learners. This view is corroborated by research indicating that technology can facilitate deeper understanding by providing interactive and engaging learning experiences (Kozma, 2003). "António's" belief that technology enhances learner outcomes brings out the value he places on ICT tools as a life-changing tool in education. His view is consistent with findings by Hattie (2008), who reported that technological interventions often positively effect learner learning outcomes when implemented effectively.

5.2.3 Action judgement

Despite some difficulties with setup time and internet connectivity issues, António is optimistic about integrating ICT tools into his teaching. Showing a true reflection of a teacher's commitment to using technology despite all the challenges. He demonstrates resilience and shows a very optimistic approach to overcoming obstacles, which is crucial for successful technology integration (Fullan, 2015). António's preparation of alternative lessons when there are electricity outages and connectivity problems indicate a realistic approach to teaching, this strategy is aligned with the findings of Ertmer et al. (2012), who highlighted the importance of flexibility and contingency planning in technology-enhanced learning environments. António's approach to managing technology-related challenges illustrates his action judgment. His strategy to prepare alternative lessons, even if they are less effective than the planned ICT-enhanced lessons, reflects António's commitment to continue his lesson education despite infrastructural limitations.

5.2.4 Barriers

The setup and resource preparation for ICT tools significantly reduces instructional time, making integration challenging. António finds it difficult to keep up with new technologies due to limited time for proper training amid his demanding teaching schedule. Highlighting the well-documented time constraints in technology integration, where teachers often face difficulties balancing curriculum and implementation of new technologies (Bingimlas, 2009).

Frequent internet and power disruptions pose significant challenges, leading to lesson delivery and learner engagement interruptions. Such infrastructural challenges are common in many educational settings, particularly in under-resourced areas, and they often hinder the consistent use of ICT (Pelgrum, 2001).

António's concerns about potential damage to expensive ICT equipment from power fluctuations illustrate the practical barriers to technology use in education. This concern is echoed in the literature, where fear of damaging expensive equipment is cited as a significant barrier adopting technology (Tondeur et al., 2017).

5.3 Teacher Response - Shantel

Shantel (teacher) spoke about the motivational benefits that ICT tools bring to her classroom. She highlighted how technology, especially devices like smartboards and projectors, changes the learning environment into a more dynamic and engaging space for her: *Learners learn better when they use technology; it makes them more excited, and it saves teaching time.* For Shantel, integrating ICT tools is more than keeping up with modern teaching trends; it is about making learning more efficient and captivating for her learners.

Shantel shared an impactful moment from her teaching experience: *I remember when I was teaching once, some learners didn't understand the lesson, but as soon as I did a demonstration using an ICT simulation, they grasped the concepts well.* This example illustrates how digital tools can break down complex ideas, making abstract scientific concepts more tangible for learners. By turning difficult lessons into visual and interactive experiences, technology enables Shantel to reach learners who might struggle to grasp the content. These simulations create a more profound understanding by allowing learners to visualize and experiment with concepts in real time, enhancing their learning experience. Shantel's reliance on technology, particularly for visual demonstrations, brings out the power of ICT simulations in the classroom. Whether it is through a smartboard or computer simulations, she uses these tools to make lessons more meaningful and accessible. ICT tools help to clarify lessons, making the content more understandable, she noted, reflecting on the immediate improvement in learner comprehension after incorporating ICT simulations into her teaching. In this way, Shantel always endured that technology does more than support her teaching; it works as an essential tool that actively enriches the teaching and learning processes by engaging learners and encouraging them to explore new ideas.

However, like many teachers, Shantel faced significant barriers when effectively integrating technology into her lessons. Although her school provided some resources, such as data projectors, internet access, and computers, these tools are only sometimes readily available for every lesson, she had mentioned when she was interviewed: *Not every classroom has enough computers, so we have to share. This sometimes means adjusting my lessons or limiting how much I can use the technology, depending on availability.* Limited access to ICT resources can

constrain how often she can use these teaching tools, which affects her ability to fully implement interactive and inquiry-based teaching methods regularly.

Power cuts are also one of the things that complicate her efforts to integrate ICT tools and technology in her teaching consistently. Shantel expressed frustration at the unpredictability of power cuts: *Electricity is another challenge. There are times when we're in the middle of a lesson, and the power goes out. When that happens, all the technology is useless.* These disruptions interrupt the flow of her lessons and hinder the effective use of simulations and other ICT resources. The frequent power outages force her to prepare alternative lesson plans that do not rely on technology, although she acknowledges that these alternatives often lack the same level of engagement and clarity that ICT tools provide.

Table 5.2 presents the comprehensive analysis of Shantel's teaching approach and philosophy observed in a classroom in an inquiry-based learning environment. Presenting this information in a categorized table highlights the relationships between Shantel's teaching strategies, beliefs, and the practical barriers she encounters, providing a clear and structured understanding of her inquiry-based approach to science education.

Table 5.2

Shantel's Interview Response

Category	Observed instances
Reality judgement	Shantel believes that learners construct their understanding through active participation and inquiry. She views ICT tools like the PhET simulation as essential for visualizing and exploring complex scientific concepts.
Value judgement	Shantel values a learner-centred, inquiry-based teaching approach. She emphasizes the importance of fostering critical thinking, collaboration, and deep understanding over rote memorization.
Action judgement	Shantel's actions reflect a commitment to creating an interactive and engaging learning environment. She uses questioning strategies, discussions, and ICT tools to facilitate learner exploration and conceptual understanding, guiding learners to form their hypotheses and test them.
Barriers	Shantel acknowledges potential barriers such as limited access to technology and varying levels of learner familiarity with ICT tools. However, her proactive use of interactive simulations and structured guidance helps to overcome these barriers, ensuring effective technology integration in her teaching.

The researcher explored Shantel's reality, values, and action judgments concerning the use of ICT simulations in her teaching practices. Shantel emphasizes the role of interactive and visual aids in making complex scientific concepts accessible to learners by using ICT tools like PhET simulations. Shantel focuses developing of higher-order thinking skills and group discussions over rote memorization, making her teaching philosophy rooted in learner-centred and inquiry-based methodologies.

However, despite Shantel's positive approach to effective strategies, Shantel is aware of the barriers to ICT simulation integration. These obstacles include limited access to ICT tools and infrastructural challenges such as unreliable internet and power supply. Developing strategies that support using ICT tools in teaching is crucial for understanding these challenges.

This analysis sheds light on the complexities of ICT simulation integration in education and the need for supportive structures and professional development to overcome existing barriers by examining Shantel's experiences and insights. The following sections will explore each aspect of her approach, showing a comprehensive understanding of her beliefs and teaching practices regarding ICT simulations in the classroom.

5.3.1 *Reality Judgment*

Shantel believes learners develop their knowledge by actively engaging and asking questions, consistent with constructivist theories by Vygotsky and Cole (1978). Her focus on incorporating ICT tools like PhET simulations shows the significance she places on visual aids and interactive tools in enhancing the accessibility and comprehension of complex scientific concepts. Other studies that indicate simulations can improve learners' grasp of concepts and involvement in science learning support the argument (Rutten & Soetaert, 2015).

Shantel also believes that using ICT tools in a classroom, such as simulations, is crucial for illustrating and investigating intricate scientific ideas, leading to enhanced comprehension through visualization. In agreement with Mayer and Fiorella (2022), who emphasises that effective multimedia design fosters learning by optimizing the combination of visual and auditory content. can enhance learning by combining visual and verbal content based on the cognitive theory of multimedia.

5.3.2 Value Judgement

In her lesson, Shantel prefers to choose a teaching method that focuses on the learner and uses inquiry-based techniques, stressing critical thinking and group work instead of memorization. These techniques matches the move in educational paradigms towards inquiry-based learning (IBL) and learner-centred approaches that encourage deeper cognitive engagement and higher-order thinking abilities (Hofstein & Lunetta, 2004). Her support for promoting critical thinking through ICT tools is consistent with Hennessy et al. (2010) discovery that digital tools, when used well, can improve learners' analytical and reflective thinking abilities.

Shantel believes that learners benefit from technology use and that ICT simulations improve teaching and learning, as outlined in the technology acceptance model (TAM), where perceived ease of use and usefulness significantly impact users' attitudes toward technology. Embracing ICT tools in teaching is expected to promote their adoption and incorporation, reinforcing the belief that these tools enhance learning (Teo, 2011).

5.3.3 Action Judgement

Shantel is dedicated to developing a participatory and engaging educational setting. She employs questioning techniques, conversations, and technology resources to help learners explore and grasp concepts. This strategy is consistent with the principles of scaffolding, where learners are guided and supported in developing their understanding and skills. and testing their theories to promote independent learning (Wood, 2003). Shantel's use of ICT simulations for online assessments shows her proactive efforts in incorporating ICT simulations in evaluations, facilitating instant feedback and enabling personalized learning opportunities. Shantel's proactive use of ICT tools in her science lessons aligns with studies showing that teachers who typically incorporate ICT tools in their lesson plans often have more structured and significant lessons, improving the learning process (Joke Voogt et al., 2013). Incorporating ICT simulations and digital tools in assessments can also accommodate various learning preferences, thus promoting inclusivity in education.

5.3.4 Barriers

Shantel realises that there are multiple obstacles to the efficient use of ICT tools in her classroom, such as restricted technology accessibility, differing levels of learner experience with ICT tools, and problems like inconsistent internet connection and electricity interruptions. These obstacles represent typical barriers encountered when incorporating technology into her lesson plan, particularly in environments with limited resources. Recognizing these obstacles highlights the need to tackle infrastructural and socio-economic issues to guarantee fair ICT simulations access for all learners (Kozma, 2003).

According to Howard et al. (2015), successful ICT integration involves more than having the right technology; it also involves creating a supportive setting that includes teacher and learner training. Shantel's recognition of these barriers indicates a requirement for teachers to receive training to adjust and conquer these difficulties, ultimately improving the overall efficiency of incorporating ICT in classrooms (Hew & Brush, 2007).

5.4 Teacher Responses- Abel

Abel (teacher) expressed a deep enthusiasm for using PhET simulations in his science lesson, describing them as crucial tools that simplify the teaching process while making learning more interactive and enjoyable: *I believe ICT tools help learners learn. They help learners visualize real situations and make teaching much easier and fun.* Abel sees PhET simulations as a step beyond traditional visual aids like YouTube videos, which, while helpful, do not offer the same level of interactivity or engagement. He expressed how PhET simulations allowed his learners to observe when he was explaining the content and actively engage with scientific concepts, promoting a more profound understanding.

Abel's view that drives his passion for incorporating technology and ICT tools in the classroom is that it enhances teaching effectiveness and learner understanding. He shared his experiences: *I've seen learners understand the topic so well when they use ICT tools.* This conviction stems from his observation that learners, especially in larger classes, benefit significantly from the interactive nature of simulations. The ability to manipulate variables and witness real-time outcomes helps learners visualize complex scientific principles that might

otherwise seem abstract or difficult to grasp. Abel believes these interactive tools prevent learners from becoming bored, as they can engage directly with the material and follow the experimental process hands-on. In classes with a vast number of learners, where keeping their attention and ensuring comprehension for all learners can be challenging, technology and ICT tools help bridge this gap by making science more interactive, fun, and engaging for every learner.

For Abel, PhET simulation is more than an ICT tool for teaching; it is a way to change the entire learning experience in the classroom. He is convinced that integrating technology into his science lessons significantly improves learning outcomes by creating an environment where learners can experiment, explore, and visualize concepts that would be difficult to convey through traditional methods. He sees the potential of ICT tools to change science education, enabling learners to grasp concepts more quickly and thoroughly.

Despite his strong advocacy for technology in the classroom, Abel is not blind to the challenges that come with integrating ICT tools, particularly in environments where resources are limited. One of the primary barriers, contradicting himself with what he had said earlier, is the vast number of learners in his classes: *When you have a large number of learners, it becomes difficult to ensure that everyone is following along with the ICT tools.* Although simulations and digital aids can help make lessons more accessible, the logistical difficulties of managing large groups of learners can dilute the effectiveness of these tools. Ensuring that every learner has equal access to technology, particularly in overpopulated classrooms, remains a significant challenge for Abel.

Abel explained that ICT training is restricted, making it easier to integrate technology to benefit learners with the necessary skills effectively. Despite Abel's expertise with tools like PhET simulations, he is aware that many other teachers find it challenging to use the technical skills needed to use these resources effectively in the classroom. Many teachers are forced to navigate the use of ICT tools independently due to the limited availability of thorough professional development, leading to ineffective implementation in teaching.

Moreover, Abel also mentioned how some science teachers need more motivation to integrate technology into their teaching methods. He commented that some teachers need to

recognize the importance of using ICT tools, or they find it too complicated. The absence of drive could come from different factors like the complexity of ICT tools, resistance to change, or the extra effort needed to include these ICT tools in daily teaching practices. Abel understands that promoting a culture of technology adoption demands resources, training, and a shift in teachers' mindsets. Many teachers might hesitate to use technology in their lessons if they do not honestly believe in its advantages.

Table 5.3 organizes the responses according to categories of reality judgment, value judgment, action judgment, and barriers. This method highlights Abel's emphasis on understanding fundamental scientific concepts, like the relationship between resistance, current, and voltage, through hands-on and inquiry-based learning. The structure helps analyse how Abel's teaching philosophy and actions align with learner-centred, technology-enhanced education.

Table 5.3

Abel's Interview Response

Category	Observed instances
Reality judgement	Abel believes that understanding the relationship between resistance, current, and voltage is crucial for mastering electrical circuits. He emphasizes that adjusting resistance directly influences current and voltage.
Value judgement	Abel values an interactive and learner-centred teaching approach. He believes that inquiry-based learning and hands-on experimentation are essential for deepening understanding and engagement in the subject matter.
Action judgement	Abel consistently poses stimulating questions and encourages learners to test their hypotheses through simulations. He structures his lessons to break down complex concepts into manageable segments, facilitating comprehension and critical thinking.
Barriers	Abel appears to face no significant barriers to ICT use. He effectively integrates the Circuit Construction Kit: AC simulation into his teaching, demonstrating confidence and proficiency with the technology.

Abel provides examples of how the realities of technology availability, value placed on ICT tools, practical actions taken, and barriers encountered shape the use of ICT simulations in an educational setting. Through an analysis of Abel's teaching practices, the practical, value-driven, and action-oriented aspects of using technology in education, and the challenges that must be addressed to achieve effective ICT simulation integration are explored. The present study explores Abel's reality, value, and action judgments, along with the barriers he faces, to understand the multifaceted role of ICT in enhancing educational outcomes.

5.4.1 Reality Judgment

Abel's reality judgments focus on the tools and ICT resources available for teaching, such as smartphones, laptops, and projectors. These reality judgments reflect his practical recognition of the technological infrastructure in his educational environment. Moreover, he acknowledges that learners have used PhET simulations and computers but notes a lack of familiarity and proficiency among them.

Abel's reality judgment highlights the practical aspects of integrating ICT simulations into teaching. The availability of devices like smartphones and laptops indicates the potential for a blended learning environment where traditional and digital methods can coexist. However, his observation that learners often do not know how to use ICT simulations suggests a gap between the availability of technology and its practical use. This gap could be attributed to a lack of training or exposure, which aligns with findings in educational technology research. For instance, Howard et al. (2015) emphasize that providing access to technology does not guarantee practical usage; there must be a structured approach to training teachers and learners to use these tools effectively.

5.4.2 Value Judgment

Abel believes in interactive teaching methods that focus on the learner. He thinks engaging in hands-on experimentation and inquiry-based learning is crucial for enhancing comprehension and interest in the topic.

Abel's assessment shows a high preference for IBL, which aligns with current education trends and focuses on interactive, learner-centred learning (Barzilai & Chinn, 2017). Abel's confidence in the value of hands-on experimentation and learner-focused methods shows his dedication to developing his learners' critical thinking and problem-solving abilities. Educational research indicates that involving learners in inquiry-based activities can significantly improve their comprehension and application of knowledge in new scenarios (Sandoval & Reiser, 2004).

Abel's value judgment reflects a positive attitude toward using ICT simulations to enhance educational outcomes. His belief that ICT makes teaching more accessible and fun underscores technology integration's motivational benefits.

5.4.3 Action Judgment

Abel implements ICT simulations by providing step-by-step instructions, facilitating the visualization of complex processes, and considering the number of learners in a class. Abel's action judgment reveals her strategy for making ICT tools accessible and understandable for his learners. The use of step-by-step instructions indicates an awareness of varying levels of familiarity with technology among his learners, which is crucial for inclusivity. He emphasises the number of learners per class using ICT simulations effectively and suggests that smaller class sizes may facilitate better interaction and individualized attention. This finding is consistent with Hennessy et al. (2005), who argue that structured, guided use of ICT simulations can channel learner activity towards educational goals and away from distractions.

5.4.4 Barriers

Abel identifies several barriers to ICT simulations use, including large class sizes, lack of training for some learners, and low motivation among learners.

The barriers identified by Abel are common in many educational settings. Large class sizes can limit the effectiveness of ICT tools because teachers may need help to provide individualized support. Learners may need more training to use ICT tools and prevent frustration and disengagement effectively. These barriers are consistent with the results of Liu et al. (2017), who emphasises the significance of training and support in addressing obstacles to integrating ICT tools. Furthermore, learners' lack of motivation may be connected to their limited grasp of how ICT tools benefit their learning, indicating the need for more personalized and interactive teaching methods involving technology.

5.5 Teacher Responses - José

José (teacher) describes himself as a dedicated and enthusiastic user of technology, incorporating a variety of hardware and software into his teaching practice. His daily toolkit

includes laptops, projectors, and specialized educational software, all of which play a vital role in streamlining the teaching process and enhancing the educational experience for his learners. José emphasised how technology helps him manage the often-extensive curriculum demands: *I believe that ICT tools support what I am teaching by saving time, allowing me to cover the entire curriculum more effectively.* For José, the time-saving nature of ICT tools is a significant advantage. The ability to quickly pull up diagrams, videos, and interactive simulations allows him to understand concepts more efficiently than traditional methods would do.

Beyond saving time, José is aware of the pedagogical benefits of ICT tools, particularly in improving the clarity and precision of his lessons: *They improve clarity and accuracy on concepts and diagrams that I could never express or display as precisely on my own,* he noted. This point is particularly salient regarding complex scientific concepts, where visual representation can make abstract ideas more tangible for learners. José can effectively present these concepts visually appealing using projectors and ICT tools. ICT tools help bridge the gap between theory and practical understanding, allowing learners to engage with and manipulate information in ways that could not be achieved through traditional teaching methods like textbooks and chalkboards.

José's educational belief is firmly based on interactive, learner-focused teaching. He thinks that learners achieve good results when they are actively involved in the learning process through group discussions, many activities in class, or problem-solving tasks. José stated that he likes those classes where with lots of interaction and lessons focused on the learners, expressing his preference for being a facilitator rather than a traditional lecturer in the classroom. His teaching's primary goal is to stimulate learners to think critically, inquire, and enhance their questioning abilities. He uses ICT tools to enhance learners' abilities, allowing them to interact actively with content instead of passively receiving information.

José explained how he integrates ICT tools into different parts of his teaching: *I emphasize and rely on class activities, homework, and class discussions.* José can foster a dynamic learning environment where learners are empowered to take control of their education through ICT tools like interactive simulations, digital quizzes, and group online platforms. This method enhances learners' self-assurance and nurtures essential critical thinking abilities vital for

their future achievements in both school and the real world. José encourages his learners to develop problem-solving skills using technology and PhET simulation to explore and investigate, helping them become critical and innovative thinkers.

Even though he is very passionate about ICT, José openly acknowledges the obstacles and difficulties that impede incorporating technology in his teaching. He confirmed that his most significant obstacle is time: *finding the time to prepare lessons that effectively incorporate ICT tools can be difficult*. While ICT tools save time during lessons, the preparation required to find the right digital resources, set up equipment, and ensure everything functions is demanding. José recognizes that integrating technology is not just about using a laptop or projector; it involves careful planning and coordination, all of which add to an already heavy teaching workload. The time constraints associated with ICT use can sometimes create additional stress for teachers already balancing multiple responsibilities.

Another challenge José encounters is the language of instruction: *the language barrier can be an issue when using ICT tools*. Many digital resources, particularly high-quality educational software and online platforms, are developed in English, which may not be the primary language of instruction for many learners. The language barrier adds another difficulty for teachers like José, who must decide between translating into Portuguese for better comprehension or adjusting the material to suit their learners' requirements. Sometimes, inadequate ICT resources can hinder the performance of these tools, making it more challenging to incorporate them into the curriculum thoroughly. Jose also highlighted the absence of resources as a significant obstacle. Although he is lucky to have some ICT tools, these resources are not always consistently available. He clarified that every learner does not always have sufficient devices or software licences. Often, schools have a restricted quantity of laptops or projectors, which results in teachers having to share or take turns using them. This restriction of laptops can decrease how often ICT tools are used in the classroom and restrict its influence on learner learning. Furthermore, he mentioned that the high expense associated with maintaining and upgrading technology makes it challenging for the school to stay current with the rapid advancements in educational technology.

Table 5.4 summarizes the insights from José’s interview, illustrating his belief in the importance of understanding projectile motion factors, his value for integrating structured inquiry with interactive tools to enhance learner engagement, his effective use of a blend of direct instruction and hands-on experimentation, and his seamless integration of ICT resources without facing significant barriers.

Table 5.4

José’s Interview Response

Category	Observed instances
Reality judgement	José believes that understanding the factors influencing projectile motion, such as initial velocity and launch angle, is essential for predicting and analysing the path of any object in motion.
Value judgement	José values a blend of structured inquiry and guided exploration. He believes that integrating simulations and interactive learning tools can enhance comprehension and engagement in scientific concepts.
Action judgement	José employs a mix of direct instruction and interactive learning. He poses engaging questions, uses simulations to demonstrate principles, and encourages learners to test their hypotheses through hands-on experimentation.
Barriers	José faces no significant barriers to ICT use. He seamlessly integrates the PhET simulation, laptops, and a data projector into his lesson, demonstrating confidence and proficiency with these technologies.

José’s approach to using ICT simulation in his lesson reflects a practical understanding of the technological tools available, such as smartphones, laptops, and projectors, while recognizing the challenges associated with their practical use. Despite having access to these technologies, José notes a significant gap in learners’ familiarity and proficiency with ICT simulations, pointing to a need for better training and support. However, barriers like large class sizes, inadequate training, and low learner motivation persist, highlighting the complexities of integrating technology in educational settings.

5.5.1 Reality Judgement

José believes that understanding factors influencing projectile motion, such as initial velocity and launch angle, is crucial for predicting and analysing the path of any object in

motion. In practice, learners use laptops and projectors for daily classwork, with ICT simulations being utilized to simulate scientific concepts.

José's reality judgment emphasizes the importance of foundational knowledge in physics, particularly in understanding projectile motion. This foundational knowledge in physics is critical in physics education as it integrates mathematical and conceptual understanding. Using laptops and projectors indicates a classroom environment that is already somewhat digitally enabled, allowing for the integration of ICT tools to demonstrate and visualize complex scientific phenomena. Research by Hennessy et al. (2005) supports this approach, highlighting how ICT simulations can create dynamic and interactive visualizations that enhance conceptual understanding. By using technology to simulate the conditions and variables of projectile motion, José allows learners to engage with the material more effectively and meaningfully.

5.5.2 Value Judgement

José values a blend of structured inquiry and guided exploration. He believes integrating simulations and interactive learning tools can enhance comprehension and engagement in scientific concepts. He sees ICT tools as providing access to additional resources, improving learners' inquiry skills, and maximizing understanding of the content.

José's value judgment reflects a strong endorsement of inquiry-based learning (IBL) and the use of ICT to facilitate this approach aligning with constructivist theories, which suggest that learners build knowledge through exploration and inquiry (Barzilai & Chinn, 2017). According to Zacharia and Anderson (2003), integrating simulations and interactive tools allows learners to manipulate variables and observe outcomes in a controlled, risk-free environment. They are beneficial in science teaching, as they can be used effectively to enhance scientific inquiry skills and provide learners with opportunities to test hypotheses, observe outcomes, and refine their understanding. José's approach to integrating ICT tools into his teaching strategy can also be seen as an effort to engage learners actively.

5.5.3 Action Judgement

José employs a mix of direct instruction and interactive learning. He poses engaging questions, uses simulations to demonstrate principles, and encourages learners to test their

hypotheses through hands-on experimentation. ICT simulations substitutes for a conventional laboratory, improving content retention and fostering critical thinking skills.

José's action judgment reveals his practical approach to teaching, which involves balancing direct instruction with interactive, learner-centred learning experiences. His use of simulations to demonstrate principles indicates a commitment to making abstract concepts tangible and understandable. This method is consistent with educational practices that promote cognitive engagement and active learning. ICT simulations as a substitute for conventional laboratory experiences is particularly notable, as it allows learners to engage in experimental activities without physical laboratory resources which is supported by research that indicates virtual laboratories can effectively replicate the learning experiences of physical labs, providing similar benefits in terms of understanding scientific concepts and developing critical thinking skills (De Jong et al., 2013).

5.5.4 Barriers

Due to time limitations, teachers may face challenges in planning and implementing technology-enhanced lessons, especially when they have to balance curriculum demands with incorporating new tools (Ertmer et al., 2015). The language used in ICT simulations or digital resources can be a significant obstacle if learners or teachers need to be proficient, making it another essential barrier in instructional contexts. Ertmer et al. (2012) study emphasizes the significance of offering accessible and culturally appropriate material to guarantee that ICT tools benefit all learners. This problem is significant in classrooms with multiple languages, where the teaching language may differ from the learner's or teacher's primary language.

Finally, the absence of resources such as device availability, dependable internet connections, and technical assistance may retard the successful integration of ICT in classrooms. According to Kozma (2003), having fair access to technology is crucial for maximizing the advantages of ICT simulations in education. Technology's ability to improve learning and engagement will not be fully achieved without sufficient resources.

5.6 Teacher Responses - Paulo

Paulo (teacher) expressed his enthusiasm for integrating various ICT tools into his science lessons, particularly PhET simulations, which he finds invaluable for creating interactive and engaging learning experiences. Paulo explained that ICT tools offer a dynamic and visually appealing way to teach complex scientific concepts. His appreciation for simulations stems from their ability to replace traditional laboratory materials while providing precise and time-efficient demonstrations of experiments that would otherwise require significant setup and resources: *Sometimes I also let my learners use smartphones in certain lessons as visual aids for diagrams and to explore different perspectives of the same diagram through Google Images*, illustrating how technology has become a versatile and essential component of his teaching practice. In addition to smartphones, Paulo incorporates laptops and data projectors for simulations, whenever necessary, to ensure learners can explore and engage with scientific concepts visually and interactively.

Paulo views technology as more than just a supplementary tool; for him, it has fundamentally changed the teaching dynamics in his classroom. He pointed out how using ICT tools not only saves time but also enhances the accuracy of scientific demonstrations. Paulo emphasized: *Technology transforms teaching dynamics*, noting that by using digital simulations and visual aids, he can achieve a level of precision that traditional methods often lack. This precision is crucial when teaching subjects that require precise and accurate representation of scientific phenomena, where even minor inaccuracies can lead to misunderstandings among learners. For Paulo, ICT tools bridge abstract theory and tangible, observable outcomes, helping learners grasp challenging concepts more effectively.

Paulo is committed to a teaching style that focuses on the learner. He is highly committed to inspiring and empowering his learners to actively engage in their learning, primarily through ICT tools like PhET simulation. Paulo explained that allowing learners to interact directly with PhET simulation excites them to investigate a particular concept in various scenarios, providing valuable learning opportunities. By allowing learners to explore PhET simulations and ICT tools freely, Paulo thinks he is nurturing curiosity and prompting them to analyse the topic critically. This interactive experience assists learners in gaining a more profound comprehension of the

content material by allowing them to experiment with their theories, share their results, and change the variables accordingly. According to Paulo, actively participating in the subject enhances critical thinking abilities and increases confidence in learners.

Paulo is incredibly enthusiastic about the impact of ICT tools on boosting learners' self-assurance. He emphasized the motivational advantages of technology in the classroom by stating that learners are empowered when they can experiment with various scenarios and witness the outcomes firsthand. ICT tools enable learners to be more autonomous in their learning by promoting exploration and experimentation. This feeling of empowerment is crucial, particularly in a field such as science, where learners are frequently expected to use theoretical understanding in real-world situations.

For Paulo, the confidence gained from these interactive experiences extends beyond the classroom, helping learners become more competent and assured in their academic abilities.

Like many of his colleagues, Paulo faces obstacles that slow down technology integration in his classroom. One of the main challenges Paulo faces is time constraints: *Time constraints are a big issue*. Paulo needs help to balance the preparation and integration of technology with his other teaching duties, especially when making the lesson flow smoothly. While ICT tools can save time during the lesson, the upfront work can be demanding, creating additional pressure for teachers.

Another significant barrier Paulo highlighted is network connectivity: *Network connection issues are a constant problem*. Reliable internet access is essential for many digital tools Paulo uses, including online simulations and resources. A slow or unstable network can negatively impact the lesson plan by causing delays and interruptions, which may result in learners losing focus. Paulo stated that these connection problems can cause significant disruptions during classes that heavily depend on immediate interaction with digital material, like PhET simulations or virtual laboratories. When the internet fails, Paulo is often forced to revert to traditional methods. In addition to time and connectivity challenges, Paulo acknowledges that the lack of ICT skills of some teacher's poses a significant barrier to effective technology integration: *Not all teachers are comfortable using ICT tools*. The potential of ICT tools in the classroom may be restricted by a lack of confidence and training among science

teachers, causing them to be hesitant or not fully use ICT tools. Paulo thinks additional training opportunities are necessary to assist science teachers in improving their ICT skills and becoming more comfortable with the technology. He emphasized that insufficient or inadequate training and support could lead to teachers losing interest in using ICT tools in the classroom, thus limiting their effectiveness in enhancing learner learning.

Table 5.5 summarises the insights from Paulo's interview, highlighting his belief in the importance of understanding atomic interactions for grasping chemical behaviour, his commitment to a learner-centred, inquiry-based teaching approach that fosters collaboration, his use of diverse methods like group work and digital simulations to promote critical thinking, and the absence of significant barriers to integrating ICT simulations in his teaching practice.

Table 5.5

Paulo's Interview Response

Category	Observed instances
Reality judgement	Paulo believes that understanding atomic interactions is foundational for comprehending chemical behaviour and properties. He emphasizes that learners should explore and grasp different types of atomic bonds and their implications.
Value judgement	Paulo values a learner-centred, inquiry-based approach to teaching. He believes in facilitating a collaborative and interactive learning environment where learners build on their prior knowledge and actively participate in the learning process.
Action judgement	Paulo employs a variety of teaching methods including group work, hands-on activities, and digital simulations. He acts as a facilitator, guiding learners through critical thinking and exploration of atomic interactions, rather than directly instructing.
Barrier	Paulo faces no significant barriers to ICT simulations use. He effectively integrates digital simulations alongside other teaching tools, demonstrating proficiency and confidence in using technology to enhance learning.

Paulo uses ICT simulations to foster a deeper understanding of science concepts among his learners. His approach promotes independent learning and critical thinking. The following analysis explores Paulo's beliefs and practices concerning ICT simulations use in science education. It examines its benefits for enhancing learner motivation in the classroom and concept understanding, as well as the challenges, such as time constraints and technological barriers, that can hinder effective implementation.

5.6.1 Reality Judgement

Paulo thinks that grasping atomic interactions is essential for understanding chemical behaviour and properties. He stresses the importance of learners examining and understanding atomic bonds and their consequences using various teaching tools, such as ICT simulations.

Paulo's view on the significance of comprehending atomic interactions demonstrates a solid dedication to conceptual learning in science education. A study in this field, done by Taber (2013) indicates that learners must have a strong understanding of atomic and molecular interactions to comprehend more significant chemical concepts and occurrences. Learners must have this basic understanding to develop a deeper comprehension of chemistry, a discipline that heavily depends on visualizing and conceptualizing abstract ideas.

Incorporating ICT simulations to help comprehend atomic interactions supports constructivist learning theories, in which learners build knowledge by interacting with interactive tools and resources. Digital simulations allow learners to see and control atomic structures, leading to a better understanding of how atoms bond and interact to create various substances.

In addition, Paulo's use of smartphones, laptops, and projectors to conduct ICT simulations indicates a hands-on method for integrating technology in science education which supports Hegarty (2018) research, who demonstrated that technological tools can significantly improve learners' spatial skills and comprehension of intricate scientific ideas through dynamic visualizations that are not achievable with traditional teaching approaches.

5.6.2 Value Judgement

Paulo loves using ICT tools and prefers a learner-centred approach when teaching. He feels that using ICT simulations can improve learners' motivation in class, increase confidence, and reduce teaching time. Moreover, Paulo highlights that ICT simulations enables learners to discuss ideas in various situations, which he believes is essential for enhancing concept understanding.

Paulo believes in a learner-centred, inquiry-based method that aligns with educational theories promoting active involvement of learners and learner independence. IBST motivates

learners to inquire, investigate, and develop their comprehension, which fits nicely with Paulo's methodology.

Research suggests that ICT simulations can increase motivation and engagement by making learning experiences interactive and immersive (Squire, 2011). These tools enable learners to see and control scientific phenomena in ways that traditional teaching methods cannot, increasing interest and learners' involvement in the topic.

Clarke-Midura and Dede (2010) suggest that ICT simulations can significantly improve learning by enabling learners to manipulate variables and see results quickly. This feature is especially useful in science teaching, as conducting experiments in the real world can take up much time and resources.

5.6.3 Action Judgement

Paulo also uses different teaching techniques, like as group work, hands-on tasks, and PhET simulations. He is a facilitator, guiding learners in critical thinking and exploration instead of giving them straightforward answers.

Paulo's teaching methodology as a facilitator, rather than a traditional one, reflects a constructivist education approach, where the main goal is to assist learners in learning and exploration content. This method reflects contemporary trends in education that prioritize interactive, learner-centred approaches and the integration of innovative teaching strategies on cultivating critical thinking abilities and promoting learner self-reliance (Bransford et al., 2000).

Using ICT simulations, Paulo establishes an engaging learning environment that promotes exploration and hands-on learning experiences. A study by Rutten et al. (2012) shows that ICT simulations are valuable for encouraging inquiry-based learning and critical thinking in science education. These instruments enable learners to interact with scientific ideas practically, improving their comprehension and capacity to use knowledge in new scenarios. In addition, Paulo integrates group work, hands-on activities, and ICT simulations to create a blended learning environment that accommodates various learning styles. Schramm et al. (2018) suggest that cooperative learning techniques, like group projects, can enhance academic performance and

social dynamics among learners, creating a more inclusive and encouraging classroom atmosphere.

5.6.4 Barriers

Paulo shows skill and confidence in incorporating ICT simulations with other teaching tools, and there are no significant obstacles to using ICT. Nevertheless, obstacles like limited time, connectivity problems, and learners' lack of ICT proficiency hinder the successful use of ICT simulations.

Even though Paulo does not have significant obstacles to using ICT, some of the challenges he faces in incorporating technology in his lessons are related to limited teaching time, network problems, and learners' ICT. Ottenbreit-Leftwich (2010) categorize barriers to technology integration as first-order (extrinsic) barriers, including access to technology and time, and second-order (intrinsic) barriers, such as teachers' beliefs and skills.

Internet connection problems and power outages reflect the results of studies on technology inequalities and access gaps, highlighting how infrastructure restrictions can impede the efficient use of technology in educational settings, especially in unprivileged schools (Warschauer, 2004). Tackle these infrastructure challenges is essential to guaranteeing fair access to ICT tools, teaching and learning materials, and opportunities.

Furthermore, learner's different levels of ICT abilities indicate the need to include digital literacy education in the curriculum. According to Buckingham (2007) research, learners require both access to technology and the ability to use it effectively for learning purposes. Continuous support and learners' and teachers' training are crucial in addressing these obstacles and optimizing the advantages of using ICT simulations in education.

5.7 Summary

Chapter 5 comprehensively analyses science teacher's varied experiences and perspectives in incorporating ICT simulations and IBST within their classrooms. Teachers' responses indicate a strong commitment to leveraging ICT tools to enhance learner engagement and deepen understanding of scientific concepts, although their approaches differ based on

personal beliefs and practical constraints. While teachers like António and Abel acknowledge the instructional value of ICT simulations and visual aids, infrastructural challenges such as time constraints, power outages, and inconsistent internet access limit their ability to integrate these tools effectively. These logistical issues necessitate creative workarounds, including backup lesson plans and selective use of technology.

Teachers such as Shantel and José highlight the benefits of ICT simulations in fostering an interactive and learner-centred environment, noting how simulations and visual aids make abstract scientific concepts more accessible. They view ICT simulations as essential for encouraging inquiry, critical thinking, and learner engagement. However, resource limitations and varying levels of familiarity with ICT simulations among learners pose additional challenges. Professional development and access to reliable infrastructure emerge as critical needs to support teachers in realizing the full potential of ICT simulations and IBST integration.

In summary, this chapter underscores that while teachers believe in the transformative potential of ICT simulations for inquiry-based learning, the extent of integration is primarily shaped by contextual realities. By examining the interplay between teachers' beliefs, classroom practices, and the external challenges they face, this chapter highlights the need for tailored support to enhance the effective use of ICT simulations in science education.

EXPLORING SCIENCE TEACHERS' BELIEFS AND PRACTICES

6.1 Introduction

Chapter 6 delves into classroom observations and interviews with participating science teachers, highlighting the influence of teachers' beliefs on their instructional decisions. By examining varied teaching approaches and integrating ICT simulations tools like PhET simulations, the analysis revealed distinct pedagogical patterns that illustrate how science teachers balance constructivist and traditional strategies within the inquiry-based framework.

On this chapter the researcher employed a combination of conceptual frameworks grounded in constructivist principles to analyze the alignment between teachers' beliefs and their instructional practices using ICT simulations in Inquiry-Based Science Teaching (IBST). Central to the analysis is the Vickers Framework, which examined teachers' decision-making through Reality Judgments (classroom contexts), Value Judgments (beliefs about effective teaching), and Action Judgments (science teachers' practical pedagogical choices). This framework allowed for understanding how science teachers navigated and reconciled their beliefs with the realities of their teaching environments. Additionally, the chapter also integrated the Extended BIUT Framework, which extended the analysis to include systemic influences such as curriculum constraints, infrastructure challenges, and professional development opportunities. By combining these frameworks, the analysis captured the complex relationships of teacher beliefs, systemic barriers, and practical classroom decisions, offering a multidimensional view of how teachers integrated ICT simulations within IBST practices.

The findings provide insight into the dynamics between teachers' theoretical beliefs and classroom practices, offering valuable implications for the effective use of ICT simulations in science education. Confirmability was achieved through crystallization of data from multiple sources, including lesson observations, interviews, and lesson plans. Data generated from classroom observation were cross-referenced with documented teaching practices and participants' stated beliefs to validate findings. Detailed observation notes were supplemented, providing a reliable record for later verification. The researcher maintained a reflective journal to document decisions, interpretations, and potential biases during the analysis process. Peer review

was also used to evaluate observational interpretations, ensuring they aligned with the raw data and avoided subjective bias.

This chapter presents an analysis of the data generated to address the research question:

“How do science teachers’ beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations?”

6.2 Teacher Classroom Observation Summary - Shantel

In Shantel’s lesson on Coulomb’s Law for a Grade 11 class with 16 physical sciences learners, the setup for the PhET simulation was planned to ensure engagement for all learners. Most learners arrived on time, but a few arrived a few minutes late. Shantel briefly summarized the key points for those late, allowing them to catch up quickly without interrupting the lesson flow. Before the class began, Shantel ensured that all computers and tablets were ready with the PhET simulation pre-loaded. She had spent time before the lesson making sure every device was connected and working correctly, trying to avoid any potential technical issues that could disrupt the lesson flow.

Once all learners were seated, Shantel took about five minutes to explain how the PhET simulation worked, using a data projector to display the simulation on a white screen. She slowly explained to the learners how to adjust variables such as charge and distance and demonstrated how to observe the resulting changes in electrostatic force. Her straightforward, step-by-step explanation ensured that the learners felt comfortable and confident using the simulation on their devices.

Shantel’s Physical Sciences lesson started with her writing the topic and objectives on the whiteboard, ensuring that the lesson objectives were clear for all learners. From the beginning, she started the lesson by involving the learners in deep thinking with questions about what they already knew: *What makes a force attractive or repulsive? Could someone states Newton’s third law as it relates to electrostatic forces?*

Some learners responded, sharing their hypotheses: *I think the charges determine whether it’s attractive or repulsive*, while another added: *Newton’s third law states that forces are equal*

but opposite in direction. Shantel acknowledged these responses, using them to bridge their understanding with the topic of the day's lesson on Coulomb's Law.

Shantel continued outlining the core concepts on the whiteboard, focusing on the relationships between charge, distance, and electrostatic force. She emphasized how Newton's third law applies to electrostatic interactions: *Newton's third law states that, for every action there is an equal and opposite reaction. If object A exerts a force on object B, object B also exerts an equal and opposite force on object A. Forces result from interactions.*

Shantel then introduced the PhET simulation. She explained that they would use this ICT tool to explore how changes in charge and distance affect the electrostatic force and to determine Coulomb's constant through measurement.

Shantel demonstrated using the PhET simulation on the projector, guiding learners step-by-step through the simulation. She began with a simple question that immediately sparked curiosity: *What do you think will happen to the electrostatic force if we increase one of the charges in our simulation?*

A learner quickly answered: *The force will increase because more charge means a stronger force.* Shantel smiled and responded: *Let's test that hypothesis.* She then instructed all the learners: *Increase the charge in the simulation and observe what happens.*

Shantel moved around the room as the learners manipulated the simulation, offering guidance and encouragement. A sense of excitement and focus was evident among the learners as they watched the force bar change in real time based on their adjustments. After each experiment, Shantel asked: *Based on what we just observed, can someone describe the relationship between charge and electrostatic force?*

In unison, learners responded: *More charge, stronger force.* Shantel encouraged learners to investigate what happens to the electrostatic force if we change the distance between charges: *What about the distance between the charges? How does changing the distance affect the force?*

One learner hesitated a bit before answering: *Maybe increasing the distance decreases the force?* Shantel agreed and invited one of the learners to test this hypothesis by adjusting the distance within the PhET simulation.

As the learner experimented with different variables, teacher Shantel invited everyone to participate in group discussions. She actively monitored their progress, addressing questions and helping them correct some mistakes. For example, one learner was unsure why the force decreased so significantly with small increases in distance. Shantel used this moment to elaborate on the inverse-square law and its impact on electrostatic interactions: *Did you notice how the force decreases as the distance increases. This happens because the force follows the inverse-square law, meaning that doubling the distance decreases the force by four times.*

This explanation clarified learners' understanding and demonstrated how theoretical concepts were reinforced through some hands-on exploration.

Towards the end of the lesson, teacher Shantel shifted the focus from experimentation to reflection and application. She gathered all learners' attention and asked them to reflect on the patterns they had observed throughout the PhET simulation: *What have we learned today about the relationships between charge, distance, and electrostatic force? How does this relate to Coulomb's Law?*

Learners took turns sharing their insights, discussing how the PhET simulation helped them visualize and understand the concept of electrostatic forces. One learner remarked: *Seeing the change in force when I changed the charges and distance made it easier to understand the formulas we learned.*

Shantel concluded the lesson by challenging all learners to think about real-world applications of Coulomb's Law. She provided examples from everyday life, like the forces between charged objects in static electricity, and asked the class to brainstorm more: *Can you think of other real-world examples where we see Coulomb's Law in action? How might understanding these forces help us in practical situations?*

Learners were eager to contribute, linking their new understanding of electrostatic forces to real-life contexts. Shantel reinforced the importance of applying scientific concepts to solve

real-world problems and encouraged the learners to continue exploring these ideas beyond the classroom.

During the lesson, both the teacher and the learners showed positive and attentive reactions. Shantel stayed calm, accessible, and well-spoken, ensuring each learner felt supported. Her knowledge and self-assurance in the topic were evident as she addressed inquiries and led learners in their investigations. Learners showed great enthusiasm for the interactive style of the lesson, actively engaging in discussions, experiments, and group discussions. They demonstrated an increasing grasp of Coulomb's Law as they explained their discoveries and established links between the theoretical ideas and their observations in the simulation.

Based on Shantel's classroom observation during her lesson, Table 6.1 illustrates the observed teaching activities associated with IBST, categorized into different types of inquiry along with corresponding themes, codes, and observed instances.

Table 6.1*IBST Teaching Activities - Shantel*

Categories	Themes	Codes	Observed instances
Confirmation inquiry	Teacher-led instructions	Teacher explains relationships between charge and electrostatic force	Shantel explained Newton's third law and the inverse-square law during her demonstrations.
	Pre-set tasks	Learners confirm predictions	Learners followed Shantel's lead in increasing the charge and observed the effects on force.
	structured Follow-up questions	Teacher asked closed questions	Shantel asked, "What do you think will happen to the electrostatic force if we increase the charge?"
Structured inquiry	Step-by-step guidance	Teacher-led exploration	Shantel demonstrated how to adjust variables in the simulation while learners followed her guidance.
	Set parameters	Teacher predefined variables	Learners adjusted charge and distance according to instructions, under the teacher's set parameters.
Guided inquiry	Hypothesis testing teacher support	Learners explored predefined questions	Learners tested how distance affects electrostatic force and recorded results based on Shantel's prompts.
		Teacher monitored progress	Shantel moved around the class, offering guidance and addressing mistakes during the simulation.
Open inquiry	Learner-driven exploration	Learners formulated own predictions	Shantel encouraged learners to test hypotheses related to real-world examples and Coulomb's Law applications.
	Reflection and real-world application	Learners applied knowledge	Learners reflected on Coulomb's Law and brainstormed real-world applications like static electricity forces.

6.3 Teacher Classroom Observation Summary – Abel

Unlike Shantel's more structured approach, Abel's setup was flexible, with desks arranged in small groups to encourage collaboration during the hands-on activities since he only had ten learners. Due to a limited number of computers, some learners had to share their devices, working in pairs to manipulate the PhET Circuit Construction Kit simulation. This arrangement fostered group work as learners discussed ideas and adjusted variables like resistance and current together. The data projector was placed right in front of the room, projecting the simulation onto

a screen, which Abel used to project the PhET Simulation. A whiteboard was attached to the front wall next to the screen.

At the beginning of the lesson, Abel spent a few minutes ensuring that all computers and the PhET simulation were adequately set up. Unlike Shantel, who had everything pre-loaded and had a quicker start, Abel took extra time during the lesson to ensure that each shared device was working correctly and that all learners understood how to navigate the PhET simulation. This setup process caused a slight delay, especially as two learners arrived late and needed to be caught up on how to set up the simulation.

Despite the slower start, the shared computer setup allowed learners to ask questions and work together while familiarizing themselves with the simulation. This approach helped the learners become comfortable with the technology, and not everyone began at the same time; it ensured a stronger foundation for using the tools effectively. Once all the learners were confident, the hands-on exploration became more engaging and collaborative, with learners actively experimenting, talking, having fun, and learning together with smiles on their faces. However, some of them looked surprised.

Abel started the lesson by writing the lesson's date, topic, and objectives on the whiteboard. He then explained to the learners that they would be using ICT tools, the PhET simulation, to explore how changes in resistance affect the behaviour of circuits. His interactive teaching style became immediately evident right from the beginning of the lesson when he posed an open question to all learners: *How do you think changing the resistance in an AC circuit will impact the current and voltage?*

A few learners quickly responded, drawing on prior knowledge. One learner stated: *I think increasing the resistance will reduce the current because there's more opposition to the flow.* Abel agreed with the learner and encouraged the class to think about real-world applications: *That's a good observation. Well done, but now think about your home's electrical system, what happens when you add more appliances to a circuit? What might that do to the overall current?*

By engaging learners with this question, Abel activated their preconceptions about electric circuits and created an environment for a deeper investigation into circuit behaviour through the PhET simulation.

Abel then moved into the interactive part of the lesson, introducing the PhET Circuit Construction Kit AC Simulation, projected onto a screen. He demonstrated how to adjust the resistance in the circuit and asked learners to observe changes in current and voltage: *What do you think it will happen to the current if we increase the resistance in our circuit.* His question guided and encouraged the learners to talk and think.

One learner stated: *I think the current will decrease because higher resistance slows it down.* Abel responded with encouragement: *Let's test that hypothesis. Go ahead and increase the resistance in the simulation. Watch what happens to the current and voltage.*

As learning worked individually and in pairs on their laptops, adjusting variables in the simulation, Abel moved around the room, providing personalized feedback and answering individual questions. He monitored learners' progress carefully, ensuring that all learners were engaged in the investigation. The atmosphere was one of quiet concentration, punctuated by excitement as learners observed real-time changes in the simulation. One learner stated: *Look, when we added more resistance, the current dropped, just like we thought!*

Abel used these moments to reinforce critical concepts: *Exactly! As resistance increases, the current decreases, which is a fundamental relationship in Ohm's Law.*

Part of Abel's teaching approach involved breaking the class into small groups to encourage collaborative problem-solving. During these group discussions, Abel presented a challenge: *Now that you've tested how resistance impacts current and voltage, work together to design a circuit that maximizes energy efficiency. Think about how you can adjust resistance to minimize power loss.*

In their groups, learners discussed possible solutions and answers and spoke about what they had observed in the simulation. One group proposed reducing resistance in specific circuit parts to maintain high current while minimizing voltage drops. As they debated different strategies, teacher Abel kept moving around the room, offering suggestions and asking: *If you*

lower resistance too much, what might happen to the current? Can you think of a way to balance it?

The discussions were lively and interactive, with learners exchanging ideas and trying their theories in the simulation. Abel motivated learners to engage in peer learning by encouraging them to share their reasoning.

As the lesson was about to end, Abel gathered the class for a reflective discussion. He asked each group to share their findings and strategies to design an efficient circuit: *What did you find worked best for optimizing the circuit? Did anyone find any unexpected challenges?*

One group explained how reducing the resistance too much allowed more current to flow, while another noted how balancing resistance across different components helped maintain stable current flow. Abel used these reflections and asked: *How might understanding these principles help you in designing electrical systems for a home or a building? Why is it important to consider resistance when planning circuits?*

Learners enthusiastically engaged in the conversation, providing insights on how circuit design can be applied practically, such as reducing energy consumption in devices or enhancing the effectiveness of electrical devices. Abel concluded his lesson by reinforcing the importance of these concepts in everyday life: *Knowing the relationship between resistance, current, and voltage is essential for solving practical issues.* Mastering these principles will assist in creating safer and more efficient circuits, whether designing electronics or working on larger systems.

During the lesson, Abel stayed calm and approachable, creating an environment of exploration and questioning. His learners reacted well to that approach, displaying authentic curiosity about the subject and excitement during interactive tasks. Abel's teaching approach empowered learners to assume responsibility for their learning process, as his thought-provoking questions led them toward a more significant comprehension without revealing the solutions.

Learners exhibited a firm commitment, especially while participating in group discussions, where they engaged in exciting debates and problem-solving. Their excitement was evident upon uncovering the connections between resistance, current, and voltage, and they became more confident as they used these concepts in practical situations.

Based on Abell's classroom observation during his lesson, Table 6.2 illustrates the observed teaching activities associated with IBST, categorized into different types of inquiry along with corresponding themes, codes, and observed instances.

Table 6.2

IBST Teaching Activities – Abel

Categories	Codes	Themes	Observed instances
Confirmation inquiry	Revisiting prior knowledge	Teacher asked learners to recall previous knowledge about circuits.	Abel asked: "How do you think changing the resistance in an AC circuit will impact the current and voltage?"
	Testing established concepts	Learners confirmed their understanding of Ohm's Law through the simulation.	Learners observed how increased resistance decreased the current, confirming their prior knowledge.
Structured inquiry	Teacher-led experimentation	Teacher guided learners through the PhET simulation setup and variable manipulation.	Abel demonstrated how to adjust resistance and observe the effects on current and voltage in the simulation.
	Application of known principles	Teacher structured the investigation of relationships between resistance, current, and voltage.	Abel asked learners to test the hypothesis that increasing resistance reduces current.
Guided inquiry	Hypothesis formation and testing	Learners formed hypotheses based on predictions about circuit behaviour.	Learners predicted the relationship between resistance and current and tested it in the PhET simulation
	Inquiry-driven exploration	Teacher guided learners in group work to solve circuit optimization problems	Abel asked learners to design a circuit that maximizes energy efficiency through group discussions.
Open inquiry	Independent problem-solving	Learners engaged in open-ended tasks to design efficient circuits.	Abel challenged learners to independently design circuits and explore the impact of various resistances.
	Real-world applications	Learners connected theoretical concepts to practical circuit design.	Abel asked learners how understanding resistance and current would help them in designing electrical systems in real life.

6.4 Teacher Classroom Observation Summary – José

In José's Projectile Motion lesson, the class consisted of 15 learners, allowing for a relatively small and manageable group. The classroom setup was designed to facilitate both individual exploration and group discussions. In the beginning, all desks were facing the

whiteboard, but then the teachers asked learners to move desks and chairs around to be arranged in small clusters with a maximum of two or three learners per cluster to encourage group discussions, much like Shantel's setup, creating an environment of interactive learning where learners could easily share ideas and work together. Each group had access to computers equipped with the PhET simulation, allowing them to test different variables related to projectile motion.

The data projector was placed in the middle of the class and used to display the simulation, which José controlled during the initial demonstration. He ensured that all learners could see the projection clearly without being blocked by other learners while simultaneously working on their computers. The whiteboard was attached to the wall in front of the class, and José used it to write down and explain key concepts, such as the relationships between initial velocity, launch angle, and gravity, before moving on to the practical lesson. José spent a few minutes ensuring that the PhET simulation was installed and ready on each computer, which delayed the start of the lesson slightly; once everything was set up and ready, the learners could dive into the activity.

José's classroom observation focused on introducing the topic of projectile motion through the use of the PhET simulation. The lesson was well structured to promote group debates and discussions, with José encouraging learners to ask questions, engage in group discussions, and actively explore concepts.

José began the lesson by writing the lesson topic on the whiteboard. José's enthusiasm was evident from the start: *How do you think different initial velocities affect the trajectory of a projectile?*

The whole class appeared intrigued, and a few hands immediately went up. One learner responded: *I think the faster it's launched, the higher it will go.*

José nodded positively and encouraged further inputs, setting the tone for a discussion-driven lesson. He outlined the key concepts on the whiteboard, explaining projectile motion and giving some examples before introducing the PhET simulation as an ICT tool. His explicit

instruction and approachable manner made learners comfortable asking questions early on, contributing to an open and engaging classroom environment.

Once the conceptual foundation was laid, José transitioned to the interactive part of the lesson, where learners used the PhET Projectile Motion simulation to explore the effects of different variables on the projectile's trajectory. José guided the learners through an initial example, setting the launch velocity and angle in the simulation and projecting it on the screen. José asked: *What do you predict will happen if we launch the projectile at a higher speed but keep the angle the same?*

Several learners spoke almost simultaneously, trying to answer the question, but they needed to be louder. One of the learners then answered: *It should go farther and maybe higher.*

José encouraged them to test their hypothesis by adjusting the simulation variables themselves. He asked the class, in small groups, each group were given a task to perform the same experiment using different launch angles and speeds. His support for group discussions was evident as he moved around the room, engaging with each group, offering hints, and clarifying misconceptions. For example, he approached a group struggling to understand gravity's impact and helped them: *Remember, gravity always pulls the object downward. What do you think will happen if we reduce gravity? Try it in the simulation and observe the result.*

The groups worked well together, with each member taking turns manipulating the simulation and recording observations. The classroom was buzzing with activity, with learners discussing their findings and debating different hypotheses and solutions. José facilitated these discussions by posing additional questions to the groups: *How does changing the launch angle affect the range of the projectile? What angle gives the maximum range? Can you explain why?*

Learners enthusiastically responded, with some testing angles close to 45 degrees, while others adjusted different variables to see how they influenced the projectile's path. José's approach created an active learning environment where learners were encouraged to ask questions, work together, and discuss. The group debates and discussions were very productive, and it was clear that learners supported each other's understanding and developed different results in projectile motion.

As the lesson was about to end, José realized that the class was running short on time. Even though he had planned to have each learner per group present their findings, he quickly realized he did not have enough time for all the activities. When one group asked if they could share their results, José replied: *I'd love to hear what you have found out, but unfortunately we're running out of time.* Despite the time pressure, José focused on guiding learners through the key concepts. He posed one final question to the class: *Based on what we've seen today, what's the most important factor in determining how far the projectile will travel?*

Learners shared their results; one learner replied: *It's the combination of speed and angle. We found that when we increased the speed and set the angle around 45 degrees, the projectile travelled the farthest.* José was about to wrap up when the school bell rang, and the lesson ended. Although he did not have enough time to finish all the planned activities, the class engaged with the lesson content and gained a solid understanding of projectile motion.

Based on Jose's classroom observation during his lesson, Table 6.3 illustrates the observed teaching activities associated with IBST, categorized into different types of inquiry along with corresponding themes, codes, and observed instances.

Table 6.3

IBST Teaching Activities - José

Categories	Codes	Themes	Observed instances
Confirmation inquiry	Verifying hypotheses	Testing known principles	Learners confirmed that a 45-degree angle produces the maximum range in projectile motion.
Structured inquiry	Predefined questions	Teacher-directed exploration	José guided learners through set questions about initial velocity and launch angles.
Guided inquiry	Hypothesis testing	Teacher support during exploration	Learners explored the effect of gravity and speed on projectile motion with José's guidance.
Open inquiry	Learner-led exploration	Independent investigation	Groups worked collaboratively to test variables and make predictions using PhET simulation.

6.5 Teacher Classroom Observation Summary – Paulo

In Paulo's Atomic Interactions lesson, the small class size of only eight learners allowed for a more personalized and interactive classroom setup than those of Shantel, Abel, and António. All desks and chairs were arranged in a semi-circle, creating an environment where all learners could easily see each other, and the data projector made it easier for them to engage in

discussions with one another. This setup contrasted with António's traditional rows and Abel's group-based seating, as Paulo's arrangement emphasized open discussions and individual attention while maintaining a cohesive group dynamic.

Each learner had access to computers placed on desks, allowing them to explore the PhET simulation independently. Paulo spent a few minutes at the beginning of the class ensuring that the simulation was loaded and ready to go. However, unlike António, who maintained tight control over the simulation, Paulo allowed learners to adjust the variables, encouraging exploration. He began the simulation with a brief demonstration projected onto the screen, after which learners could explore how changing variables like atomic distance and charge affected bonding interactions.

Since there were only eight learners, Paulo was able to provide real-time guidance and ensure that all learners were fully engaged asking questions, and collaborating. Unlike Shantel, who quickly moved to hands-on activities, or Abel, who spent more time setting up the simulations, Paulo took his time ensuring everyone was comfortable with the simulation and could explore the simulation at their own pace. The class ran smoothly, and all learners arrived on time, creating a highly interactive learning experience.

Paulo's lesson on Atomic Interactions used a PhET simulation to explore the forces that govern atomic bonding, including ionic, covalent, and van der Waals interactions. His small class size, with only eight learners, allowed for a personalized and interactive learning environment. Paulo's teaching style focuses on group discussions and encouraging learners to ask questions throughout the lesson.

Paulo began the class by briefly outlining the lesson's objectives: understand different types of atomic bonds and explore how forces act between atoms. Paulo immediately set a collaborative tone: *What do you think makes atoms stick together or repel each other? Can someone explain what might be happening when we have ionic or covalent bonds?*

Learners took turns sharing their thoughts, clearly comfortable in the small, intimate class setting. One learner stated: *I think it has to do with the charges of the atoms*, while another stated: *Covalent bonds probably involve sharing something between atoms*. Paulo encouraged

more input: *Good thinking. Yes, charges are crucial for ionic and covalent bonds, involve sharing electrons. Today, we'll see how these interactions behave using the PhET simulation.* Paulo briefly reviewed key concepts about atomic structure and bonding before moving on.

Once some important concepts were revisited, Paulo introduced the PhET Atomic Interactions simulation, projecting it onto the screen. He explained how learners would use the simulation to explore atomic bonds and interactions by adjusting variables like charge and distance between atoms. He demonstrated a simple example to get the learners started: *Here, we'll bring two atoms together. What do you think will happen as we move them closer or farther apart?* One learner quickly answered: *The closer they get, the stronger the attraction.* While another predicted: *But at some point, they might start to repel.* Paulo encouraged them to test these hypotheses in the PhET simulation: *Great ideas! Go ahead and use the PhET simulation to test that. Work in pairs and remember to discuss your findings with each other as you go.*

Paulo's support for group discussions was evident as he encouraged learners to work in pairs, even with such a small class. The atmosphere in the room became lively as pairs worked through the simulation, adjusting the variables and discussing the results. Paulo moved around the room, listening to conversations and offering help when needed. At one point, a pair was unsure why the atoms began repelling after getting too close: *We thought they'd keep attracting, but now they're pushing each other apart. Why is that?*

Paulo took this opportunity to explain the concept of electrostatic repulsion in greater depth: *That's a great observation! When atoms get too close, the repulsive forces between their nuclei become stronger. Even in a bond, there's a balance between attraction and repulsion.*

Throughout the group discussions, Paulo remained engaged, asking probing questions to help learners think critically and deeply about the atomic forces they observed. For example, he prompted one group to consider the differences between ionic and covalent interactions: *How does the interaction between charged atoms in an ionic bond differ from what you see in a covalent bond? Can you see that in the simulation?*

Learners enthusiastically discussed these questions, refining their understanding through dialogue with their peers and Paulo. The small class size allowed for constant interaction, ensuring that every learner had the opportunity to participate and contribute to the discussion.

During the group discussions, Paulo actively asked questions to encourage learners to analyse atomic forces more deeply and critically. For example, he encouraged a pair of learners to consider the differences between ionic and covalent interactions: *What is the difference in the interaction between charged atoms in an ionic bond compared to a covalent bond? Is it possible for you to observe that in the simulation?*

Learners engaged in lively discussions about these questions, trying to understand and looking for answers through conversations with their classmates and the teacher. The class size facilitated continuous engagement, guaranteeing that each learner could participate and add to the conversation. Paulo then gathered the class together for a discussion. He asked each pair to share their findings with the rest of the group: *What did you discover about atomic interactions? How did changing the charge or distance between atoms affect their bonding behaviour?*

One pair presented their findings on ionic bonds, explaining that more vital charges led to stronger attractions between atoms. Another pair shared their insights on covalent bonds, explaining how the distance between atoms affected their shared electron clouds. Paulo gave feedback, accepting their answers and elaborating more on their explanations by adding, Paulo then gathered the class together for a discussion.

Learners, once again, engaged in an open discussion, linking the concepts of atomic interactions to scenarios like chemical bonding in compounds, material strength in engineering, and even biological processes such as DNA structure. One learner commented: *I think knowing how atoms interact can help when designing new materials, like making something stronger by controlling the types of bonds.* This thoughtful reflection demonstrated how deeply learners had engaged with the lesson's content. Paulo concluded by praising the learners for their participation and encouraging them to continue thinking critically about atomic interactions in future classes. Based on Paulo's classroom observation during his lesson, Table 6.4 illustrates the observed teaching activities associated with IBST, categorized into different types of inquiry along with corresponding themes, codes, and observed instances.

Table 6.4*IBST Teaching Activities – Paulo*

Categories	Codes	Themes	Observed instances
Confirmation inquiry	Testing known concepts	Testing atomic bond strength Validating previous understanding	Learners confirmed the known relationship between charge strength and attraction in ionic bonds.
Structured inquiry	Teacher-guided investigation	Exploring atomic bonds based on teacher's guidance Structured exploration of specific concepts	Paulo led learners in exploring how charge and distance affect bonding in ionic and covalent bonds.
Guided inquiry	Learner exploration with prompts	Investigating ionic vs. covalent bonding interactions Facilitating critical analysis and deeper understanding	Learners, guided by Paulo, tested atomic interactions by adjusting variables like charge and distance.
Open inquiry	Independent learner investigation	Discussing and experimenting with atomic forces Encouraging independent and creative investigation	Learners were encouraged to explore the PhET simulation on their own and share their findings.

6.6 Teacher Classroom Observation Summary - António

The classroom setup in António's lesson on the Conservation of Mechanical Energy reflected his structured approach. There were 12 learners in the class, and all desks and chairs were arranged in traditional rows, facing towards the whiteboard in front of the classroom. Unlike Shantel and Abel, who used flexible seating arrangements, António's setup showed a more passive setup and observation-based learning style. All learners had access to the PhET simulation but did not interact with it independently; instead, they followed along as António controlled the simulation projected via the data projector onto a white wall at the front of the class, right above the whiteboard.

António spent minimal time setting up the simulation, as he had preloaded the PhET simulation before class began.

All learners arrived on time, and António quickly started the lesson, ensuring they were ready to listen actively. This highly controlled setup contrasted with Shantel's and Abel's more flexible and interactive environments, where learners were encouraged to talk and explore the simulations independently and engage in group discussions. While he effectively used the PhET simulation to demonstrate key concepts, António's teaching style was focused more on direct instruction over collaborative learning.

António began the lesson by writing the topic "*Conservation of Mechanical Energy*" on the whiteboard. From the outset, it was evident that António's teaching approach was more authoritative. He began by prompting learners to recall definitions from previous classes: *Who can explain what kinetic energy is? What about gravitational potential energy?*

Two learners attempted to give definitions of those concepts. António listened but did not engage with the learners' responses; instead, he used their answers to continue talking and reiterating the core concepts. He then clarified the differences between the two concepts: *Kinetic energy depends on motion or movement, while gravitational potential energy is related to an object's height above the ground. Today, we will see how these energies change when different variables are adjusted*, ensuring that all learners have a solid conceptual background before they start the lesson.

Although António's explanations were clear and concise, the interaction remained one-sided. When learners raised their hands to ask questions or seek clarification, the teacher answered by saying, "Let's move on; we will cover that later..." indicating a preference to stay on planned schedule rather than addressing the inquiry immediately. That attitude discouraged learners from asking further questions, and it became evident that António preferred a more controlled environment where he delivered the lesson content without many learner interruptions.

Once the core concepts were established, António moved on to the interactive part of the lesson, projecting the PhET simulation of a skater on a track onto the screen. He explained how the simulation would help demonstrate the conservation of mechanical energy, highlighting the need to observe the changes in energy as variables like mass, friction, and gravity were manipulated. However, rather than allowing learners to explore the simulation independently or

in groups, António maintained strict control over the activity: *Watch the screen carefully. I will adjust the mass, and you will see how the energy changes in the graph and pie chart.*

António adjusted the settings in the PhET simulation, and all learners followed along passively: *What happens to the skater's energy when we increase the mass?* He answered the question before learners had a chance to respond and added: *You'll notice that the kinetic energy increases while potential energy decreases.*

This approach left little room for learners' inquiry or exploration, as António quickly provided the answers without encouraging learners to form their hypotheses or test them using the simulation.

António continued adjusting the variables as the simulation progressed, narrating all the changes he was making: *Adding friction decreases the total mechanical energy because some of it is lost as thermal energy. This is why friction always reduces the efficiency of real-world systems.* He then pointed out how friction affected energy distribution. Again, while António's explanations were accurate, the absence of learners' input and exploration was quite apparent. Learners sat down quietly, observing the PhET simulation but not actively engaging with the experiment and not showing excitement.

Unlike the previous teachers, who encouraged group work or collaborative problem-solving, António's approach left no room for group discussions or debates. When learners began discussing their observations amongst themselves, António quickly stopped them: *There's no time for discussions. Focus on the simulation, try to understanding it and those things you don't get it I'll explain.*

This approach shut down any attempt to group discussions, which could have helped learners to process and apply the concepts. António's teaching method reflected a more traditional approach where the teacher was the primary source of information, and learners were expected to absorb the content without creating an environment to engage in discussions.

António then moved on to the last part of the lesson. He asked learners to reflect on what they had observed in the simulation but only allowed two learners to share their thoughts, not giving the rest of the class much opportunity to share. When the third learner raised his hand to

ask a question about why the skater slowed down when friction was added, António gave a brief, technical explanation: *It's because friction converts some mechanical energy into thermal energy. You should all know that already since I have mention it so many times.*

However, rather than letting learners explore the concept further through group work or independent inquiry, António asked them to write down their ideas individually and submit them after class, indicating that the lesson was over without further discussion.

Based on António's classroom observation during his lesson, Table 6.5 illustrates the observed teaching activities associated with IBST, categorized into different types of inquiry along with corresponding themes, codes, and observed instances.

Table 6.5

IBST Teaching Activities - António

Categories	Codes	Themes	Observed instances
Confirmation inquiry	Teacher-led simulation	Predefined answers	António asked questions but answered them himself before allowing learners to respond.
	Direct instruction	Passive learning	Learners followed the simulation projected by António without any interaction or independent exploration.
Structured inquiry	Observation-based learning	Control of variables	António controlled all variables in the PhET simulation and guided learners to observe changes in energy.
Guided inquiry	Preloaded simulation	Minimal learner involvement	António preloaded the simulation and explained it while learners passively watched and took notes.
	Limited questioning	Teacher-led reflection	António asked learners to reflect on the simulation, but only allowed two learners to share their thoughts.
		Discouragement of questions	Learners' questions were dismissed with comments like "We'll cover that later" or "You should already know this."
Open inquiry	No open inquiry	Absence of hypothesis testing	Learners were not given opportunities to form hypotheses or test them independently within the PhET simulation.

6.7 Summary

Chapter 6 analysed classroom observations and teacher interviews to explore how beliefs about IBST and ICT simulations inform science teachers' instructional practices. Each teacher's approach to PhET simulations differed based on their comfort with technology, pedagogical style, and perceived benefits of inquiry-based learning. Teachers like Shantel and Abel promoted active learner engagement, encouraging collaborative exploration of PhET simulations, while others, such as António, used a more controlled, teacher-centred approach. This diversity highlights how beliefs and practical constraints shape the use of ICT simulations in IBST. The findings revealed the importance of aligning professional development and support structures with teachers' beliefs and classroom realities to foster effective inquiry-based teaching practices using simulations.

CHAPTER 7

THE IMPACT OF SCIENCE TEACHERS' BELIEFS ON IBST

7.1 Introduction

This chapter explored how science teachers' beliefs about IBST and ICT simulations influence their instructional choices, classroom practices, and overall integration of simulations in teaching. Focusing on five science teachers, António, Shantel, Abel, José, and Paulo, the analysis reveals how these teachers navigate the challenges and opportunities of incorporating simulations into their lessons. Each teacher's approach reflects a distinct interpretation of IBST, with varied emphasis on learner autonomy, teacher control, and the role of technology as a means to facilitate complex scientific concepts. By examining factors such as lesson plan integration, classroom dynamics, and teacher-centred versus learner-centred practices, this chapter sheds light on the impact of teachers' beliefs and the practical realities that shape their use of ICT simulations in science instruction.

Confirmability was addressed by linking findings directly to the data collected, including classroom practices and participant interviews. A transparent audit trail was maintained, detailing the steps taken in analyzing how science teachers' beliefs influenced teaching strategies and outcomes. The researcher employed member checking, inviting participants to review and provide feedback on their respective analyses to ensure that their beliefs and practices were represented accurately.

7.2 Teacher António

7.2.1 Teachers' Beliefs

It is clear from the interviews that António has a strong belief in the ability of ICT tools to improve learning. His focus is on preparing learners for the modern world by integrating technology: *It is crucial for learners to be equipped for the modern world and the 4th Industrial Revolution.* This statement reflects António's view that ICT tools are essential, rather than optional, for contemporary education.

António also believes that ICT tools provide critical visual aids that support learners' understanding of complex scientific concepts: *ICT tools serve as visual aids in helping children learn, learners can understand better because ICT tools help them to visualize the concept.*

His perspective here shows his belief that technology enhances comprehension, a view that aligns with contemporary educational research that highlights the role of ICT tools in supporting diverse teaching and learning styles.

While António is optimistic about the role of ICT tools in teaching, his beliefs about IBST are less evident in his classroom practice. His inclination towards inquiry-based learning is often overshadowed by a teacher-centred approach, where he tightly controls the learning environment, limiting learner autonomy. For instance, in his lesson on the conservation of mechanical energy, António led the entire lesson, with learners primarily observing the PhET simulation as he adjusted the variables and explained the outcomes, asking: *What happens to the skater's energy when we increase the mass?* He immediately answered, disallowing learners to think and explore independently.

7.2.2 Implementation in the Classroom

António's implementation of PhET simulations was a notable strength but is limited by his control over all lessons. The PhET simulation on mechanical energy is a core part of his teaching strategy. His lesson plan outlined the use of the simulation to help learners understand concepts like kinetic energy and gravitational potential energy by adjusting variables such as mass, friction, and gravity: *Simulations provide a visual way for learners to understand complex concepts*, which reflects his belief in the pedagogical value of simulations.

PhET simulations were implemented in his class in contrast with the spirit of IBST. During his lesson, António maintained control over the PhET simulation, projecting it onto the screen and explaining all the changes himself, limiting learner interaction with the simulation and reducing the opportunity for learners to engage in independent inquiry or exploration. For instance, instead of letting learners test their predictions about how changes in mass or friction would affect the skater's energy, António guided the process entirely: *Watch the screen carefully. I will adjust the mass and you will see how the energy changes in the graph and pie*

chart. This teacher-directed activity leaves little room for learners to explore variables or form hypotheses, which are critical components of IBST.

7.2.3 Challenges with ICT Integration

Despite António's strong belief in the value of PhET simulations, he faced numerous challenges that hindered the effective integration of technology into his lessons. One of the main challenges he faced was the time-consuming part of the simulations. António expressed frustration over how long it takes to prepare the equipment: *Setting up all the equipment before class time takes a lot of time, and I end up using the time I should be teaching*. António's frustration showed a practical challenge that many science teachers face in balancing the use of technology within a constrained teaching schedule. These issues not only prevented António from using technology effectively but also forced him to constantly develop backup plans that were less engaging and not as effective as the original PhET simulation lesson.

In addition to these logistical challenges, António also struggled to keep up with the fast-evolving nature of technology: *Keeping up with all the new technology is challenging. I try to learn as much as I can, but with my teaching schedule, it's hard to find the time for proper training*. This statement shows a significant challenge experienced by many science teachers. There is a considerable gap between technological advances and the time allocated for professional development. António's teaching experience also indicated that while he is motivated to use PhET simulations, not having enough time to set up the ICT tools and structured training limits his ability to use them often.

7.2.4 Lesson Plan Integration

António incorporated inquiry-related tasks in his lesson plan, such as asking learners to design skate parks using the PhET simulation. However, in practice, learners were not given the autonomy to manipulate variables independently during the lesson. Instead, they followed along passively while António adjusted the settings and narrated the outcomes, further limiting the inquiry aspect of the lesson.

7.2.5 Learner Outcomes

António thinks simulations and other ICT tools significantly improve learner engagement and learning results. He noticed that learners show more interest when engaging with simulations, supporting his belief that these tools make abstract concepts more tangible. He also noted that environments with advanced technology help learners understand concepts more effectively and result in enhanced academic achievements: *Technology helps learners engage and explore concepts beyond the textbook, and I've seen improvements in their grades.*

However, the observations suggested that while António's use of simulations enhances conceptual understanding, his teaching style limits active learner engagement. For example, during the PhET simulation, learners were primarily observers rather than active participants in the learning process. António's approach discouraged inquiry by answering questions before learners could think critically or experiment with the variables. As a result, the potential benefits of using simulations to foster inquiry-based learning were not fully realized. António's skills with ICT tools were evident as he used a range of devices, including laptops, projectors, and smartphones, to improve his teaching. However, his confidence level with all these ICT tools is often challenged by the practicalities of using them in the classrooms.

For example, while he showed enthusiasm for using PhET simulations, he also admitted that setting up and managing the ICT tools can be overwhelming, particularly when he has to fit it with an already demanding teaching schedule. He thought about the challenge and stated: *You can't just pick up a new ICT tool and use it right away. It takes time to understand how to integrate it effectively, and that's something I struggle with balancing along with my other teaching duties.*

António's experience with unreliable infrastructure, unstable internet, and frequent power outages also adds a layer of complexity to his teaching practices when using ICT tools. His fear of worrying about the possibility of expensive equipment getting damaged by power is a genuine concern: *Power cuts have damaged some of our equipment before, and it's expensive to repair or replace them. This makes me cautious about using ICT tools too much.* His fear of damaging the equipment is one of the obstacles that create tension between his desire to use ICT tools and the reality of his challenges.

7.3 Teacher Shantel

7.3.1 Teachers' Beliefs

Shantel's approach to teaching focuses on the importance of learners actively engaging with scientific concepts rather than passively receiving information. During her interview, Shantel expressed her belief in the effectiveness of inquiry-based learning: I believe that learners do learn best when they discover things for themselves. I prefer guiding them through experiments and letting them find the answers. This belief is in agreement with the fundamental principles of IBST, which emphasize learner autonomy, exploration, and the construction of knowledge through inquiry.

Shantel also highlighted the value of ICT simulations in making science more accessible and engaging. She firmly believes that technology transforms the learning environment: Learners learn better when they use technology; it makes them more excited and it saves teaching time, making abstract concepts easier for learners to grasp. This reflects her belief that ICT simulations, particularly simulations, can enhance engagement and comprehension by providing learners with visual and interactive representations of complex concepts. For Shantel, technology is not just a tool for efficiency but a means to create a more dynamic and engaging learning experience.

Furthermore, Shantel views simulations as particularly powerful in bridging the gap between theoretical concepts and practical understanding. She shared a specific instance where ICT simulations had a transformative impact: Some learners didn't understand the lesson, but as soon as I did a demonstration using an ICT simulation, they grasped the concepts well. Her views on ICT tools underscores the belief that simulations can simplify complex ideas by providing learners with real-time visual feedback, allowing them to experiment and learn by doing.

7.3.2 Implementation in the Classroom

Throughout the lesson, Shantel adopted a facilitative role, guiding learners through the simulation while allowing them the freedom to explore. She demonstrated how to adjust variables such as charge and distance and then posed follow-up questions to deepen learners'

understanding: *What happens if you increase the charge? How does that affect the force?* These questions were designed to encourage learners to experiment with the simulation, test their hypotheses, and reflect on their observations.

Shantel's approach to classroom management is learner-centred, aligning with the principles of IBST. She moves around the room, offering support and asking probing questions that help learners refine their understanding. For instance, when a group struggled to explain why increasing the distance between charges reduced the electrostatic force, Shantel provided a scaffold: *Think about how the inverse-square law applies here. What happens to the force when you double the distance between the charges?* This type of questioning guided learners toward the correct conclusion and encouraged them to think critically about the underlying principles.

Shantel's learners are empowered to lead their learning in her classroom. She motivated them to take control of the simulation, explore their ideas, and foster a culture of curiosity, leading to active learner involvement in the learning process. Shantel's teaching style demonstrated her belief in IBST, where the teacher facilitates, and learners are prompted to explore, collaborate, and uncover.

7.3.3 Challenges with ICT Integration

While Shantel's enthusiasm for ICT simulations is visible in her lesson plan and classroom observation, her interview sheds light on her challenges in effectively implementing these tools. One of her significant barriers is limited access to technology. Although her school provides resources such as computers, data projectors, and internet access, these tools are not always available for every lesson.

Shantel's view is evident: *Not every classroom has enough computers, so we have to share. This sometimes means adjusting my lessons or limiting how much I can use the technology, depending on availability.*

The lack of consistent access to ICT resources can hinder Shantel's ability to integrate interactive and inquiry-based methods into every lesson fully. When technology is unavailable or shared between classes, she must modify her approach or rely on more traditional teaching methods, which may lack the engagement and clarity provided by ICT simulations. These

limitations require her to be flexible but also restrict how much she can implement her preferred teaching methods. As a reaction, Shantel needs to create different lesson plans that do not depend so much on technology, even though she admits that these alternatives often lack the same level of engagement as her technology-based lessons.

7.3.4 Lesson Plan Integration

Shantel's lesson plans revealed a clear and intentional integration of ICT tools and IBST principles. In her lesson on *Coulomb's Law*, for example, she incorporated the PhET simulation as a central rather than supplementary element of the lesson. The lesson plan began with a review of critical concepts such as charge magnitude and electrostatic force and then moved to an investigation and a phase of inquiry where learners were allowed to use the PhET simulation to test these ideas.

The lesson plan was meticulously created to lead learners through the inquiry process. Once the PhET simulation was introduced, Shantel allowed learners to independently explore by adjusting variables like charge and distance. Throughout the lesson, she included guiding questions. She embedded guiding questions throughout the lesson to ensure that learners remained focused on the critical learning objectives while still having the freedom to experiment and draw their conclusions: What happens when you double the distance between charges?

Group discussion also played a significant role in Shantel's lesson plan. Following their experiments, learners were instructed to discuss their findings in small groups, focusing on the effect of the variables they changed on the force between charges. This group discussion and reflection helped learners deepen their understanding and provided an opportunity for peer-to-peer learning. Shantel then led a whole-class discussion: How does the simulation help you understand Coulomb's Law in the real world? The discussion encouraged learners to connect the concepts and principles with practical applications.

Overall, Shantel's lesson plans consistently integrate ICT tools like simulations as core elements of her instructional strategy. By embedding simulations into the lesson's structure, Shantel ensures that learners engage with the material in a hands-on, inquiry-driven way, reinforcing the principles of IBST.

7.3.5 *Learner Outcomes*

Shantel's use of simulations significantly impacts learner engagement and learning results. While learning about Coulomb's Law, learners were seen to be actively involved with the PhET simulation, making changes to variables and talking about their findings with classmates. The interactive nature of the Phet simulation allowed learners to visualize, experiment, see, and interact with electrostatic forces in real time, which enhanced their understanding of the relationships between charge, distance, and force.

After manipulating the charge and distance in the simulation, one learner commented: Seeing the change in force when I changed the charges and distance made it easier to understand the formulas we learned. Her statement illustrated how the simulation helped learners connect theoretical knowledge with practical application, a key outcome of inquiry-based learning. The ability to test hypotheses and receive immediate feedback in the simulation environment reinforced the learners' conceptual understanding.

Shantel's emphasis on group discussions also helped enhance the learning results. After finishing their experiments, learners were encouraged to share their findings with the class and reflect on how the variables they tested affected the outcomes. Shantel's questions helped learners link their observations to more significant scientific ideas: What does the inverse-square law tell us about the relationship between distance and force?

Shantel's lessons, which were hands-on and collaborative, create a learning atmosphere where learners are actively involved and responsible for their learning. By using PhET simulations, Shantel created a dynamic environment in the classroom where learners were not only absorbing information but also applying it through inquiry and experimentation. This method resulted in a better grasp of concepts, as learners could see complicated scientific principles in action and think about how they related to real-life scenarios.

7.4 Teacher Abel

7.4.1 Teachers' Beliefs

Abel highlighted the importance of learners actively engaging in finding solutions rather than just listening, showing his strong belief in the effectiveness of inquiry to promote thorough comprehension: *Learners should not just listen but be actively involved in discovering solutions themselves*. He sees his role as a mentor or facilitator who helps learners understand scientific concepts by encouraging them to ask questions and investigate independently.

Abel used grade 10 textbook Physical Sciences textbook (Crossman, 2017), which focuses on electricity and circuits, as a guideline for his lesson. The lesson plan clearly addressed the main objectives: learners should be able to identify different electrical components and their symbols. He also asked the learners to explain the difference between parallel and series circuits and to describe how to measure voltage, current, and resistance.

The lesson's inquiry-based method was enhanced using PhET simulation, an interactive instrument for learners to create virtual electrical circuits and test their hypotheses and ideas. The 90-minute lesson included a combination of teacher-led explanations and group-based exploratory activities, with the PhET simulation being a part of it. Abel's emphasis on inquiry-based learning was demonstrated through his use of technology, flexible classroom arrangements, and the encouragement of group discussion.

His belief that technology can transform learning into an interactive experience aligns well with the principles of IBST, where learners actively construct their understanding through exploration and experimentation.

Abel's facilitation of inquiry was a core element of his teaching approach. His lesson plan emphasized structured inquiry through guiding questions and activities centred around the PhET simulation. Abel's questions were designed to raise critical thinking and engage learners in constructing their understanding of electrical circuits.

During his lesson, Abel indicated that PhET simulations are crucial in helping learners visualize and understand complex science concepts and theories in ways that traditional methods

would take much longer to achieve: *PhET Simulations give learners a hands-on experience they can't get from just reading a textbook.* Abel believes that ICT tools or PhET simulation can change learning practices into a more interactive experience amongst learners, where they can actively construct their understanding and ideas through exploration and experimentation.

7.4.2 Implementation in the Classroom

The lesson started with Abel presenting the topic and explaining the PhET simulation. His first question encouraged learners to reflect on their prior knowledge of electricity and circuits: *What do you believe about how a circuit functions?* Abel used this question as a foundation to involve and engage learners in an investigative journey, allowing them to explore ideas through the PhET simulation.

According to the classroom observation, Abel maintained a balance between teacher guidance and learner autonomy by asking: *What do you think will happen if we connect two light bulbs in series? Will the brightness change?*

The way Abel asked his learners questions motivated them to make predictions and discuss the experiment in pairs. Abel developed an environment that encouraged active investigation by letting learners manipulate circuit elements like resistors, batteries, and light bulbs in the simulation. He frequently prompted learners to explain their reasoning, fostering a deeper conceptual understanding of the principles behind electrical circuits.

Abel's formative feedback was a key feature of his instructional practice. As learners worked through the simulation, Abel observed their progress and intervened when necessary to clarify misconceptions or offer guidance. For instance, when one group struggled to understand how voltage was distributed in a parallel circuit, Abel provided real-time feedback: *In a parallel circuit, the voltage across each branch is the same. What do you think will happen to the total current when we add more branches?*

Abel ensured that learners actively constructed their understanding, promoting independent problem-solving.

7.4.3 Challenges with ICT Simulations Integration

Abel's approach to ICT simulations integration in the classroom was shaped by several barriers, both logistical and pedagogical. While he acknowledged the potential of technology, particularly PhET simulations, in enhancing science instruction, his use of ICT simulations remained limited and supplementary. The key challenges he faced included structural constraints, pedagogical preferences, and a lack of targeted professional development. Abel's primary instructional approach aligned with a structured, teacher-led methodology. His strong preference for maintaining lesson control limited his willingness to fully integrate ICT tools into inquiry-based teaching. Abel was cautious about allowing learners to explore ICT simulations independently, fearing that they might deviate from lesson objectives. His concern about maintaining structured lessons aligned with findings from Tondeur et al. (2017), who noted that teachers with traditional pedagogical beliefs often used ICT as a complementary tool.

Despite his enthusiasm for ICT tools, Abel faced significant logistical hurdles in integrating them effectively into his lessons. One of the primary constraints was the large class size, which made it challenging to ensure that every learner had meaningful access to digital tools. He noted that managing ICT simulations use in an overcrowded classroom environment was difficult, particularly when learners were expected to interact with simulations in groups. Limited availability of technological resources, including computers and reliable internet access, further complicated the integration of ICT simulations into his teaching.

Abel's professional development experiences had largely reinforced his existing teacher-centered approach rather than encouraging inquiry-based strategies with ICT simulations. While he had received training on using simulations, these interventions had not significantly shifted his instructional beliefs toward more flexible, learner-led ICT simulation integration. His experience aligned with research by Tondeur et al. (2020), which suggested that professional development that did not challenge pre-existing pedagogical beliefs tended to reinforce traditional teaching practices rather than encourage innovative ICT simulations adoption.

Abel expressed concerns about the risks associated with ICT simulations use in science teaching. He believed that simulations, if not carefully monitored, might lead to distractions rather than productive learning. This cautious approach was reflected in his decision to integrate

simulations selectively and under strict teacher supervision. His belief system aligned with research by Ertmer et al. (2012), who found that teachers with low risk tolerance were less likely to fully embrace ICT simulations in inquiry-based contexts.

7.4.4 Lesson Plan Integration

Abel's lesson revolved around the central use of PhET simulation. The simulation allowed learners to visually and interactively explore the real-time behaviour of electrical circuits. Abel smoothly incorporated technology into the lesson, as it perfectly matched the lesson objectives.

Abel employed the PhET Circuit Construction Kit to assist learners in visualizing the concepts they were investigating. The simulation enabled learners to test voltage sources, resistors, light bulbs, and ammeters, giving instant responses on the alterations in current, voltage, and resistance when components were adjusted or added; Abel asked learners to investigate the correlation between voltage and current in a series circuit: *What do you observe when you add more batteries to the circuit?* The interactive nature of the PhET simulation enabled learners to test their predictions and visualize the outcomes of their experiments in real time. This integration of technology was crucial in helping learners grasp abstract concepts, such as the distribution of voltage and current in different types of circuits.

7.4.5 Learner Outcomes

Abel's use of simulations greatly enhances learner engagement and improves learning results. In his lesson about circuit construction, learners participated actively and enthusiastically by using the PhET simulation to test their ideas. The interactive PhET simulation enabled learners to see and test scientific hypotheses, enhancing their comprehension of how voltage, current, and resistance are connected. On one occasion, a learner expressed surprise at how quickly the bulb dimmed when the resistance was increased in the circuit: *Now it all falls into place.* This realization moment shows how PhET simulations helped learners link abstract ideas with science concepts and principles, resulting in a more profound conceptual grasp. The PhET simulation's prompt feedback enables learners to adapt their comprehension and interact more extensively with the content.

In his lesson, Abel also focused on group discussions, which contributed to improving the learning experience. Abel ensured the learning process was collaborative and reflective by asking learners to share their findings and discuss them with their classmates. This peer-to-peer engagement enabled learners to enhance their comprehension and discuss critical analysis by sharing findings and deliberating on conflicting hypotheses. Abel's inquiries in these conversations assisted learners in expressing their thoughts and linking their observations to more comprehensive scientific ideas, guaranteeing that learning went beyond just the simulation.

7.5 Teacher José

7.5.1 Teachers' Beliefs

José holds strong convictions about the role of ICT simulations in making teaching more efficient and meaningful. His teaching philosophy is deeply rooted in creating interactive and learner-centred environments. He sees ICT as essential in making complex scientific concepts more accessible and understandable: *ICT tools support what I am teaching by saving time and allowing me to cover the entire curriculum more effectively.* Technology enables him to streamline his lessons while enhancing clarity and engagement, mainly when dealing with abstract scientific principles like projectile motion.

José also significantly emphasises IBST, where learners are encouraged to discover and construct their understanding through active engagement. He believes learners learn best through exploration and inquiry rather than passive learning: *I enjoy interactive classes and learner-centred lessons.* He views technology, particularly simulations, as instrumental in facilitating inquiry-based learning: *Simulations give learners the opportunity to explore and experiment without the constraints of a real-world lab,* which shows his belief that simulations extend the possibilities for learning beyond traditional methods. José's beliefs about IBST reflected his commitment to integrating technology to empower learners to take control of their learning processes.

While Abel's beliefs are consistent with IBST principles and ICT simulations use, the practical implementation of these beliefs is sometimes limited by logistical challenges, such

as large class sizes and limited technological resources. As noted in the classroom observation, Abel had to adapt by organizing learners into groups due to the limited number of computers, which was potentially reduced.

7.5.2 Implementation in the Classroom

José's classroom practices strongly align with his beliefs about IBST and ICT simulations. José's teaching methods in the classroom align with his beliefs regarding IBST and ICT simulations. He focuses on the needs of the learners in his teaching, often incorporating simulations to aid in inquiry-based learning. While observing his classroom, José motivated learners to investigate how altering variables such as launch velocity and angle impact the path of a projectile through the PhET simulation. He began his lesson by asking the learners to make predictions: *What do you think will happen if we launch the projectile at a higher speed but keep the angle the same?* This question led learners to form hypotheses, which they then verified using the PhET simulation, allowing them to engage in the scientific inquiry process directly.

In the classroom, José fostered an environment where learners are actively participating in their learning. He shifted from direct instruction to facilitation, guiding learners as they work in small groups to explore different variables. He moved around the classroom, asking questions and providing support when needed, such as when a group struggled to understand how gravity affects a projectile's motion. José encouraged the group: *Remember that gravity always pulls the object downward. What do you think will happen if we reduce gravity? Try it in the simulation and observe the result.* This interaction reflects his ability to scaffold learning by posing questions that prompt further exploration.

However, the classroom observation also revealed some challenges mentioned in Abel's interview. For instance, while Abel used group work to overcome the limited number of computers, the large class size meant that some learners had to share devices, potentially reducing the effectiveness of the hands-on experience. This logistical issue supports his earlier statement about the difficulty of ensuring that all learners are equally engaged when resources are limited.

7.5.3 Challenges with ICT Simulation Integration

Despite being enthusiastic about ICT tools and technology, Jose recognizes the challenges, especially the requirement for ongoing professional development. He explains that the continuous struggle lies in ensuring that he stays updated constantly with new ICT tools and technologies and finding the most effective way to incorporate these tools into his science lessons. He added that there is a constant demand for science teachers' training in ICT tools and technology since these tools are being updated and available quickly. His commitment to professional development highlights his dedication to improving his teaching methods and keeping up with technological advancements. During José's interview, he said his belief and trust in constructivist learning theories and the positive impact of ICT tools and technology in improving learner engagement and comprehension. Nevertheless, it also shows his real difficulties in fully using these tools.

7.5.4 Lesson Plan Integration

In his *projectile motion* lesson, the PhET simulation plays a central role in the learners' investigation of critical concepts like velocity, angle, and gravity. Jose's lesson plan outlines specific tasks learners were asked to do, such as manipulating variables in the PhET simulation to test their hypotheses, allowing them to think critically and interact with the ICT tools and technology rather than rote memorization.

José's lesson plans carefully show how simulations can improve learners' comprehension. He ensures that learners not only interact with the simulation but discuss their findings in small groups. After conducting the hands-on exploration, he led a group discussion with the whole class: *What did you observe when you set the initial velocity to 10 m/s and the launch angle to 45 degrees?* This question strengthens the content and motivates learners to express their thinking and interact with each other's ideas.

José's lesson plan on Projectile Motion aimed to help learners predict and explain projectile paths based on varying conditions such as angle, speed, mass, and air resistance. However, the classroom execution did not fully align with the planned learning goals due to time constraints, which emerged as a significant barrier. While José intended to facilitate a structured

inquiry-based exploration using the PhET simulation, the setup time for computers and the projector delayed the start of the lesson. This meant that some planned activities had to be rushed or omitted, impacting learners' ability to engage deeply with the PhET simulation. Additionally, while the lesson plan encouraged learners to make predictions and reason through their observations, José's classroom practice leaned more toward teacher-directed explanations, limiting learner autonomy in hypothesis testing. As a result, the lesson did not cover all intended aspects, particularly the open-inquiry elements where learners were expected to design their own experiments. This gap between planning and execution highlights the challenges of time management, suggesting that lesson pacing and resource setup strategies need to be improved to maximize IBST effectiveness in the classroom.

7.5.5 Learner Outcomes

José's implementation of PhET simulations effectively enhances learner involvement and improves learning results. During the lesson on projectile motion, learners showed a strong interest in the PhET simulation. They worked together in small teams, talking about their predictions, experimenting with different variables, and evaluating the outcomes. The interactive simulation enabled learners to see how different factors affect projectile motion, enhancing their understanding of the concept. After adjusting the launch angle and speed, a learner commented: *Increasing the speed and setting the angle around 45 degrees made it go further.* This type of understanding shows how useful PhET simulations can be in aiding learners in understanding abstract concepts.

Additionally, simulations promoted a learning environment that motivated learners to take responsibility for their learning. Jose's focus on group discussions and working together in groups ensures that learners are participating and gaining knowledge from each other. His lessons encouraged learners to engage in critical thinking and enhance their scientific reasoning abilities, which are crucial for future academic achievements. By providing learners with resources and guidance to experiment with scientific principles independently, José fostered an atmosphere of curiosity, teamwork, and engagement.

The interactive simulation provided real-time feedback, enabling learners to make quick adjustments and improvements to their hypotheses, keeping the learning process flexible and

adaptable. This method aligns with José's belief: *Simulations provide a visual way for learners to understand complex concepts*. Immediate simulation feedback helped learners connect theory with practice and enhance their understanding through experimentation.

7.6 Teacher Paulo

7.6.1 Teachers' Beliefs

Paulo's enthusiasm for ICT tools, particularly simulations, was evident in his teaching philosophy. He described PhET simulations as invaluable for demonstrating complex scientific concepts: *I love PhET simulations; they offer a dynamic and visually appealing way to teach complex scientific concepts*. This statement highlights Paulo's deep belief in the power of simulations to replace traditional laboratory materials and enhance the clarity and efficiency of science lessons. He noted that ICT tools provide precision and allow for demonstrations that would otherwise require significant setup and resources.

Paulo's view on IBST is firmly rooted in his commitment to fostering an inquiry-based, learner-centred environment. He values allowing learners to engage directly with ICT tools to explore concepts independently: *Providing learners with the opportunity to use simulation tools hands-on intrigues them to explore a concept under different scenarios*. This belief aligns closely with IBST principles, where learners are encouraged to experiment, hypothesize, and discover concepts through active engagement.

7.6.2 Implementation in the Classroom

Paulo actively integrated ICT tools, particularly PhET simulations, into his teaching to create interactive and collaborative learning experiences. His lesson on *Atomic Interactions* used the PhET Atomic Interactions simulation to explore how ionic, covalent, and van der Waals forces operate. Paulo's lesson plan reflected a structured yet open approach to learner inquiry, as learners were given time to explore the simulation in small groups.

Paulo began his lessons with brief, teacher-led demonstrations of the simulations but quickly shifted the focus to learner-led exploration. For instance, in the *atomic interactions* lesson, Paulo allowed learners to control the simulation, adjust variables, and test their

predictions: *Go ahead and use the PhET simulation to test that. Work in pairs and remember to discuss your findings with each other as you go.* By fostering such autonomy, Paulo ensured that learners engage deeply with the material, actively testing hypotheses and refining their understanding through inquiry.

In contrast to more teacher-centred approaches, Paulo's implementation of simulations emphasizes collaboration and critical thinking. During group work, learners were encouraged by the teacher to discuss their observations and challenge each other's findings. Paulo facilitated these discussions amongst his learners, often posing questions to instigate deeper analysis: *How does the interaction between charged atoms in an ionic bond differ from what you see in a covalent bond?* Paulo's teaching approach aligns well with inquiry-based teaching, where the teacher acts as a guide rather than a direct source of information.

7.6.3 Challenges with ICT Simulation Integration

Despite Paulo's proficiency with ICT tools, he still faces barriers, primarily related to time management and network connectivity. Paulo expressed frustration over the time required to prepare and integrate ICT tools into his lessons: *Time constraints are a big issue.* Although the tools reduce learning time, the upfront preparation can be demanding. Paulo's challenges with ICT simulations integration mirrors the broader reality for many teachers, where the benefits of technology are often offset by the time required to incorporate it smoothly into lessons.

Another significant challenge Paulo faced was unstable network connectivity: *Network connection issues are a constant problem*, which can disrupt the flow of his lessons when the simulations rely on internet access. Connectivity problems are particularly disruptive during real-time interactions with digital tools, such as PhET simulations, which require smooth, uninterrupted access. When the internet fails, Paulo is forced to revert to traditional methods, limiting the full potential of ICT simulation in his lessons.

Paulo also recognized that not all learners had the same level of ICT skills. He pointed out that some learners struggled with basic computer literacy, which can hinder their ability to engage fully with the simulations: *Not all learners are comfortable using ICT tools.* Learners

struggling with computer literacy reflected a common barrier in many classrooms, where digital divides affect the consistency of technology integration.

7.6.4 Lesson Plan Integration

The classroom observation of Paulo's lesson on *atomic interactions* demonstrated a high level of learner engagement. Learners worked in small groups, adjusting the simulation's variables to observe how atomic forces changed. Paulo's facilitation during this process helped guide their critical thinking without dominating the lesson. For instance, when a group struggled to understand why atoms began repelling after getting too close, Paulo provided a concise explanation of electrostatic repulsion, ensuring that learners could build on their observations without being handed the answer immediately.

7.6.5 Learning Outcomes

Paulo's use of simulations significantly enhances learner engagement and fosters a collaborative learning environment. He indicated that the hands-on, interactive nature allows learners to explore scientific phenomena in ways that traditional methods do not: *Learners understand better when they use ICT simulations*. His focus on group work and discussions encouraged active participation, where learners feel empowered to ask questions and share insights.

This approach of encouraging inquiry and exploration positively affects learner confidence. Paulo mentioned that when learners can explore concepts hands-on, they take ownership of their learning: *It empowers them*. This sense of empowerment is crucial, particularly in science education, where learners must often apply theoretical knowledge in practical settings

7.7 Summary

This study reveals how *pedagogical beliefs, systemic barriers, and professional development* collectively shape teaching practices. Teachers with constructivist beliefs, such as António, regarded ICT simulations as transformative tools that allow learners to explore scientific concepts beyond traditional limitations. António described them as “opening a window

to another dimension of science.” In contrast, teachers with traditional views, like José, saw simulations as supplementary at best, expressing concerns about their potential to disrupt structured teaching approaches. These divergent beliefs, rooted in teachers’ experiences and influenced by systemic factors, often dictated whether ICT simulations were perceived as tools for innovation or just as supplementary tools.

However, the study also uncovers a persistent “belief-action gap,” where teachers’ intentions to adopt simulations were frequently undermined by practical challenges such as unreliable technology, insufficient training, and curriculum pressures. Shantel’s frustration captured this reality: “I plan lessons that include simulations, but when the internet fails or the equipment doesn’t work, I have no choice but to revert to traditional methods.”

Amid these challenges, the study underscores the critical role of professional development in bridging the gap between beliefs and practice. Structured and iterative training programs emerged as crucial in transforming teachers’ confidence and competence in using ICT simulations. Paulo, reflecting on his experience, noted, “Before the training, I found simulations intimidating. But after working with colleagues and seeing their successes, I started experimenting in my classroom.” These efforts not only enhanced teachers’ technical skills but also redefined their perspectives on the potential of simulations. When successfully implemented, simulations were shown to significantly improve learner engagement, deepen conceptual understanding, and strengthen inquiry skills. Abel recounted a powerful teaching moment: “Watching my students test hypotheses with simulations and see the results in real time was incredible, it was as though they discovered a new way to learn.”

Ultimately the study calls for a systemic, holistic approach to integrating ICT simulations into science education. By addressing both internal beliefs and external barriers, it promotes the creation of an environment for ecosystems that empower teachers and learners to adopt inquiry-driven, technology-enhanced education.

CHAPTER 8

TEACHERS' BELIEFS, PRACTICES, AND BARRIERS

8.1 Introduction

This chapter analysed science teachers' beliefs, practices, and constraints that shape science teachers' integration of IBST and ICT simulations in their classrooms. Through an in-depth examination of these factors, this chapter sought to understand how teachers' beliefs influence their instructional decisions, particularly incorporating simulations to support inquiry-driven learning. Although teachers may access similar resources, their individual perceptions and educational beliefs result in diverse approaches to using ICT simulations in science education.

This analysis addresses three key research questions: *What are science teachers' beliefs about IBST and ICT simulations? How do science teachers' beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations? Why do science teachers' beliefs about the use of ICT simulations as a form of IBST influence their teaching in the manner that they do?* The answers to these questions provide insight into how social and cognitive constructivist theories intersect with teachers' practices and contextual realities. By drawing on frameworks such as the BIUT and the Vickers' framework, this chapter highlights the complexity of implementing IBST and ICT simulation integration across varied educational contexts.

Additionally, visual frameworks in the form of diagrams illustrate how teachers' beliefs, contextual factors, and technological affordances converge to shape instructional strategies. The diagrams aid in visualizing the themes discussed, encompassing factors such as teachers' beliefs about the potential of IBST, the perceived risks of ICT simulation use, and how practical constraints affect these teaching approaches.

This chapter will examine the science teachers' beliefs, practices, and constraints that shape science teachers' integration of IBST and ICT simulations but will also explore the feedback loops where classroom contextual realities and resources affect, influence, reinforce, or challenge teachers' instructional beliefs. The analysis will be grounded on social and cognitive constructivist theories and supported by frameworks such as the Vickers, Hew and Brush and

BIUT framework (Juggernath & Govender, 2020), and extended BIUT (created by the author) to facilitate valid answers to its primary research questions. Figures 3.1, 3.2, 3.3 and 3.4 offer a visual framework to explore the core themes surrounding science teachers' beliefs, their instructional applications, and the practical constraints they navigate when implementing IBST with ICT simulations. Grounded in constructivist theories and supported by frameworks such as Vickers, Hew and Brush's technology integration framework, the BIUT (Juggernath & Govender, 2020) and the extended BIUT diagrams provide a structured approach to analysing the dynamic relationship between teachers' beliefs and instructional outcomes.

8.2 Beliefs Shaping Instructional Approaches in IBST and ICT Simulation Integration

The analysis focuses on *teacher's beliefs about IBST, teacher's beliefs about ICT simulations and the factors influencing ICT simulation integration in the classroom*. The Reality Judgment provides a basis for understanding how teachers' beliefs shape their instructional strategies and adaptation to classroom constraints.

8.3 Teachers' Beliefs

This theme examines the core perspectives that science teachers hold regarding the purpose and impact of IBST and ICT simulations in enhancing learner engagement and learning. Drawing from Vickers' framework, which suggests that individual judgments and values significantly shape actions in specific contexts, this theme highlights how beliefs act as interpretative filters. These filters guide teachers in assessing the value of IBST and ICT simulations within their educational setting, ultimately influencing whether simulations are considered essential tools for hands-on, inquiry-driven learning or supplementary resources. These beliefs shape practical decisions about technology use and instructional design, underscoring the connection between individual perspectives and teaching approaches.

8.4 Beliefs About Risk

This theme explores the perceived risks associated with integrating ICT simulations, particularly in contexts facing infrastructural challenges. For some teachers, beliefs about technology's reliability and accessibility play a crucial role in their decisions about ICT

simulation use, where risk assessment becomes a factor in weighing the potential benefits against possible disruptions. Ertmer et al. (2012) underlines that teachers' beliefs about technological dependability directly influence their openness to using ICT simulations in the classroom, significantly when external factors could hinder smooth implementation. Here, risk considerations tied to beliefs about practical usability reflect a balance between pedagogical intentions and logistical realities.

8.5 Constructivist Epistemology

Some teachers apply ICT simulations to foster a constructivist learning environment grounded in social and cognitive constructivist theories. Aligning with Vygotsky's social constructivist approach, this perspective emphasizes interactive and collaborative learning, where simulations serve as tools to promote active engagement and shared knowledge-building. Through simulations, learners can visualize and manipulate scientific concepts, constructing understanding through experiential, inquiry-based interactions. This approach reflects the belief that learning occurs through active social engagement, with ICT simulations facilitating deeper cognitive connections and supporting learners' ability to explore and make meaning.

8.6 Curriculum Design

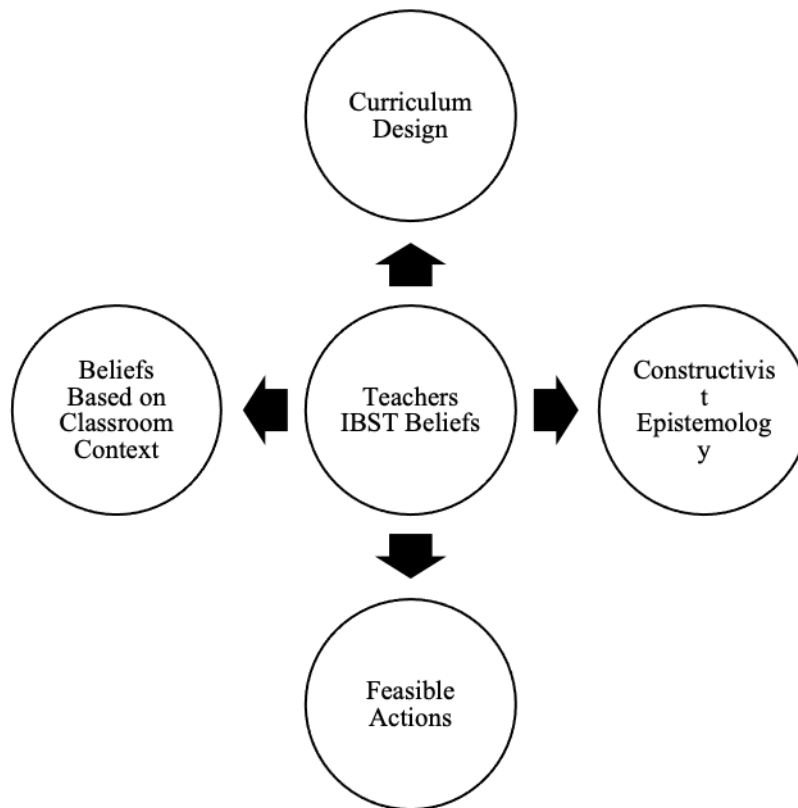
This theme focuses on how teachers' beliefs about the goals of science education influence their curriculum planning, particularly in their use of ICT simulations to achieve inquiry-based learning objectives. Teachers who view ICT simulations as integral to their curriculum design rather than supplementary often adopt a constructivist perspective. The BIUT framework supports this perspective, advocating for curriculum structures informed by teachers' educational beliefs that promote inquiry in the classroom. This approach results in a curriculum where ICT simulations is used intentionally to support scientific exploration and reasoning. In this view, teacher's beliefs about learner engagement and knowledge construction drive instructional planning and curriculum choices.

8.7 Beliefs Based on Classroom Contexts

This theme highlights how specific classroom environments shape teachers' beliefs about the feasibility and frequency of ICT simulation use. Factors such as class size, learners' familiarity with technology, and available resources influence teachers' interpretations of the benefits and practicality of ICT simulations. In classroom contexts with limited resources or small class sizes, teachers may adapt their ICT simulation integration strategies to ensure alignment with the learning environment and optimize outcomes. The BIUT framework illuminates how teachers' beliefs adapt to such demands, suggesting that beliefs about IBST and ICT simulations are flexible and responsive to specific classroom contexts. This adaptive approach allows science teachers to balance their instructional goals with practical considerations, leading to a more context-sensitive use of simulations that aligns with their beliefs about effective teaching. Figure 8.1 focuses on the teachers' beliefs in IBST and ICT simulation integration that science teachers hold about IBST and ICT, which influence how they design and deliver instruction in the classroom; this includes themes such as: curriculum design, constructivist epistemology, beliefs about risk, beliefs based on classroom contexts.

Figure 8.1

Beliefs Shaping Instructional Approaches in IBST and ICT Simulation Integration



Note. Author's work.

8.8 Aligning Teacher Beliefs with Curriculum, Assessment, and PD

Teachers have faced many barriers, such as infrastructure limitations, curriculum demands, and learner readiness, impacting their ability to implement ICT simulations. These constraints are analysed in light of Fullan's work, which suggests that effective teaching involves making pragmatic adaptations that align instructional aims with available resources (Fullan, 2015).

8.8.1 Assessment Practices

This theme explores how teachers assess learner learning in an inquiry-based environment supported by ICT simulations. Constructivist-oriented teachers may favour

formative assessment strategies that help reveal learners' conceptual understandings and address gaps in real time, allowing for adjustments that promote deeper inquiry. Chinn and Malhotra (2002) underscore the importance of assessments that go beyond rote memorization and instead focus on scientific reasoning, reflective thinking, and the processes involved in scientific exploration. Assessments designed to probe learners' understanding of complex concepts foster a process-oriented and continuous learning environment, aligning with inquiry-based pedagogies that emphasize critical thinking and conceptual depth. Thus, assessment practices become vital for understanding how well ICT simulations contribute to inquiry goals, reinforcing teachers' beliefs in the efficacy of IBST when assessments confirm constructive learning outcomes.

8.8.2 *Intervention*

In this theme, targeted interventions are examined as strategies that bridge the gap between teachers' theoretical beliefs and the practical realities of classroom teaching. Guided by the BIUT framework, interventions are structured to provide focused support that strengthens teachers' belief in inquiry-oriented methods by addressing specific challenges and promoting reflective practices. These interventions may include structured PD, collaborative planning sessions, or mentoring, allowing teachers to align their constructivist intentions with tangible teaching practices. BIUT emphasizes that for beliefs about IBST to translate effectively into action, interventions must account for individual teachers' contexts, promoting a feedback loop where beliefs, intentions, and practices reinforce each other in a way that makes simulation-based inquiry feasible and sustainable.

8.8.3 *Simulation Efficacy*

This theme highlights teachers' beliefs about the effectiveness of simulations as tools for supporting inquiry-based teaching, which can vary widely depending on individual goals and pedagogical orientations. According to Zacharia and Anderson (2003), the perceived efficacy of simulations depends significantly on infrastructural factors, such as technological reliability, which affects teachers' confidence in using simulations as core instructional tools rather than visual aids. Teachers who see simulations as effective, emphasize their role in fostering active exploration and problem-solving, which aligns with constructivist ideals. For these teachers, simulations are valued for their visual appeal and ability to make abstract concepts tangible, thus

supporting inquiry and learner engagement. The Technology Acceptance Model (TAM) can further elucidate this by suggesting that teachers' belief in a technology's usefulness directly impacts its adoption and integration into inquiry-oriented practices. Thus, as perceived by teachers, the effectiveness of simulations is influenced by both practical and pedagogical considerations, which collectively shape the depth of simulation use in their classrooms.

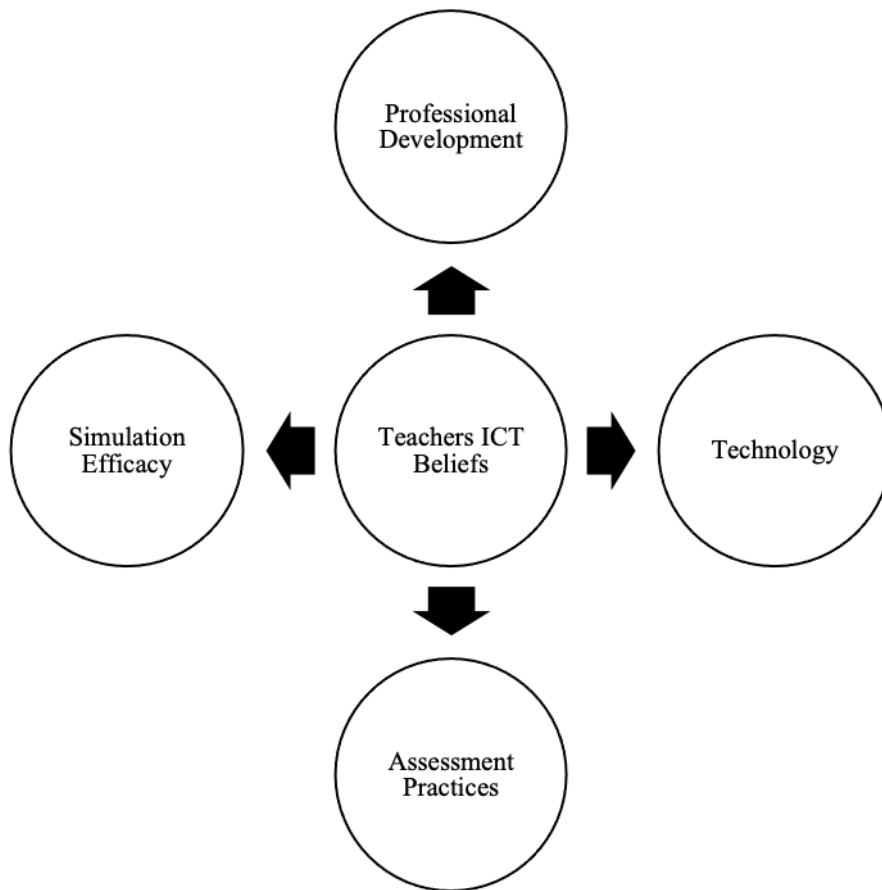
8.8.4 Professional Development

This theme examines the role of PD in shaping and reinforcing science teachers' beliefs about the value and practicality of ICT simulations within IBST frameworks. Effective PD goes beyond merely enhancing technical skills; it also aims to align teachers' beliefs with inquiry-based practices that leverage ICT simulations to facilitate learner-centred learning. Grounded in the BIUT framework, PD programs address hesitations or misconceptions about technology reliability, aiming to build confidence and skills that support constructivist teaching approaches. Well-designed PD initiatives introduce teachers to tools and pedagogies that exemplify inquiry, providing a basis for reflective practice and continuous improvement. Through ongoing training, teachers learn the technical aspects of ICT simulations and pedagogical strategies that can make simulations more impactful, enabling them to incorporate simulations as active learning tools rather than supplemental aids. Ultimately, such PD shapes teachers' confidence and readiness to integrate simulations within IBST by reaffirming constructivist principles and fostering a mindset that embraces technology to deepen scientific inquiry and understanding.

Figure 8.2 addresses how teachers' beliefs shape their instructional planning, assessment methods, selected interventions to support IBST and ICT integration, and PD in shaping ICT simulation beliefs in science education. Key themes include: *Professional development, intervention, assessment practices and simulation efficacy*.

Figure 8.2

Aligning Teacher Beliefs with Curriculum, Assessment, and Professional development



Note. Author's work.

8.9 Navigating Barriers, Understanding, and Practical Constraints in ICT Simulation

This section examines how PD experiences influence teachers' beliefs about the efficacy of ICT simulations. Their beliefs about simulations align with those of Chinn and Malhotra (2002) who found that effective PD encourages teachers to use ICT simulations as core instructional tools, promoting deep engagement with scientific content.

8.9.1 Barriers

This theme explores the infrastructural and pedagogical barriers science teachers face in integrating ICT simulations, specifically simulations, into their science teaching practices.

External barriers, such as limited internet connectivity, inadequate access to devices, or lack of technical support, can significantly hinder ICT simulations implementation and reduce the potential for implementing IBST. Drawing from Hew and Brush (2007), whose model of technology integration barriers categorizes obstacles as resources, knowledge and skills, institution-level factors, and attitudes and beliefs, this theme emphasizes the role of external constraints in shaping teachers' instructional decisions. When infrastructural reliability is lacking, teachers may hesitate to rely on ICT simulations as a core component of their lesson plans, impacting the consistency and depth of simulation use. Pedagogical barriers, such as time constraints and curricular expectations, also pose challenges, as teachers may struggle to align the inquiry goals of IBST with the demands of standardized content delivery. This framework highlights that overcoming barriers is essential to enabling effective ICT simulation integration and creating an environment where ICT simulations can enhance inquiry-based teaching.

8.9.2 Understanding

This theme examines the variation in teachers' understanding of ICT's role within the context of IBST, emphasizing that a firm grasp of constructivist principles and technology's educational potential is crucial for meaningful simulation use. Teachers with a deep understanding of constructivist pedagogy tend to view ICT simulations as interactive tools facilitating active, learner-centred learning and scientific reasoning. This perspective aligns with Vygotsky (1987), whose concept of technology as a mediating tool in knowledge construction supports the notion that ICT simulations are not merely visual aids but essential instruments in fostering inquiry and engagement. ICT simulations allow learners to build knowledge through experimentation and collaborative problem-solving by mediating the interaction between learners and complex scientific phenomena. Thus, the constructivist interpretation of simulations reveals the need for science teachers to see ICT simulations as integral to the learning process rather than supplementary tools. Teachers' beliefs and comprehension of ICT's role, shaped by constructivist theories, guide their willingness to integrate ICT simulations as a fundamental component of IBST.

8.9.3 Feasible Actions

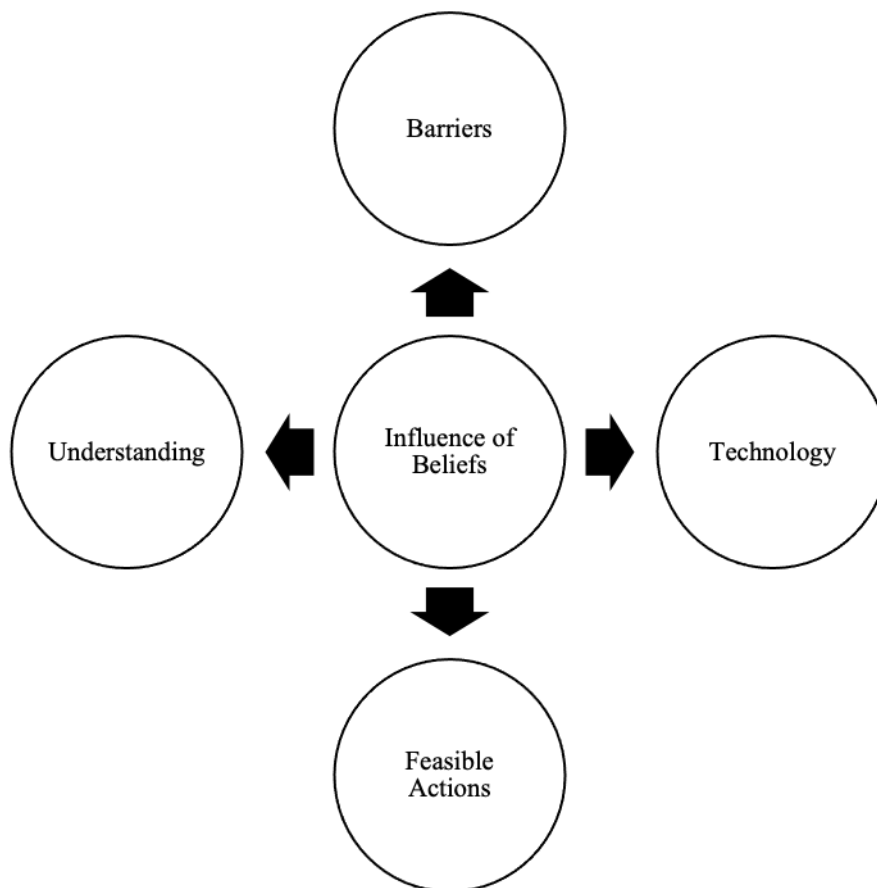
This theme highlights science teachers' adaptive strategies to work within practical limitations and maintain effective ICT simulation use in their teaching practices. Faced with constraints such as limited resources or varying levels of learner readiness, teachers often employ different approaches or modified strategies to support ICT simulation-based teaching. This adaptability aligns with Fullan (2013), whose advocacy for context-specific responses highlights the importance of teachers making practical adjustments when using the principles of IBST while accommodating real-world limitations. For example, teachers may implement smaller-sized group work or scaffolded ICT simulations to maximize engagement and learning within existing constraints. Such context-driven adaptations show teachers' commitment to maintaining instructional integrity and significant commitment to ICT simulations even when full integration is challenging. This flexibility reflects a nuanced understanding of IBST, where feasible actions optimize learning outcomes within the limitations of the classroom environment.

8.9.4 Technology

This theme examines how access to reliable technology influences teachers' ability to integrate ICT simulations consistently and effectively in the classroom. Science teachers' use of ICT simulations can be selective and strategic, mainly when infrastructure is unreliable or inadequate for consistent implementation. This problem was discussed by Pelgrum (2001), who demonstrated that science teachers often adapt their use of ICT simulations based on available resources and technical support. When technology access is lacking or inconsistent, teachers may limit ICT simulation use to situations where it is highly effective or relevant rather than a regular component of their lessons. Technology Acceptance Model (TAM) provided further insight by highlighting that perceived ease of use and usefulness influence teachers' willingness to adopt ICT simulations. If teachers perceive difficulties in technology access, they may be less inclined to design lessons around ICT simulations. However, when technology is accessible and available, teachers are more likely to view ICT simulations as viable tools to enhance the inquiry process, supporting a more comprehensive integration into IBST in the classroom. This approach demonstrates the teachers' nuanced decision-making to balance ideal pedagogical practices with infrastructural realities in their classes.

Figure 8.3 explores the role of external and internal barriers, technological understanding, and feasible actions within constraints. This diagram shows how these factors collectively shape teachers' use of ICT simulations. Key themes include: Barriers, technology, feasible actions and understanding.

Figure 8.3



Navigating Barriers, Understanding, and Practical Constraints

Note. Author's work.

By examining these factors across all five science teachers, the chapter seeks to contribute a deeper understanding of the complex relationship between science teachers' beliefs about ICT simulations, classroom realities, and instructional practices within IBST-enhanced science education. These diagrams, support the frameworks described in Chapter 3, revealed that

educational objectives and pragmatic classroom constraints mould teachers' beliefs. Through this framework, the diagrams underscore the need for targeted interventions that address belief systems and contextual challenges in supporting effective IBST and ICT simulation integration.

8.10 Teacher António

8.10.1 Teacher Beliefs

Antonio's beliefs about IBST and ICT simulations are shaped by a cautious appreciation for technology's potential in the classroom, tempered by practical constraints. He values ICT simulations for their capacity to enhance complex scientific concepts visually, aiding learner understanding in topics such as energy transformation and conservation. However, his approach is conservative, believing that while technology is beneficial, it must align with classroom realities. Antonio's beliefs about ICT simulation integration align with Vickers framework, which suggests that beliefs are inherently influenced by the constraints and conditions in which they are applied. On the other hand, Prestridge Prestridge (2019) suggests that teachers with a robust pedagogical belief in ICT's role in active learning often find creative ways to incorporate ICT simulations, even in low-resource environments, by using available tools more strategically. This perspective challenges Antonio's restrained use of ICT simulations and implies that a belief in ICT's potential may encourage broader and more dynamic ICT simulation integration than his conservative approach.

8.10.2 Beliefs About Risk

Antonio's beliefs about risk reflected a pragmatic stance shaped by infrastructural limitations, such as unreliable internet and occasional power outages. He views these risks as potential disruptions to lesson continuity and learner focus. For instance, he expressed concern about losing valuable classroom time or equipment due to technical failures. His statements revealed a belief that there consider these risks into consideration and that precautions have to be taken in ICT use unless he feels confident about technology reliability. This approach aligns with Ertmer et al. (2012), who found that teachers' willingness to adopt ICT tools is closely tied to perceptions of technological dependability, which contradicts the TPACK framework. Koehler et

al. (2013) suggest that risk can be mitigated through a more flexible approach to technology, where teachers adapt ICT use based on pedagogical goals rather than infrastructure alone.

8.10.3 Constructivist Epistemology

While Antonio's approach includes elements of constructivist pedagogy, his use of ICT simulations primarily aims to support individual cognitive development. For example, he emphasized that ICT simulations allow learners to visualize scientific concepts independently, which mirrors a Piagetian constructivist model focusing on individual learning through interaction with digital tools. Antonio's strategy aligns with cognitive constructivist principles, where tools like ICT simulations are seen as facilitator tools supported by frameworks in cognitive constructivism (Kalina & Powell, 2009). Kim and Rha (2018) propose that simulations, when viewed as merely tools for social engagement, allow learners to construct understanding and explore scientific concepts collectively. This social constructivist stance challenges Antonio's individual-focused use of ICT simulations, suggesting that simulations might be used to aid visualization and facilitate collaborative problem-solving and exploration, thus promoting the inquiry process.

8.10.4 Beliefs Based on Classroom Contexts

Antonio's beliefs about the practical value of ICT simulations are heavily influenced by the logistical challenges he faced in the classroom. Limited time, unreliable internet, and the need for substantial setup time all impacted his enthusiasm for ICT simulation integration in the classroom, leading to a selective use of ICT simulations. He frequently prepares non-digital backup plans to ensure that classes carry on as usual, revealing a belief that ICT's benefits are dependent on the teaching environment's stability. Antonio's belief that infrastructural and time limitations necessitate selective ICT simulation integration aligns with Hew and Brush (2007), who find that classroom context and external factors significantly influence teachers' views on technology efficacy. However, recent studies challenge the idea that classroom context should solely dictate ICT usage. (Tondeur et al., 2017b) argue that even within constrained environments, ICT simulations can play a central role when integrated flexibly. For instance, teachers may employ blended methods using ICT simulations and traditional hands-on activities

to support inquiry. This approach encourages teachers to view ICT simulations not as an isolated component but as part of an adaptable teaching strategy that adjusts to context.

8.10.5 Curriculum Design

Antonio's curriculum design reflects a balance between using ICT simulations to illustrate abstract scientific concepts and navigating practical limitations. He incorporates simulations to help learners grasp complex topics, such as energy dynamics, yet faces challenges in pacing due to the extra time required for setup and troubleshooting. His approach proves Hew and Brush (2007) finding that logistical barriers in curriculum planning often dictate the extent of ICT simulations integration. While António sees the curriculum as a space to introduce digital tools, his belief in maintaining control and efficiency limits ICT's role to a supplementary one, primarily for enhancing concept visualization rather than full inquiry-based integration.

Table 8.1 summarizes António's beliefs about risk, constructivist epistemology, classroom contexts, and curriculum design. It highlights how his cautious approach to ICT simulations integration stems from infrastructure concerns, yet he values ICT simulations for visualizing complex concepts. The table reflects how António's approach is shaped by pragmatic constraints while maintaining a belief in the potential of ICT simulation for supporting individualized learning.

Table 8.1

António's Risk, Epistemology, Contexts, Curriculum Design, and Beliefs

Theme	Summary
Beliefs about risk	Cautious about relying on ICT due to infrastructure issues like power outages and unreliable internet. Prefers to avoid disruptions and prepares non-digital backups, expressing concern about the risk of lesson interruption and potential loss of classroom time.
Constructivist epistemology	Uses ICT primarily to support individual cognitive development, following a more Piagetian, cognitive constructivist approach. Sees simulations as tools for visualization but limits collaborative or social constructivist engagement.
Beliefs based on classroom contexts	Believes that limited resources, technical setup time, and internet reliability significantly impact the effectiveness of ICT in his classroom. This influences his selective approach to ICT use, which he views as feasible only under stable conditions.
Curriculum design	Incorporates simulations in lesson plans for enhancing understanding of complex topics (e.g., energy dynamics), but limits their use to supplementary, teacher-directed activities. Focuses on visualization over inquiry-based exploration.

Theme	Summary
Teacher's beliefs	Believes ICT tools are beneficial for visualizing scientific concepts but views them as optional enhancements rather than essential components of science education. Maintains a teacher-centred approach due to practical constraints and limited trust in technology.

8.10.6 Assessment Practices

Given the infrastructural limitations António faced, he primarily assessed learners' comprehension through visual aids and direct observations rather than relying on ICT simulations alone. He faced difficulty aligning ICT simulation-based assessments with the curriculum, as the availability of technology disrupted the ICT simulation use. His assessment practices, therefore, emphasize content mastery and concept visualization, which supports Ottenbreit-Leftwich (2013), who found that logistical constraints can limit teachers' capacity to align assessment with inquiry-based methodologies. However, Chinn and Malhotra (2002) suggest that assessments should capture learners' scientific reasoning and investigative processes rather than just content mastery. They further suggest that science teachers can use ICT simulations as formative assessment tools, where learners demonstrate problem-solving and reflective thinking within the ICT simulation environment. This view challenges Antonio's emphasis on visual assessment by proposing that simulations offer unique opportunities to assess learners' inquiry skills, encouraging a broader and more dynamic use of ICT simulations as part of an assessment strategy.

8.10.7 Intervention

António advocates for more technical support and targeted PD to overcome his challenges in ICT simulation integration. He acknowledged that ongoing interventions, such as troubleshooting resources or access to reliable internet, would enhance his ability to use ICT simulations effectively. Additionally, he highlights the importance of hands-on support that addresses context-specific needs, such as preparing backup options for technology failures, recommending interventions for specific contexts to address practical barriers in technology adoption, and enabling teachers to maximize ICT simulation use even in under-resourced environments (Prestridge, 2017).

8.10.8 Simulation Efficacy

António views ICT simulations as valuable visual aids that enhance learner understanding of complex scientific concepts but see their efficacy as contingent on reliable technology. For instance, he uses simulations to help learners visualize and engage with abstract topics but does not integrate them as primary teaching tools due to technical reliability concerns. ICT simulations function as supplementary tools rather than central instructional resources, with their effectiveness relying on stable infrastructure and practical feasibility. (Zacharia & Anderson, 2003).

8.10.9 Professional Development

Antonio's PD experiences have been limited, affecting his confidence and skills in fully adopting emerging ICT tools in his teaching. He has expressed a desire for PD programs responsive to his teaching context, providing strategies for using ICT simulations within the infrastructural limitations he faces. Antonio's preference for PD that builds teachers' technical skills while offering realistic application guidance goes along with Hew and Brush (2007), who states that effective PD should be tailored to teachers' contextual needs, supporting the integration of ICT simulations in diverse educational settings. His limited PD background indicates a gap that, if addressed, could enable him and other science teachers to expand ICT simulation use within the boundaries of the classroom environment. Darling-Hammond et al. (2017) suggested that PD should focus on building teachers' ability to flexibly integrate ICT tools and adapt strategies to meet real-time challenges. This approach contrasts with Antonio's request for only context-specific interventions, suggesting that teachers benefit from broader PD that addresses current barriers and equips them with skills to overcome new challenges as they arise.

Table 8.2 presents António's practices, interventions, and PD in the context of IBST with ICT. António's strong constructivist beliefs drive his extensive use of ICT simulations, with the table emphasizing how PD has reinforced his strategies for interactive, inquiry-based teaching. This table highlights the alignment between his beliefs and practices, where technology is central to fostering learner engagement and collaborative exploration.

Table 8.2*António's Practices, Interventions, and PD in IBST with ICT Simulations*

Theme	Summary
Assessment practices	Uses visual aids and direct observations to assess learner comprehension due to unreliable ICT infrastructure. Focuses on content mastery and visualization rather than inquiry-based assessment, as simulations are often supplementary.
Intervention	Suggests need for technical support and PD that addresses specific context-based challenges like internet reliability. Would benefit from interventions that focus on managing ICT simulations limitations and alternative strategies for lesson continuity.
Simulation efficacy	Sees simulations as valuable visual aids but not as primary teaching tools due to concerns about technology reliability. Believes simulations support content visualization, enhancing understanding of abstract concepts.
Professional development	Limited PD experience with ICT tools. Expresses a need for PD programs tailored to his infrastructural challenges and focused on practical strategies for using ICT simulations within constraints.

8.10.10 Barriers

António also faced several logistical barriers that impacted his ability to implement ICT simulations effectively in the classroom, including unreliable internet access and frequent power outages. These infrastructural challenges create a high-stakes environment for ICT simulations use, as he fears potential disruptions to his lesson flow and learner engagement. His approach is, therefore, marked by caution, as he balances the benefits of ICT simulations with the risk of technical failures. Limited technology infrastructure can act as a significant barrier to implementing inquiry-based learning in resource-constrained contexts (Hew & Brush, 2007).

8.10.11 Understanding

Antonio's understanding of ICT simulations centre around their potential as visual tools to aid learner comprehension of complex scientific concepts, such as kinetic energy. He sees simulations as valuable for concept clarification, yet a conservative view of ICT simulations shapes his understanding as a supplementary tool rather than a core element of inquiry. António's view demonstrates a limited constructivist alignment, where ICT simulations is used primarily to enhance visualization rather than to facilitate hands-on exploration or collaborative inquiry. He also noted, consistent with Ertmer et al. (2012), that teachers often perceive ICT's role through the lens of practical constraints.

8.10.12 Feasible Actions

Given his technical challenges, António has developed a set of feasible actions to ensure continuity in his teaching practices. He often prepares backup and non-digital activities to fall back on if some ICT resources fail, a proactive approach that reflects the Reality Judgement framework. His strategic use of non-digital alternatives allows him to meet curriculum goals despite unreliable technology. This pragmatic response shows his adaptability, where he maximizes learner learning within the boundaries of available resources, which aligns with Fullan (2013), who advocated for context-specific adaptability in technology use.

8.10.13 Technology

Selective ICT simulations mark Antonio's relationship with technology use, driven by the realities of his classroom infrastructure. He believes technology has the potential to make science more accessible but regards it as inherently unpredictable in his context. As a result, he limits ICT simulations use to scenarios where its benefits are most likely to outweigh the disruption risks. This perspective is consistent with Pelgrum (2001), who shows that teachers in under-resourced settings often adopt a cautious, selective approach to technology integration, viewing it as a supplementary rather than a central teaching tool.

Table 8.3 outlines António's barriers, understanding, feasible actions, and technology use. It highlights the logistical challenges he has faced, such as unreliable internet, and his adaptive strategies for overcoming these challenges. The table also discusses his selective approach to ICT simulations, using it as a supplementary tool rather than a central component of his teaching, reflecting a conservative view influenced by classroom realities.

Table 8.3*Antônio's Barriers, Understanding, and Feasible Actions*

Theme	Summary
Barriers	Faces frequent power outages, unreliable internet, and time constraints, limiting his ability to integrate ICT simulations consistently. Prepares backup non-digital activities as contingency.
Understanding	Sees ICT simulations as valuable for visualizing complex scientific concepts but uses it as a supplementary tool rather than as a core component of inquiry.
Feasible actions	Prepares backup plans to ensure lesson continuity when technology fails. Uses ICT simulations selectively to avoid disruptions, particularly in high-stakes lessons.
Technology	Values ICT simulations for making science concepts accessible but is cautious about its reliability. Uses technology selectively, focusing on controlled, teacher-led activities rather than open-ended inquiry.

8.11 Teacher Shantel

8.11.1 Teacher Beliefs

Shantel's beliefs about IBST and ICT simulations are strongly rooted in constructivist principles. She views technology as integral to fostering an engaging, inquiry-based learning environment. She believes that ICT simulations are essential for motivating learners and creating dynamic, hands-on experiences that deepen understanding. This view aligns with Hennessy et al. (2005), who found that teachers with constructivist beliefs often see ICT simulations as a means to enhance learner engagement and learning through active exploration.

8.11.2 Beliefs About Risk

Shantel demonstrates a high tolerance for the potential risks of using ICT simulations, seeing technical issues as "minor obstacles" rather than significant disruptions. Her resilient approach to technology challenges reflects her strong belief in the educational benefits of ICT simulations, which outweighs concerns about occasional failures. Shantel's high tolerance for potential risks of using technology aligns with Opre (2021), who suggests that high-efficacy teachers are more likely to persist with ICT simulations, viewing technical hiccups as manageable within the broader context of learner engagement and learning gains.

8.11.3 Constructivist Epistemology

Shantel's classroom practices reflect a solid commitment to social constructivism, as she uses ICT simulations to facilitate collaborative, inquiry-based learning. She views simulations as powerful tools for group interactions, where learners can test ideas collectively and develop a shared understanding through guided exploration. This approach aligns with Kim and Hannafin (2011), who emphasize the role of ICT simulations in fostering dialogue and collaborative inquiry in constructivist classrooms.

8.11.4 Beliefs Based on Actual Classroom Contexts

Shantel could fully integrate ICT simulations into her lessons in a stable classroom environment with reliable technology without significant disruption. She sees her context as conducive to using ICT simulations consistently, believing that technology effectively supports her teaching objectives. This confidence is supported by Tondeur et al. (2017), who found that teachers in well-resourced settings tend to have positive beliefs about ICT's role in inquiry-based learning due to fewer interruptions. Shantel's context reinforces her belief in ICT simulations as a dependable, integral part of her pedagogy.

8.11.5 Curriculum Design

Shantel's curriculum design reflected her constructivist beliefs as she integrated ICT simulations into her lesson plans. She designed her lesson plans around inquiry-based activities that leverage simulations to explore scientific concepts interactively. This approach aligns with Tondeur et al. (2017), who found that teachers with constructivist beliefs prioritize inquiry-based, technology-enhanced curricula that engage learners in active learning. Shantel created a learning environment that emphasizes hands-on exploration and conceptual understanding by embedding ICT simulations within her lesson plans.

Table 8.4 summarizes Shantel’s beliefs, risk tolerance, constructivist epistemology, classroom contexts, and curriculum design. It shows how Shantel’s belief in ICT’s role in enhancing learner engagement and inquiry is supported by her stable classroom environment. The table also discusses her confidence in ICT simulation integration and how it aligns with her inquiry-based curriculum design, making technology an essential part of her teaching strategy.

Table 8.4

Shantel’s Beliefs, Risk, Epistemology, Context, and Curriculum Design Theme

Theme	Summary
Beliefs about risk	Views technical issues as manageable and not significant enough to deter her from using ICT simulations. High tolerance for risk, seeing the benefits of engagement and learning outweigh potential disruptions.
Constructivist epistemology	Embraces social constructivism, believing ICT simulations supports interactive, collaborative, and inquiry-based learning. Uses simulations to facilitate group exploration, enabling learners to build shared understanding through discussion and experimentation.
Beliefs based on classroom contexts	Confident in her stable classroom setup, with resources and reliable technology that allow her to use ICT simulations consistently. Sees her context as supportive of her inquiry-based approach and maximizes ICT simulations use to engage learners actively.
Curriculum design	Designs curriculum with ICT simulations as a core element, integrating simulations to support inquiry-based activities. Her lessons focus on active learning, hands-on exploration, and real-world applications of scientific concepts.

8.11.6 Assessment Practices

Shantel integrates formative assessment practices with ICT simulations to monitor and evaluate her learners’ inquiry process and conceptual understanding. She uses ICT simulations as diagnostic tools to identify areas where learners may struggle, providing timely feedback to support their learning journey. Shantel’s focus on formative assessment aligns with Bell et al. (2005), who advocate for assessments that dynamically capture learner understanding and facilitate continuous learning within inquiry-based science teaching. Her approach emphasizes “process-over-product,” focusing on learners’ critical thinking and problem-solving skills rather than solely on content mastery.

8.11.7 Intervention

Shantel's participation in professional development interventions focused on constructivist approaches aligns with her use of ICT simulations as an interactive learning tool. She finds value in PD sessions centred on "interactive learning with technology," which validates her belief in ICT's role in fostering engagement and inquiry. Her experiences align with the BIUT framework, which emphasizes that effective interventions develop technical skills and strengthen constructivist beliefs, helping teachers apply ICT simulations in ways that resonate with their instructional goals (Juggernath & Govender, 2020).

8.11.8 Simulation Efficacy

Shantel views ICT simulations as highly effective tools that enhance learner engagement and bridge the gap between theoretical concepts and hands-on experimentation. She believes that simulations "make science engaging," creating opportunities for learners to explore scientific phenomena interactively (Shantel's interview). This belief is supported by Plass et al. (2012), who emphasize that simulations can significantly enhance learner motivation and understanding through immersive, interactive learning experiences. Shantel's perception of simulation efficacy is closely linked to her commitment to inquiry-based pedagogy, where technology serves as a catalysts deeper exploration.

8.11.9 Professional Development

Shantel's PD experiences have been instrumental in reinforcing her constructivist teaching methods and bolstering her confidence in using ICT simulations. Through PD, she has gained insights into the pedagogical applications of technology, supporting her belief that "technology can make abstract concepts more accessible" for learners. Her approach aligns with Ottenbreit-Leftwich (2013), who highlight that PD focused on constructivist pedagogy can deepen teachers' commitment to using ICT as a powerful inquiry tool. Shantel's PD experiences have equipped her with strategies to overcome classroom barriers, allowing her to maximize ICT's potential in fostering learner engagement and critical thinking.

Table 8.5 presents Shantel's practices, interventions, and PD in the context of ICT simulations. It highlights how PD focused on constructivist teaching methods has strengthened

her approach to inquiry-based learning. This table reveals how Shantel’s ability to integrate ICT simulations in a meaningful way is reinforced through ongoing professional development, which supports her belief in technology’s potential for enhancing hands-on learning.

Table 8.5

Shantel’s Practices, Interventions, and PD in IBST with ICT Simulations

Theme	Summary
Assessment practices	Integrates formative assessments with simulations to monitor learners’ inquiry process. Uses simulations to identify learning gaps and provides real-time feedback, focusing on critical thinking and process-oriented understanding.
Intervention	Benefited from PD sessions on constructivist approaches, supporting her use of simulations to enhance learner engagement. Values interventions that emphasize “interactive learning with technology” to reinforce inquiry-based methods.
Simulation efficacy	Views simulations as highly effective tools for fostering engagement and bridging theory with practice. Believes simulations simplify complex concepts and make learning engaging and memorable for learners.
Professional development	Actively participates in PD sessions that focus on technology integration within constructivist frameworks. Feels confident using simulations, as PD has equipped her with strategies to overcome potential classroom barriers.

8.11.10 Barriers

Shantel faced relatively few logistical barriers in her teaching environment, allowing her to integrate ICT simulations into her lessons consistently. However, she occasionally faced some pedagogical barriers, such as learners’ initial struggles with the open-ended nature of inquiry-based simulations due to limited prior experience. She addressed these challenges by providing structured guidance, viewing them as part of the learning process rather than as limitations. Shantel realized that teachers in well-supported environments still need to navigate internal barriers like learner readiness but can adapt these to facilitate inquiry (Tondeur et al., 2017).

8.11.11 Understanding

Shantel deeply understands ICT simulations and their role in promoting learner-centred inquiry. She views simulations as critical tools for enabling learners to explore scientific concepts interactively, enhancing their curiosity and engagement. Her understanding reflects a constructivist perspective, where ICT simulations is a “mediating tool” that supports collaborative inquiry and active learning, consistent with Vygotsky’s social constructivist theory.

Shantel's belief that "technology brings motivation" indicates her confidence in ICT's potential to enrich learners' learning experiences through inquiry-based practices.

8.11.12 Feasible Actions

With minimal logistical barriers, Shantel was able to incorporate ICT simulations seamlessly, engaging learners in sustained, inquiry-based activities. Her approach included setting up lessons that leverage the stable technological environment to maximize learner participation and interaction. She provided additional scaffolding when learners struggled with open-ended tasks, gradually increasing their independence in exploring simulations. This methodology demonstrates her commitment to fostering a supportive environment for inquiry, aligning with Fullan (2013), who discussed responsive teaching within available resources.

8.11.13 Technology

Shantel viewed technology as a transformative element in her teaching, integral to creating an inquiry-rich classroom. With access to reliable ICT tools, she consistently integrated PhET simulations to make science "live and interesting," using technology as a bridge between theoretical content and hands-on experimentation (Shantel's interview). Shantel's consistent use of technology aligns with Kim and Hannafin (2011), who found that teachers who view technology as transformative integrate it deeply within constructivist frameworks, promoting an active learning environment where learners can interact with scientific concepts.

Table 8.6 provides a summary of Shantel's barriers, understanding, feasible actions, and technology use. Despite occasional power outages, Shantel remains committed to using ICT simulations, adapting her strategies to maintain continuity in her inquiry-based lessons. This table demonstrates her flexibility and the central role of ICT simulations in her teaching practice, ensuring that technology enhances the learning experience even when faced with challenges.

Table 8.6*Shantel's Barriers, Understanding, Feasible Actions, and Technology*

Theme	Summary
Barriers	Experiences occasional power outages and limited ICT resources but views these challenges as minor obstacles. Believes in persisting with ICT simulations use despite technical issues.
Understanding	Has a strong constructivist perspective, seeing ICT simulations as essential for fostering engagement and making science hands-on. Uses simulations to support collaborative learning and inquiry.
Feasible actions	Provides structured guidance for learners struggling with open-ended inquiry, gradually increasing their independence. Uses her stable ICT environment to maximize learner participation in simulations.
Technology	Considers technology transformative in making science engaging and accessible. Consistently integrates PhET simulations as central elements in her lessons to encourage learner curiosity and exploration.

8.12 Teacher Abel

8.12.1 Teacher Beliefs

Abel's beliefs about IBST and ICT simulations lean towards a structured, teacher-centred approach. He views ICT simulations as supplementary tools that can support but not replace traditional content-focused teaching. Abel's preference for a more guided instructional style aligns with a traditional pedagogical framework, where he values control over lesson structure and pacing. His approach reflects Tondeur (2020), who found that teachers with traditional beliefs may underutilize ICT's potential for inquiry, instead using it to reinforce established curriculum goals. A gap in Abel's beliefs is his limited view of ICT's role beyond content support; incorporating ICT simulations as a means for inquiry could still support structured lessons while enriching learners' analytical skills.

8.12.2 Beliefs About Risk

Abel is cautious about the disruptions that ICT simulations might bring to his classroom. He perceives technology-related risks, such as technical failures or learners becoming distracted by simulations, as challenges that could interfere with his structured lessons. His conservative approach to ICT simulations use is shaped by a desire to maintain control over the learning environment, aligning with Ertmer et al. (2012), who found that teachers are less likely to

incorporate ICT tools deeply into their instructional practice, particularly in inquiry-based contexts. By not addressing manageable risks, Abel may miss chances to foster resilience and adaptability in learners, who benefit from experiencing successes and challenges in ICT simulations -supported inquiry (Livingstone & Sefton-Green, 2016).

8.12.3 Constructivist Epistemology

While Abel recognizes the value of ICT simulations for enhancing learner understanding, he applies it within a more structured, teacher-guided framework rather than through open-ended inquiry. His approach to simulations emphasizes reinforcing content knowledge rather than facilitating learner-driven exploration. This limited application reflects a cognitive constructivist approach, where simulations support direct instruction and structured exploration rather than fostering self-directed learning. His practice diverges from social constructivist principles, aligning more with a structured, content-focused methodology. Literature on constructivist pedagogy (Laurillard, 2013), suggests that ICT simulations can guide learners in hypothesis testing and critical thinking, which could enhance Abel's teacher-centred approach. Abel's structured epistemology could benefit from integrating inquiry-based scaffolding to encourage learners' independent exploration while maintaining the desired instructional control.

8.12.4 Beliefs Based on Classroom Contexts

Abel's beliefs about ICT simulations are influenced by his preference for consistency and control in classroom dynamics. He believes structured lessons help him manage learner behaviour and maintain focus, which informs his cautious use of simulations. Abel's classroom context supports his belief in teacher-centred instruction, as he finds it more manageable and effective for meeting curriculum requirements. This perspective aligns with Cuban (2009), who found that teachers often adapt their beliefs and practices to fit their preferred classroom management styles.

8.12.5 Curriculum Design

In designing his curriculum, Abel incorporates ICT simulations as a supplementary resource rather than a central instruction component. He structures his lessons around traditional content delivery, using simulations to reinforce specific concepts rather than as primary tools for

inquiry. This design reflects Tondeur (2020), who found that teachers with traditional beliefs tend to favour teacher-led, structured curriculum models. Abel’s approach to curriculum design highlights his belief in maintaining control over the learning process, using ICT simulations selectively to enhance, rather than transform, his instructional practice.

Table 8.7 outlines Abel’s beliefs, risk perception, epistemology, classroom contexts, and curriculum design. It reflects Abel’s traditional approach to teaching, where ICT simulations serve as supplementary tools for reinforcing content rather than driving inquiry. The table highlights his cautious use of ICT simulations due to concerns about potential disruptions, emphasizing the need for structured, teacher-directed lessons.

Table 8.7

Abel’s Risk, Epistemology, Context, Curriculum Design, and Beliefs

Theme	Summary
Beliefs about risk	Cautious about using simulations due to potential distractions or technical failures. Prefers to minimize risks by maintaining a controlled, teacher-centered environment, fearing that ICT simulations could disrupt structured lessons.
Constructivist epistemology	Primarily follows a cognitive constructivist approach, using simulations to reinforce content understanding within a structured framework. Limited application of social constructivist methods, focusing on direct instruction over collaborative exploration.
Beliefs based on classroom contexts	Believes that large class sizes and limited ICT resources necessitate a more controlled use of technology. Uses ICT simulations selectively to maintain consistency in his lessons, prioritizing structure over flexible, inquiry-based approaches.
Curriculum design	Uses ICT simulations to support traditional curriculum goals, with simulations serving as supplementary, content-focused tools. Curriculum design emphasizes structured content delivery rather than open-ended inquiry.
Teacher’s beliefs	Views ICT simulations as useful for content reinforcement but not central to science education. Emphasizes teacher-led, structured learning, with ICT simulations supporting established curriculum goals rather than enabling open-ended inquiry.

8.12.6 Assessment Practices

Abel’s assessment practices reflect his preference for structured, content-focused instruction. He primarily uses assessments that measure content mastery rather than inquiry-based skills, focusing on learners’ recall and understanding of scientific concepts. For Abel, simulations play a minor role in assessment, as he views them as supplementary tools to reinforce understanding rather than primary means of evaluating inquiry skills. This approach

aligns with Tondeur et al. (2017), who found that teachers with traditional beliefs tend to favour fixed-response and structured assessments, often emphasizing factual knowledge over process-oriented learning.

8.12.7 Intervention

While Abel occasionally uses ICT simulations, these interventions have not significantly shifted his beliefs toward constructivist practices. Abel's approach would benefit from PD, which introduces inquiry-based instructional strategies to help him explore ICT's potential more broadly. Tondeur (2020) suggest that interventions that challenge pre-existing beliefs can prompt teachers to consider more flexible, inquiry-based ICT applications, potentially encouraging Abel to expand his instructional strategies.

8.12.8 Simulation Efficacy

Abel perceives ICT simulations as practical tools for reinforcing scientific concepts but not as central to inquiry-based learning. He believes simulations help clarify complex topics in a structured lesson but do not substantially contribute to open-ended exploration or inquiry. For Abel, the efficacy of simulations lies in their ability to support content comprehension rather than foster critical thinking or problem-solving. Zacharia and Anderson (2003) found that teachers often recognize simulations as effective tools for visualizing concepts but may not fully integrate them for inquiry-based learning.

Abel's PD experiences have primarily supported his structured, teacher-centred approach, emphasizing traditional instructional models. His limited exposure to PD focused on IBST or constructivist methods has reinforced his tendency to use ICT simulations in a controlled, supplemental manner. This experience reflects research by Tondeur et al., (2017), which suggests that PD can sometimes reinforce existing beliefs, especially when it lacks a focus on open-ended, inquiry-based instructional strategies. For Abel, more diverse PD offerings emphasizing inquiry-focused techniques could provide new perspectives on ICT's potential to promote learner autonomy and critical thinking.

8.12.9 Barriers

Abel encountered logistical and pedagogical barriers that shapes his use of ICT simulations in the classroom. He perceives simulations as potentially disruptive to his structured lesson plans and feels they may lead learners off track without close supervision. Abel's preference for teacher-led instruction also limits his openness to integrating ICT tools more deeply into inquiry-based activities. This alignment with Blackwell et al. (2013) suggests that teachers' intrinsic beliefs can act as internal barriers, where a preference for structure and control reduces the likelihood of fully adopting ICT simulations for inquiry-based methods.

Table 8.8 presents Abel's practices, interventions, and PD in the context of IBST with ICT simulations. It emphasizes how Abel's professional development has reinforced his teacher-centred methodology, where ICT simulations are used sparingly to support content delivery. This table illustrates the limited role of technology in Abel's approach to inquiry-based learning, where PD has yet to shift his beliefs towards more flexible ICT simulation integration.

Table 8.8

Abel's Practices, Interventions, and PD in IBST with ICT Simulations

Theme	Summary
Assessment practices	Primarily uses content-focused assessments, with limited use of simulations for inquiry assessment. Relies on structured evaluations that emphasize knowledge recall, aligning with his preference for teacher-led instruction.
Intervention	PD has reinforced his structured approach but has not significantly shifted his beliefs toward inquiry-based methods. Would benefit from PD that introduces inquiry-based assessment techniques and ICT simulation integration.
Simulation efficacy	Sees simulations as supportive tools for visualizing concepts rather than for inquiry-based exploration. Values simulations for reinforcing understanding but does not perceive them as central to his teaching.
Professional development	PD has largely supported his traditional, content-focused approach. Has limited exposure to inquiry-based ICT simulation strategies, which could broaden his use of simulations for fostering critical thinking and learner autonomy.

8.12.10 Understanding

Abel's understanding of ICT simulations is framed within a traditional, content-focused instructional approach. He values simulations primarily for their ability to reinforce existing curriculum content rather than tools for fostering inquiry or self-guided exploration. Abel

perceives simulations as helpful visual aids that can support content comprehension but does not view them as integral to inquiry-based learning. This perspective reflects Tondeur et al. (2017), who found that teachers with traditional beliefs often regard ICT simulations as secondary to direct instruction, using it as a complement to rather than a foundation for inquiry-based approaches.

8.12.11 Feasible Actions

Within his preferred structured approach, Abel takes feasible actions to ensure ICT simulations are used effectively without disrupting his lesson flow. He integrates simulations selectively, often as part of teacher-directed activities where he can control the pace and focus. By positioning ICT simulations as an enhancement rather than a core component of inquiry, Abel maintains control over lesson objectives while leveraging technology to support his instructional goals. His approach demonstrates a pragmatic balance, using ICT simulations in ways that align with his teaching style and constraints, consistent with the Reality Judgement framework, which emphasizes balancing beliefs with practical realities.

8.12.12 Technology

Abel views technology as a helpful but supplementary element in his teaching, primarily for reinforcing content rather than driving inquiry. He uses ICT simulations selectively to enhance his understanding of specific scientific concepts, though he does not see it as central to his pedagogy. Abel's cautious stance on technology aligns with Hermans et al. (2008), who found that teachers with traditional pedagogical beliefs tend to adopt ICT simulations in a limited capacity, often viewing it as a supportive tool rather than a catalyst for transformative learning. For Abel, technology serves a purpose in structured lessons but is secondary to his overall instructional goals.

Table **8.9** discusses Abel's barriers, understanding, feasible actions, and technology use. The table reflects how Abel's preference for structured lessons limits his use of ICT simulations, with a strong emphasis on managing classroom order and pacing. It also showcases how logistical barriers and his teaching philosophy influence his cautious approach to ICT simulation integration, using technology only as a reinforcement tool.

Table 8.9*Abel's Barriers, Understanding, Feasible Actions, and Technology*

Theme	Summary
Barriers	Limited devices, large class size, and a preference for control impact his willingness to use ICT simulations. Sees technology as potentially disruptive without close supervision.
Understanding	Values ICT simulations primarily for reinforcing content but does not view it as essential for inquiry. Uses simulations in a structured manner to support direct instruction rather than learner-led exploration.
Feasible actions	Selects simulations that align with structured, teacher-led activities to maintain lesson control. Uses ICT simulations as an enhancement rather than a core component of inquiry to balance structure with technology.
Technology	Views technology as helpful but supplementary, supporting content mastery rather than driving inquiry. Adopts a cautious, teacher-centred approach, viewing simulations as aids to traditional instruction.

8.13 Teacher José

8.13.1 Teacher Beliefs

José holds constructivist beliefs about IBST and ICT simulations, seeing simulations as essential tools for promoting scientific inquiry and critical thinking. He values ICT's role in creating hands-on, experiential learning environments where learners can explore concepts interactively. For José, simulations serve as “virtual laboratories,” offering opportunities for learners to experiment and engage in scientific reasoning. His beliefs align with Sandoval and Reiser (2004) findings, which suggest that teachers prioritizing inquiry-based outcomes view ICT simulations as a means to support iterative, reflective learning. The literature on blended constructivist approaches Mishra and Koehler (2006), suggests that combining structured tasks with exploratory ICT simulations could foster a more inclusive environment, allowing José to reach learners who may struggle with entirely open-ended tasks.

8.13.2 Beliefs About Risk

José maintains a balanced approach to risk when integrating ICT simulations, viewing potential technical issues as manageable. He often prepares backup plans to address unexpected disruptions, allowing him to use simulations confidently without derailing lesson objectives. His moderate risk tolerance indicates flexibility and adaptability, showing that he perceives the

educational benefits of ICT to outweigh potential challenges. José's approach aligns with research by Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010), highlighting how flexible risk management strategies enable teachers to maintain an inquiry-driven focus even in the face of occasional technical obstacles. Literature on risk management in technology-enhanced learning, according to Anderson (2013), suggests that José might benefit from developing strategies specific to critical lessons or assessments, ensuring that technical issues do not undermine pivotal learning opportunities. Expanding his view of risk could allow José to use ICT simulations even in more challenging or high-impact scenarios.

8.13.3 Constructivist Epistemology

José's classroom practices reflect a deep commitment to constructivist principles. He uses ICT simulations to support hypothesis testing and iterative exploration. For example, he integrates simulations to allow learners to test variables, observe outcomes, and refine their conceptual models through experimentation. This approach exemplifies guided inquiry, where teacher-structured activities support learner-driven investigation. José implemented scaffolding techniques, providing structured support to help learners actively engage with content and develop their understanding (Bruner, 2013).

8.13.4 Beliefs Based on Classroom Contexts

José's beliefs about ICT simulation integration are influenced by his classroom's logistical and contextual realities. Although he faces some constraints, such as limited resources and curriculum pacing demands, he adapts his use of simulations to fit within these boundaries. José's pragmatic view of ICT simulations is based on Cuban (2009), who suggested that teachers shape their beliefs based on the resources and constraints of their specific educational context. He uses the available technology to maximize learning outcomes, balancing ideal inquiry practices with the realities of his environment. According to Tondeur et al. (2017), innovative ICT simulations solutions can help teachers maintain inquiry-based learning despite resource limitations, suggesting José's classroom practices might benefit from exploring such tools to optimize his time and resources.

8.13.5 Curriculum Design

José’s curriculum design incorporates ICT simulations as core elements that foster inquiry and scientific reasoning. He aligns his curriculum with constructivist goals by using simulations for hands-on experimentation, enabling learners to engage deeply with scientific concepts through virtual manipulation of variables and observation of results. His methodology is consistent with the findings of Chiu et al. (2015), who found that simulation-based curricula support conceptual understanding and inquiry skills in IBST environments. By embedding ICT simulations within his curriculum design, José supports inquiry-driven objectives that encourage critical thinking and self-guided exploration.

Table 8.10 presents José’s risk perceptions, constructivist epistemology, classroom contexts, and curriculum design. It demonstrates how José’s balanced approach to managing ICT simulations-related risks allows for a consistent integration of simulations into his inquiry-based lessons. The table highlights how José’s understanding of ICT simulations as a “virtual lab” aligns with his commitment to fostering critical thinking and scientific reasoning.

Table 8.10

José’s Risk, Epistemology, Context, Curriculum Design, and Beliefs

Theme	Summary
Beliefs about risk	Adopts a balanced approach, managing potential ICT simulations-related risks with backup plans. Willing to handle technical disruptions due to strong belief in the educational benefits of ICT for inquiry-based learning.
Constructivist epistemology	Strongly aligned with social constructivist principles, using ICT simulations to support collaborative learning and hypothesis-driven exploration. Sees simulations as “virtual labs” where learners can test ideas and build scientific reasoning through interaction.
Beliefs based on classroom contexts	Believes that limited ICT resources and curriculum pacing constraints shape his instructional decisions but adapts simulations to fit these limitations. Balances ideal inquiry-based practices with classroom realities to maximize ICT simulations use.
Curriculum design	Integrates ICT simulations as a central part of his curriculum, designing lessons that revolve around inquiry and hands-on experimentation. Learners engage in critical thinking and self-directed inquiry, with simulations enhancing conceptual understanding.
Teacher’s beliefs	Views ICT simulations as essential for fostering scientific reasoning and hands-on inquiry. Believes that simulations enhance understanding and engagement, providing learners with opportunities to experiment and explore concepts interactively.

8.13.6 Assessment Practices

José's approach to assessment reflects his constructivist beliefs. He focuses on evaluating learners' scientific reasoning and inquiry skills through simulation-based tasks. He encourages learners to document hypotheses, test findings, and reflect on outcomes, using these assessments to gauge learners' understanding of variables and experimental processes. José's approach to assessment reflects the principles outlined by Chinn and Malhotra (2002), who emphasized scientific reasoning and critical thinking for inquiry-based assessments. José assessment methods provide a dynamic view of learner learning, capturing the iterative and reflective aspects of IBST.

8.13.7 Intervention

José values PD interventions that focus on pedagogical support for inquiry-based learning. He has found PD helpful in structuring “guided inquiry in simulations,” reinforcing his belief in technology's potential to enhance hands-on learning (Lehtinen et al., 2019, p. 198). He favours PD sessions that offer practical strategies for integrating ICT simulations into inquiry-driven science lessons, aligning with the BIUT framework of Juggernath and Govender (2020), who emphasized the importance of targeted PD that supports teachers' constructivist approaches. José's positive experiences with PD reflect his openness to strategies that help align his instructional practices with inquiry-based goals.

8.13.8 Simulation Efficacy

José sees simulations as highly effective in supporting his inquiry-based teaching. He integrates ICT simulations as “virtual laboratories” that allow learners to test hypotheses and explore scientific concepts interactively, especially in physics lessons where learners can manipulate variables such as angles and velocities. His belief in the effectiveness of simulations corresponds with the perspective of Bybee (2014), who argues that ICT simulations can be powerful tools for promoting inquiry-based skills. For José, ICT simulations play a crucial role in making abstract concepts accessible, and he views them as essential for fostering scientific reasoning and critical inquiry. However, José could explore other forms of interactive technology, such as augmented reality (AR) or virtual labs, which might offer additional means

of achieving similar objectives. Recent studies from Freese et al. (2023) suggest that Augmented Reality (AR) and Virtual Reality (VR) tools can provide immersive, multi-sensory learning experiences that complement traditional simulations, potentially enhancing learners' engagement and conceptual understanding in ways that simulations alone might not achieve.

8.13.9 Professional Development

José's engagement in PD programs has strengthened his constructivist teaching approach, mainly using ICT simulations to support inquiry-based learning. He values PD, which focuses on pedagogical techniques, enabling him to use simulations effectively within an inquiry framework. José's experiences align with PD's emphasis on technology integration within inquiry, fostering constructivist beliefs, and strengthens teachers' confidence in using ICT simulations (Prestridge, 2017). These PD experiences have reinforced José's commitment to learner-cantered, inquiry-driven teaching, equipping him with strategies to maximize the educational impact of ICT simulations.

Table 8.11 summarizes José's practices, interventions, and PD in IBST with ICT simulations. It emphasizes how José's PD experiences have reinforced his use of simulations as key tools for scientific inquiry. The table illustrates how José's confidence in using ICT simulations grows with PD that supports constructivist teaching methods, enhancing his ability to integrate technology into inquiry-driven classrooms.

Table 8.11

José's Practices, Interventions, and PD in IBST with ICT Simulations

Theme	Summary
Assessment practices	Uses inquiry-based assessments that emphasize scientific reasoning and reflection. Assesses learners through simulation tasks that require hypothesis testing and analysis, focusing on process-oriented outcomes.
Intervention	Values PD sessions that support constructivist teaching approaches. Finds value in PD that provides practical strategies for integrating simulations into inquiry-driven science lessons, reinforcing his commitment to learner-centred teaching.
Simulation efficacy	Considers simulations as "virtual laboratories" that enable learners to explore scientific concepts interactively. Believes simulations are effective for engaging learners in hands-on inquiry and enhancing scientific reasoning.
Professional development	Regularly participates in PD focused on pedagogical applications of ICT simulations for inquiry-based learning. PD experiences have strengthened his confidence in integrating simulations to

Theme	Summary
	support critical thinking and active learning.

8.13.10 Barriers

José encounters contextual and logistical barriers, such as curriculum pacing demands and limited resources, which occasionally challenge his ability to integrate ICT simulations in an inquiry-driven manner fully. Despite these constraints, he maintains a flexible approach, adapting his lessons to balance time for hands-on inquiry with curriculum requirements. José's experiences with these barriers are in agreement with Opre (2021), who found that teachers in resource-limited settings often struggle to sustain inquiry-based practices due to logistical constraints, necessitating adaptability in their instructional strategies.

8.13.11 Understanding

José deeply understands ICT's role in supporting inquiry-based science teaching, viewing simulations as virtual labs that allow learners to test hypotheses and explore scientific concepts interactively. He sees ICT simulations as engaging learners in reflective inquiry and helping them develop scientific reasoning. José's approach is consistent with Vygotsky's social constructivist theory, which emphasizes learning through mediated tools and guided exploration. His understanding aligns with Chinn & Malhotra (2002), who found that simulations in IBST can foster critical thinking and reflective learning by allowing learners to investigate scientific principles firsthand.

8.13.12 Feasible Actions

To address the constraints of his teaching context, José takes feasible actions to ensure the continued use of ICT simulations in a meaningful way. For example, he prepares backup activities to keep lessons on track when technology access is limited and adjusts the complexity of simulations based on available resources. This adaptive strategy demonstrates José's commitment to inquiry-based learning within the constraints of his environment, aligning with the Reality Judgement framework, which highlights how teachers balance ideal instructional practices with practical limitations. However, José's feasible actions might be enhanced by adopting adaptive learning technologies that automatically adjust difficulty or provide alternative

pathways when resources are limited (Ainley & Ainley, 2019). By exploring such adaptive technologies, José could ensure that his learners continue to engage in meaningful inquiry even when resources fluctuate.

8.13.13 Technology

José views technology as crucial in inquiry-based science teaching, particularly in enhancing learners' engagement and understanding of complex concepts. He uses ICT simulations to create interactive learning experiences, allowing learners to experiment with scientific variables that might be difficult to replicate in a physical lab. José's regular use of technology in this manner is consistent with the findings of Ottenbreit-Leftwich et al. (2010), who found that teachers who view technology as central to their instructional approach are more likely to integrate it deeply into their practices, fostering an inquiry-based, constructivist learning environment. However, José's focus on simulations might limit his exploration of other ICT simulations forms that could similarly enhance inquiry. Research on multi-modal ICT use suggests that combining simulations with other tools, such as interactive platforms or mobile apps, could provide José's learners with a broader range of inquiry opportunities (Means et al., 2014).

Table 8.12 provides an overview of José's barriers, understanding, feasible actions, and technology use. It reflects how José navigates logistical constraints, such as limited resources, while still maintaining a strong commitment to using ICT simulations to enhance inquiry-based learning. The table demonstrates his adaptability and how his deep understanding of ICT's role supports his ability to make the most of available resources.

Table 8.12*José's Barriers, Understanding, Feasible Actions, and Technology*

Theme	Summary
Barriers	Faces constraints related to limited ICT resources and curriculum pacing but adapts his use of simulations to these limitations.
Understanding	Has a deep understanding of ICT simulations as a virtual lab that fosters hypothesis testing and scientific reasoning. Uses simulations to support interactive, inquiry-based learning.
Feasible actions	Prepares backup activities for situations where technology access is limited. Adapts simulation complexity to fit available resources, balancing ideal practices with constraints.
Technology	Sees technology as essential for enhancing scientific inquiry. Integrates ICT simulations consistently, providing hands-on experiences to engage learners in hypothesis-driven exploration.

8.14 Teacher Paulo

8.14.1 Teacher Beliefs

Paulo holds constructivist beliefs about IBST and views ICT simulations as valuable tools for facilitating reflective, inquiry-based learning. He believes simulations can support learners' deeper understanding of scientific concepts by allowing them to explore and experiment with abstract ideas actively. For Paulo, ICT simulation is a vehicle for fostering independent thought and critical inquiry. His approach reflects findings by Sandoval and Reiser (2004), who found that teachers with constructivist beliefs often use technology to encourage iterative and reflective learning, positioning learners as active participants in knowledge construction. Research on collaborative constructivism suggests pairing independent work with group-based simulation activities could foster richer dialogue, shared problem-solving, and collaborative critical thinking, enhancing Paulo's current approach (Tondeur et al., 2017).

8.14.2 Beliefs About Risk

Paulo has a moderate tolerance for the risks of using ICT simulations in his classroom. Although he recognizes the possibility of technical disruptions, he mitigates these by closely monitoring learner groups and addressing issues as they arise. His approach reflects a proactive stance on managing technological risks, where he feels confident handling potential interruptions. This strategy is consistent with Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010)

, who recommended adaptive teaching, where careful monitoring allows teachers to minimize the impact of ICT simulations-related challenges on instructional goals.

8.14.3 Constructivist Epistemology

Paulo's classroom practices are heavily influenced by constructivist principles, particularly the cognitive constructivist approach, as he uses ICT simulations to guide learners through reflective, metacognitive inquiries. For instance, he employs simulations on topics like atomic structures to encourage learners to investigate, analyse, and refine their understanding iteratively. Al Husaeni and Rahmat (2023) emphasize that constructivist methods are particularly effective in STEM education, where problem-solving tasks and inquiry-based learning allow learners to develop critical thinking skills and deep understanding of content. They argue that constructivist epistemology aligns with 21st-century educational goals, fostering autonomy and adaptability in learners. By integrating peer-supported inquiry, Paulo could foster both individual reflection and social learning, enriching the constructivist environment in his classroom.

8.14.4 Beliefs Based on Classroom Contexts

Paulo's beliefs about the efficacy of ICT simulations are shaped by his teaching context, which includes a smaller class size that allows for personalized guidance and individualized inquiry. He believes the intimate classroom setting enables him to engage more closely with learners, making ICT simulations a feasible and effective method for exploring scientific concepts. This approach aligns with Cuban (2009), who found that small class sizes allow teachers to tailor ICT simulations use to meet learners' needs, thereby maximizing the impact of technology on learning outcomes.

8.14.5 Curriculum Design

Paulo incorporates ICT simulations into his curriculum design to foster scientific inquiry and metacognitive reflection. His curriculum includes simulations that allow learners to manipulate variables and analyse outcomes, reinforcing inquiry skills within the scientific content. Paulo's approach is consistent with the framework proposed by Chiu et al. (2015), who argue that simulation-based curricula enhance conceptual understanding by supporting hands-on experimentation and critical thinking. By embedding ICT simulations into his curriculum, Paulo

enables learners to engage deeply with content through structured inquiry activities. Research on blended inquiry environments suggests that combining physical with digital ICT simulations could reinforce learning and help learners connect abstract concepts to tangible experiences (Herrington et al., 2014). This combination could make Paulo’s curriculum design more accessible to learners who prefer hands-on learning.

Table 8.13 outlines Paulo’s risk perceptions, constructivist epistemology, classroom contexts, and curriculum design. It shows how Paulo’s moderate risk tolerance allows him to integrate ICT simulations effectively, despite occasional technological challenges. The table reflects how Paulo’s belief in ICT simulations as an essential tool for fostering reflective inquiry shapes his curriculum design, where simulations support metacognitive learning.

Table 8.13

Paulo’s Risk, Epistemology, Context, Curriculum Design, and Beliefs

Theme	Summary
Beliefs about risk	Has a moderate tolerance for risk, managing potential technical issues by closely monitoring learner groups. Views risk as manageable with proactive planning and values the benefits of inquiry over concerns about disruption.
Constructivist epistemology	Aligns with cognitive constructivism, using ICT simulations to foster metacognitive skills and reflective learning. Encourages learners to analyse, hypothesize, and refine their understanding through simulation-based exploration.
Beliefs based on classroom contexts	Views his smaller class size as conducive to individualized, inquiry-based learning. Uses ICT simulations extensively to support a learner-centered environment that maximizes engagement within the given resource constraints.
Curriculum design	Curriculum design emphasizes inquiry-based learning with simulations as key tools for exploring scientific concepts. Learners engage in hypothesis testing and critical thinking, with Paulo facilitating reflective, metacognitive assessments.
Teacher’s beliefs	Believes in ICT’s potential to foster deep, reflective inquiry and critical thinking. Sees simulations as essential for helping learners explore complex ideas, encouraging autonomy and deeper engagement with scientific principles.

8.14.6 Assessment Practices

Paulo’s assessment practices emphasize metacognitive skills and scientific reasoning, aligning with his constructivist approach. He uses ICT simulations to encourage learners to document their hypotheses, analyse findings, and reflect on how simulations shape their understanding. His focus on reflective assessment aligns with Chinn and Malhotra (2002), who recommended inquiry-based assessments, prioritizing evaluating scientific reasoning over rote

memorization. Paulo's assessment approach highlights his value on critical thinking, as he assesses learners' ability to synthesize and reflect on the knowledge they construct through simulation-based inquiry.

8.14.7 Intervention

Paulo has benefited from interventions emphasizing critical thinking and inquiry within ICT simulations frameworks, helping him refine his constructivist teaching approach. He values PD, which focuses on pedagogical strategies for integrating simulations in ways that promote reflective learning. Paulo's approach reflects Essalih et al. (2024), who argue that interventions that support critical thinking in ICT simulations environments are essential for effective IBST integration. These PD experiences have equipped Paulo with strategies to implement simulations in ways that foster deep inquiry and learner autonomy.

8.14.8 Simulation Efficacy

Paulo perceives ICT simulations as highly effective tools that promote individualized reflection and conceptual understanding. He views simulations as "enablers of critical thinking," allowing learners to explore complex scientific concepts, such as atomic interactions, iteratively (Paulo's interview). His belief in simulation efficacy aligns with Chiu et al. (2015), who argue that simulations enhance learning by providing repeated, scaffolded experiences that encourage self-reflection and mastery of content. For Paulo, simulations are essential for helping learners engage deeply with scientific principles, facilitating an inquiry-based, reflective learning process.

8.14.9 Professional Development

PD has played a significant role in shaping Paulo's inquiry-based use of ICT simulations. His PD experiences have reinforced his commitment to fostering critical thinking and reflective inquiry, mainly through targeted training combining constructivist pedagogy and technology integration. Paulo values PD, which connects ICT simulations use with reflective questioning, and aligns with the BIUT framework's emphasis on PD, which supports reflective, inquiry-based learning Juggernath and Govender (2020). These experiences have strengthened Paulo's confidence in using ICT simulations as tools foster independent exploration and higher-order thinking skills.

Table 8.14 summarizes Paulo’s practices, interventions, and PD in the context of IBST with ICT simulations. It illustrates how Paulo’s PD experiences have deepened his commitment to using simulations for critical thinking and independent learning. The table also highlights how Paulo values PD that connects technology integration with constructivist teaching strategies, further enhancing his ability to foster reflective learning through ICT simulations.

Table 8.14

Paulo’s Practices, Interventions, and PD in IBST with ICT Simulations

Theme	Summary
Assessment practices	Focuses on metacognitive assessments and scientific reasoning, using simulations to assess learners' ability to analyse, hypothesize, and reflect on their learning. Values reflective assessment aligned with inquiry-based learning.
Intervention	Participates in PD focused on critical thinking and ICT integration within constructivist frameworks. Finds interventions that encourage reflective inquiry to be particularly valuable for reinforcing his inquiry-based teaching style.
Simulation efficacy	Views simulations as essential for promoting critical thinking, reflection, and deeper understanding of scientific concepts. Sees simulations as “enablers of critical thinking” that support independent exploration and learner autonomy.
Professional development	Engages in PD that combines constructivist pedagogy with ICT simulations integration, building his confidence in using simulations as tools for fostering inquiry and reflection. PD has helped him refine strategies for deeper learner engagement and metacognitive inquiry.

8.14.10 Barriers

Paulo encountered contextual and resource-related barriers, such as limited digital resources and curriculum pacing constraints, impacting his ability to implement inquiry-based ICT activities fully. However, his smaller class size allows for individualized attention, which helps him navigate these constraints. Paulo’s ability to provide close monitoring and adapt his instruction minimizes the impact of barriers, allowing him to use ICT simulations effectively despite limitations. His approach reflects Opre (2021), who found that flexible teaching strategies can help overcome logistical barriers in resource-limited environments, particularly in smaller class settings.

8.14.11 Understanding

Paulo firmly understands ICT’s role in supporting inquiry-based science teaching, viewing simulations as tools that facilitate critical thinking and reflective inquiry. He uses

simulations to engage learners in exploring scientific phenomena through iterative learning, focusing on developing their analytical skills and metacognitive awareness. His perspective is in line with Chinn and Malhotra (2002), who theorised that simulations in IBST environments support reflective inquiry, helping learners engage deeply with scientific principles through scaffolded, learner-centered exploration. However, his focus on ICT simulations may limit his awareness of other digital tools that could provide alternative inquiry paths, such as interactive simulations that allow learners to collaborate online or hybrid tools that combine virtual with real-world data. Studies suggest that various tools can provide learners with unique pathways for inquiry Ainley and Ainley (2019).

8.14.12 Feasible Actions

To address classroom constraints, Paulo takes actions that balance his instructional goals with available resources. He often integrates ICT simulations selectively, prioritizing quality over quantity by focusing on high-impact, reflective activities. His smaller class size allows him to provide personalized support, which helps learners engage fully with simulations even within a resource-limited setting. Paulo's strategic use of ICT simulations within these constraints demonstrates his adaptability, which is consistent with the Reality Judgement framework, which emphasizes teachers' practical decision-making to achieve instructional aims despite limitations.

8.14.13 Technology

Paulo regards technology as essential for enabling individualized inquiry and reflection in his science teaching. He views ICT simulations as invaluable for creating interactive learning experiences, allowing learners to explore complex concepts at their own pace. Ertmer (2005) conceptualized that teachers who view technology as central to learning are more likely to integrate it deeply to support inquiry-based learning. In classrooms with limited resources, technology can serve as a bridge to foster critical thinking and engagement with scientific content, enhancing a constructivist approach to teaching. Table 8.15 presents a summary of Paulo's barriers, understanding, feasible actions, and technology use. It reflects how Paulo adapts his ICT simulation integration based on classroom constraints, making use of smaller class sizes to maximize engagement with simulations. The table demonstrates his strategic approach to

overcoming barriers and his commitment to using technology to enhance inquiry-based, reflective learning.

Table 8.15

Paulo's Barriers, Understanding, Feasible Actions, and Technology

Theme	Summary
Barriers	Encounters limited digital resources and pacing challenges but benefits from a smaller class size, enabling close monitoring of ICT simulations use.
Understanding	Views ICT simulations as critical for fostering independent reflection and critical inquiry. Uses simulations for iterative, metacognitive inquiry, aligning with constructivist principles.
Feasible actions	Focuses on high-impact, reflective simulation activities due to limited resources. Provides personalized support for learners to maximize simulation engagement, balancing constraints with inquiry goals.
Technology	Regards technology as a fundamental tool for enabling individualized inquiry and critical thinking. Consistently integrates simulations to create interactive, reflective learning experiences that reinforce scientific concepts.

8.15 Summary

Chapter 8 presents a multifaceted analysis of the relationship between science teachers' beliefs, instructional practices, and the contextual limitations influencing their implementation of IBST with ICT simulations. Overall, teachers' constructivist-oriented beliefs significantly impact their curriculum design, assessment strategies, and how they navigate practical barriers in the classroom. While teachers generally view ICT simulations as valuable for enhancing learner engagement and comprehension, individual perspectives on ICT's role in fostering independent learning vary.

Teachers with a strong belief in the role of ICT simulations for inquiry-driven learning, like Shantel, José, and Paulo, integrated ICT simulations as central components of their lessons. Their practices align with constructivist ideals, emphasizing inquiry, critical thinking, and learner autonomy. In contrast, teachers with more traditional beliefs, such as Abel, use ICT simulations in a supplementary role, reinforcing content rather than promoting open-ended inquiry. Across the cases, logistical and infrastructural barriers further influence teachers' instructional strategies, requiring them to balance ideal practices with classroom constraints.

PD experiences also play a role in shaping teachers' beliefs and readiness to integrate ICT simulations. Teachers with targeted training in inquiry-based, technology-integrated instruction exhibit greater confidence and flexibility in using simulations. Ultimately, the analysis highlighted that while teachers' beliefs guide instructional decisions, classroom practices are dynamically shaped by available resources, risk tolerance, and pedagogical support. Highlighting the importance of interventions that address both the belief systems and the practical realities of teachers in supporting effective IBST and ICT integration.

Table 8.16 shows a summary of each teacher's classroom implementation, ICT simulations-related challenges, lesson plan strategies, learning outcomes, and beliefs about IBST and ICT integration.

Table 8.16

Summary of Classroom ICT Implementation

Teacher	Classroom implementation	Challenges with ICT integration	Lesson plan integration	Learning outcomes	Teachers' beliefs
António	Teacher-centred, controls simulations, limited learner autonomy	Time constraints, unstable internet, power outages, lack of training	Integrates simulations, but primarily teacher-controlled, limits inquiry	Enhanced understanding, limited active engagement, conceptual comprehension	Strong belief in ICT's and BST, but overshadowed by control-focused approach
Shantel	Facilitates learner interaction, promotes exploration	Limited access to ICT resources, power outages	Central use of ICT simulations in inquiry, focuses on guiding questions and peer discussions	High engagement, learners connect concepts practically, critical thinking fostered	Strong belief in learner-centred, inquiry-based learning and ICT simulations for engagement and understanding
Abel	Encourages exploration, balances guidance and learner autonomy	Limited number of computers, large class sizes require group-sharing	Uses simulations as a core part of the lesson, emphasizes hands-on exploration	Improved conceptual grasp, active participation, peer learning	Believes in interactive learning through inquiry, values ICT simulations for making complex concepts accessible
José	Interactive and learner-centred, encourages hypothesis testing	Large classes, limited computers, ongoing need for professional development	Plans simulations for critical engagement, uses group discussions to deepen understanding	Promotes curiosity and ownership of learning, learners demonstrate conceptual clarity	Believes in IBST role and ICT simulations for time efficiency and clarity, sees PhET simulations as essential

Teacher	Classroom implementation	Challenges with ICT integration	Lesson plan integration	Learning outcomes	Teachers' beliefs
Paulo	Learner-centred, promotes collaboration and inquiry	Time management issues, unstable network, varying learner ICT skills	Central use of simulations, encourages variable testing and peer discussions	Enhances learner confidence, empowers inquiry, facilitates concept application	Strong proponent of ICT simulations and IBST, values simulations for dynamic visualization and hands-on interaction

The methodology used to analyse data gathered from all the different sources was crucial in this study to capture the multifaceted nature of science teaching in technology-enhanced learning environments. The analysis of all five teachers—Paulo, Shantel, José, António, and Abel—revealed that while they embraced the principles of IBST, their classroom practices often leaned towards traditional, teacher-directed methods. Although some teachers, such as Shantel and Paulo, integrated PhET simulations to promote learner engagement, they still relied on structured guidance that limited full learner autonomy. The data shows that teachers struggled to implement the level of learner-directed inquiry they aimed for entirely. Most lessons observed followed a teacher-led approach, with learners participating primarily in material manipulation rather than directing their inquiry despite their intentions to foster a more learner-centred environment, due to challenges such as resource limitations, time constraints, and varying readiness, which led to a predominantly teacher-guided approach to IBST.

In conclusion, the study highlights that while science teachers generally hold positive beliefs about the value of IBST and ICT simulations in enhancing learner learning, the extent to which these beliefs are realized in practice depends on various factors, including available resources, teacher and learner proficiency with technology, and institutional support. Teachers like Shantel and Paulo, who fully embraced the inquiry-based potential of simulations, demonstrated how such tools can foster deeper learner engagement and understanding. However, challenges related to ICT infrastructure and the policy-practice gap highlight the need for comprehensive support systems to ensure that all teachers can effectively integrate simulations into their teaching.

CHAPTER 9

CONCLUSION AND RECOMMENDATIONS

9.1 Introduction

This chapter concludes the exploration of science teachers' beliefs about IBST and ICT simulations, and how these beliefs shape their instructional decisions and integration of simulations in classroom practice. Grounded in constructivist theories and frameworks such as the Vickers Framework, Hew and Brush's model, and both the BIUT and Extended BIUT frameworks this chapter synthesizes key findings on the dynamic interactions between teachers' pedagogical beliefs, technological contexts, and instructional actions. Through these lenses, the study reveals that teachers' beliefs about IBST and ICT simulations are central to understanding how they did navigate complex instructional choices, often balancing constructivist intentions with pragmatic responses to infrastructural constraints.

This chapter addresses the research questions that have guided this investigation. First, it examines the beliefs that teachers hold about IBST and ICT simulations, uncovering a range of perspectives that influence how they conceptualize and use these ICT tools in science teaching. Teachers who view ICT simulations as integral to learning perceive these ICT tools as essential in making abstract or complex scientific concepts more tangible and accessible to learners. For the science teachers, who are grounded in constructivist theory, they view ICT simulations as catalysts for learner-centred inquiry and knowledge co-construction. Yet, different beliefs emerge among teachers who, due to logistical concerns or hesitations, consider ICT simulations as supplementary aids rather than primary instructional methods.

Further, the researcher will show how these beliefs translate into instructional planning and classroom implementation. For some teachers in the study, the perceived effectiveness of ICT simulations motivated their integration into inquiry-based strategies, recognizing their potential to enhance learner engagement and conceptual understanding. However, in their contexts where technological or infrastructural barriers persist, these teachers had to adapt their lesson plans, opting to use ICT simulations cautiously and only when reliable conditions are ensured. This approach demonstrated how science teachers' beliefs, contextual factors, and

practical judgments converge to shape teachers' decisions around ICT simulation use, aligning with the Vickers Framework's concept of Reality, Value, and Action Judgments.

The findings in this chapter contribute new insights by highlighting the evolving nature of science teachers' beliefs in response to their classroom realities and professional constraints. Through the Extended BIUT framework, this research shows that beliefs can change and be adjusted with time, shaped by practical teaching experiences and contextual demands. These dynamic reveals the need for professional development that reinforces teachers' constructivist ideals while addressing logistical and technical challenges, allowing for a balanced, practical application of ICT simulations in supporting IBST. This chapter, also reveals the important role of teachers' beliefs in shaping the integration of ICT simulations in science education, indicating that promoting teachers' constructivist-oriented, adaptable belief systems can improve the effectiveness of using ICT simulations. And at the end, the researcher presents recommendations aimed at supporting science teachers in harnessing the full potential of ICT simulations within IBST, advocating for a comprehensive approach that addresses infrastructural, professional, and collaborative needs to sustain effective, inquiry-driven science education.

9.2 Summary of Findings

The study revealed a spectrum of science teachers' beliefs about IBST and the integration of ICT simulations. These science teachers' beliefs, deeply rooted in their pedagogical orientations, significantly shape instructional choices or practices. Drawing on frameworks such as the Extended BIUT and the Vickers' framework (Cohen-Blankshtain et al., 2004), the research illustrated how teachers' beliefs about IBST and ICT simulations is connected with their understanding of technology's role in inquiry-based learning. Teachers with strong constructivist beliefs, such as Shantel and Paulo, demonstrated a deep integration of ICT simulations into their teaching styles or approaches in the classroom. For some teachers, ICT simulations works as "virtual laboratories," giving learners opportunities to interact, to predict, test, and analyze scientific phenomena in the classroom, supporting Vygotsky's social constructivism, which emphasizes the construction of knowledge through active engagement and social interactions.

Science teachers used ICT simulations to encourage learner-centred learning, incorporating them into lessons to stimulate exploration and critical thinking. By allowing learner independence, they take advantage of the benefits of ICT tools to develop complex, investigation-focused settings that are in line with the inquiry cycle described in models such as Chinn and Malhotra (2002) inquiry-based assessment model. Teachers' practices in the classrooms illustrated how technology can support conceptual understanding while encouraging learners to engage with scientific inquiry actively. This approach reflected high levels of BIUT framework, where the affordances of ICT simulations are fully used to achieve inquiry objectives. In contrast, teachers with more traditionalist orientations, such as Abel, view ICT simulations as supplementary tools rather than important components of teaching. Teachers with the same view, employ ICT simulations selectively, often to reinforce content rather than drive inquiry. Their cautious ICT simulation integration reflects lower confidence in technology, concerns over reliability, and adherence to teacher-centred instructional methods. The conservative approach implemented by some teachers is supported with Hew and Brush's (2007) framework, which identifies technological barriers and belief systems as critical factors limiting ICT simulations adoption. These teachers with traditional views prefer a structured, predictable lesson formats, using ICT simulations just to visualize scientific concepts rather than to facilitate open-ended exploration, highlighting how traditional beliefs can limit the depth and frequency of ICT integration, underscoring the need for targeted professional development to broaden these teachers' perceptions of ICT's potential for inquiry-based teaching.

Beliefs about the role of ICT simulations in achieving IBST objectives strongly influence lesson planning. Teachers with constructivist orientations, such as Shantel, usually structured their lessons to use ICT simulations as important tools for critical thinking and collaborative exploration. Their lesson planning often integrates inquiry-based teaching cycles, as described by Bybee's 5E Model (Engage, Explore, Explain, Elaborate, Evaluate), allowing learners to actively investigate and construct knowledge. ICT simulations are used as main tools to these processes, enabling learners to manipulate variables, test hypotheses, and engage in reflective analysis.

This ICT simulation integration reflected the alignment of teachers' beliefs with constructivist learning theory. These teachers conceptualize ICT simulations as more than a content delivery tool; instead, they see it as a dynamic platform for fostering inquiry and

enabling deep learning. By embedding ICT simulations into IBST frameworks, constructivist teachers ensure that their curriculum aligns with the epistemological underpinnings of inquiry science, where learners learn by doing the tasks and reflecting. Teachers who adopt this perspective demonstrate an advanced understanding of the interplay between technology, content, and pedagogy, illustrating how the alignment of these domains fosters a richer, more engaging learning environment. The findings suggest that professional development focusing on the integration of TCK with constructivist strategies could empower more teachers to use ICT simulations as catalysts for inquiry and deep learning. Teachers who adopt this perspective demonstrate an advanced understanding of the connection between technology, content, and pedagogy, illustrating how the alignment of these domains fosters a richer, more engaging learning environment. The findings suggested that professional development focusing on the integration of technology with constructivist strategies could empower more teachers to use ICT simulations as catalysts for inquiry and deep learning

Teachers who are more conservative or hold traditional beliefs when they set up their lesson plans ICT simulations, usually play a secondary role, reserved for specific, predictable instructional contexts. This reflects a Reality Judgment, as described in the Vickers Framework, where logistical and infrastructural constraints heavily influence decision-making. For these teachers, simulations supplement traditional instructional methods, such as lectures or textbook-based teaching, rather than forming the core of inquiry-driven activities. Their curriculum designs align more closely with teacher-centred pedagogies, where ICT simulations are used sporadically to clarify content rather than to facilitate active exploration. This selective integration only shows the importance of addressing belief-based barriers through professional development that highlights the versatility and inquiry-aligned potential of simulations.

The study identified a distinct divergence in how science teachers incorporate ICT simulations into assessment practices, shaped by their beliefs about inquiry and evaluation. Teachers with constructivist views, use ICT simulations as formative assessment tools, aligning their teaching practices with IBST approach. These teachers set up assessments within the ICT simulation activities, allowing learners to demonstrate inquiry skills such as hypothesis testing, data analysis, and critical thinking. For example, ICT simulations are used to create iterative feedback loops, enabling real-time adjustments to instruction based on learner performance.

Teachers, with more traditional views, on the other hand, rely more heavily on static assessments, such as tests and observational methods, to measure content mastery. Their use of ICT simulations focuses on visualizing concepts to reinforce understanding, rather than assessing inquiry skills. This approach supports the traditional assessment paradigms, where the emphasis is placed on results rather than processes. The gap between these approaches highlights the need for professional development programs for the teachers that emphasize the use of ICT simulations for formative assessment. Training could focus on helping traditionalist teachers integrate simulation-based assessments that align with IBST principles, fostering a more holistic evaluation of learner learning.

A significant finding of the study is the role of adaptability in ICT simulation integration. Teachers with flexible, constructivist beliefs demonstrate a higher degree of resilience in managing infrastructural challenges, finding innovative ways to use ICT simulations even in resource-constrained settings. These teachers exhibit context-responsive adaptability, a concept rooted in Fullan's (2013), which emphasizes the importance of flexible leadership and teacher agency in addressing systemic challenges. For example, they adapt ICT simulations to function offline or change their instructional strategies to go along with available resources, ensuring that inquiry-based teaching continues despite limitations. Teachers adaptability reflects a high level of the ability to integrate ICT tools in a creative ways within diverse contexts. Training programs that focus on risk management, technical problem-solving, and context-specific adaptation can empower teachers to overcome barriers and maintain instructional integrity.

In contrast, traditionalist teachers exhibited lower adaptability, avoiding the use of ICT simulations in unpredictable or resource-limited scenarios. Their practices align with Value Judgments, as described in the Vickers Framework, where concerns about reliability and control outweigh the perceived benefits of ICT simulation integration. This teacher's behaviours highlights the need for targeted interventions that build confidence and equip science teachers with strategies for managing the uncertainties associated with technology use. By fostering adaptability and resilience, professional development can help teachers navigate challenges and leverage ICT simulations more effectively across diverse instructional scenarios.

9.3 Research Questions Answered

This research delved into the intricate interplay between science teachers' beliefs about IBST and ICT simulations, their teaching practices, and the systemic contexts within which they operate. Drawing on theoretical frameworks and employing a robust qualitative methodology, the study provides a comprehensive analysis of how these beliefs influence planning, implementation, and the extent to which simulations are utilized in science education. The findings underscore the complexity of integrating ICT simulations and IBST, highlighting opportunities for transformation and persistent challenges that demand systemic and pedagogical attention.

The study's theoretical foundation, grounded in constructivist paradigms, emphasizes the role of learners as active participants in constructing knowledge through inquiry and interaction. Vygotsky's social constructivism highlighted how teachers with constructivist beliefs perceive simulations as tools for scaffolding inquiry, enabling learners to engage critically with scientific concepts. Piaget's cognitive constructivism provided insight into how teachers view simulations as facilitating learners' cognitive development by making abstract ideas tangible and accessible through hands-on exploration. These frameworks were complemented by the Vickers Framework, which analyzed teachers' Reality Judgments (practical barriers like limited ICT access), Value Judgments (beliefs about the importance of IBST and ICT simulations), and Action Judgments (choices made in classroom practices). This lens illuminated how these beliefs are both shaped by and responsive to systemic and contextual factors, such as resource availability, professional development, and institutional culture.

The Hew and Brush Framework further contextualized the barriers to ICT simulation integration, distinguishing between internal challenges (e.g., teachers' lack of confidence in using technology) and external factors (e.g., infrastructure deficits). These barriers were especially relevant in understanding how traditionalist teachers, who prioritize content delivery and teacher control, perceive simulations as supplementary tools rather than transformative ones. The Extended BIUT Framework, which incorporated systemic factors like policy alignment and institutional support, provided an overarching model to understand how external conditions mediate the relationship between beliefs and practices.

A qualitative research design aligned with the interpretivist paradigm allowed for an in-depth exploration of teachers' beliefs and practices. The study used semi-structured interviews to capture the cognitive and affective dimensions of teachers' beliefs about IBST and ICT simulations, exploring their philosophical orientations and experiences. Classroom observations provided critical insights into how these beliefs translated into real-world teaching, revealing consistencies and tensions between planning and implementation. Document analysis, including lesson plans and curriculum materials, offered a triangulated perspective on how beliefs were articulated and operationalized. The qualitative approach ensured a nuanced understanding of the relationship between beliefs, practices, and systemic constraints. The conclusions presented in this section are based on the discussions in previous chapters. The discussions focussed on the multiple-case approach findings and results and were centred around the three research questions:

Research Question 1

What are science teachers' beliefs about IBST and ICT simulations?

Table 9.1 provides a concise overview of each teacher's beliefs about Inquiry-Based Science Teaching (IBST) and the use of ICT simulations. It highlights their epistemological orientations and how these beliefs shaped their perspectives on teaching and technology integration.

Table 9.1

Teachers' IBST and ICT Beliefs

Teachers	IBST Belief	ICT Belief
António	Strongly rooted in constructivist principles; emphasizes exploration and learner autonomy.	Believes ICT simulations can enhance inquiry but is cautious due to systemic barriers and limited resources.
Shantel	Supports guided inquiry and collaborative learning; emphasized structured exploration.	Views ICT simulations as a tool to make lessons interactive but faces challenges like unreliable access.
Abel	Balanced traditional and constructivist approaches; he was hesitant to fully embrace open inquiry.	Uses ICT simulations minimally; lacks confidence in integrating ICT simulations effectively.
José	Advocated for open inquiry, promoted critical thinking and experimentation.	Sees ICT simulations as transformative but is constrained by lack of infrastructure and training.

Paulo	Encouraged learner-driven exploration through IBST; incorporated group discussions effectively.	Innovates with ICT tools, integrated them deeply into lessons despite resource limitations.
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Summary: Teachers’ beliefs about IBST range from strongly constructivist to hybrid approaches, shaped by personal pedagogical orientations and systemic factors. Similarly, ICT simulations beliefs vary, with some science teachers seeing its potential for transforming inquiry while others use it cautiously due to barriers like resources and confidence.

Teachers’ beliefs about IBST and ICT simulations emerged as a spectrum ranging from constructivist to traditionalist orientations. Constructivist teachers viewed IBST as a transformative pedagogical framework that emphasizes learner autonomy, critical thinking, and real-world problem-solving. They saw ICT simulations as aligned with these principles, enabling inquiry-driven learning and the visualization of abstract scientific phenomena. For these teachers, simulations were integral to creating dynamic, learner-centred learning environments. However, traditionalist teachers, who prioritize teacher-led instruction and structured learning environments, often perceived simulations as supplementary tools. This divergence highlights the significant role of educational philosophies in shaping attitudes toward IBST and ICT simulations. Across both groups, systemic barriers such as resource limitations, curriculum rigidity, and lack of professional development influenced how these beliefs were enacted.

Science teachers’ beliefs about IBST and ICT simulations reflect a dichotomy between constructivist orientations, which prioritize inquiry, autonomy, and critical thinking, and traditionalist perspectives, which emphasize teacher-led instruction and structured learning. These beliefs are shaped by personal experiences, systemic barriers, and professional development opportunities.

Research Question 2

How do science teachers' beliefs about IBST and ICT simulations relate to their planned and implemented teaching using simulations?

Table 9.2 outlined how teachers' beliefs about IBST and ICT simulations relate to their planned and teaching practices. It compared the intentions behind their lesson plans with their implementations in the classrooms, showing the influence of both their beliefs and contextual constraints.

Table 9.2

Relationship Between Beliefs and Teaching Using Simulations

Teacher	Planned Teaching	Implemented Teaching
António	Planned simulations as supplementary tools to foster concept clarity and inquiry.	Implemented ICT simulations cautiously, adapting to resource constraints and focusing on key concepts.
Shantel	Designed structured ICT simulation activities to support collaborative inquiry.	Incorporated ICT simulations selectively, often emphasizing collaboration over independent inquiry.
Abel	Integrated ICT simulations in teacher-led demonstrations to reinforce traditional teaching.	Relied heavily on direct instruction, using ICT simulations sparingly due to limited confidence.
José	Developed open-ended ICT simulation tasks to encourage critical thinking and experimentation.	Struggled to fully implement plans due to technical and systemic barriers.
Paulo	Planned extensive use of ICT simulations to enable hands-on exploration and learner-led activities.	Effectively integrated ICT simulations, aligning them with inquiry objectives despite some challenges.

Summary: Teachers' planned and implemented use of ICT simulations often diverges due to systemic and contextual barriers. While plans tend to align with inquiry-based ideals, implementation is frequently adjusted to address resource and confidence limitations.

The study revealed a dynamic relationship between teachers' beliefs and their planned and implemented teaching practices. Teachers with constructivist beliefs demonstrated alignment between their planning and classroom practices, integrating simulations as core tools for guided or open inquiry. These teachers designed lessons that emphasized learner exploration, hypothesis testing, and critical engagement with scientific concepts. In contrast, traditionalist teachers

exhibited a disconnect, often planning to use simulations but implementing them minimally or in structured, teacher-directed ways. Confidence in technology emerged as a critical mediator; teachers with high confidence effectively incorporated simulations into their plans and practices, while those with low confidence avoided or limited their use. Systemic factors, including curriculum demands and resource availability, further constrained the translation of beliefs into practice, particularly for teachers operating in under-resourced contexts.

Teachers' beliefs significantly influence their planning and implementation of teaching practices. Constructivist beliefs drive inquiry-driven planning and dynamic implementation, while traditionalist beliefs result in structured, teacher-centred approaches. Confidence in technology and systemic constraints mediate the relationship between beliefs and practices.

Table 9.3 examined the extent to which teachers' beliefs about IBST and ICT simulations influence their use of ICT simulations in classroom teaching. It emphasizes how their pedagogical orientations translated into practical application, considering factors like confidence, systemic challenges, and resources.

Table 9.3

Influence of Beliefs on Use of ICT Simulations in Teaching

Teacher	Extent of Influence
António	Beliefs moderately influenced his use, driving thoughtful integration but constrained by systemic and contextual challenges.
Shantel	Beliefs significantly shaped her ICT simulations use, prioritizing structured and collaboration but limited by infrastructure issues.
Abel	Limited influence; traditional beliefs dominate, leading to minimal and cautious use of ICT simulations.
José	Beliefs strongly influenced intent of use ICT simulations but practical application is hindered by external barriers.
Paulo	Highly influenced; constructivist beliefs drive consistent and innovative ICT simulation integration.

Summary: The extent to which teachers' beliefs about IBST and ICT simulations shaped their ICT simulation use varies widely. Constructivist beliefs generally correlate with higher ICT simulation integration levels, but systemic barriers often temper the practical integration of these beliefs.

Research Question 3

Why do science teachers' beliefs about the use of ICT simulations as a form of IBST influence their teaching in the manner that they do?

The extent to which teachers' beliefs about IBST and ICT simulations influenced their use of simulations was shaped by the convergence of pedagogical philosophies, technological competence, and systemic conditions. Constructivist beliefs promoted the comprehensive use of simulations as central tools for fostering inquiry and critical thinking. These teachers leveraged simulations to create dynamic, interactive learning environments that aligned with IBST principles. Conversely, traditionalist beliefs constrained simulation use, relegating them to illustrative roles that reinforced content rather than fostering inquiry. The Hew and Brush Framework highlighted how systemic barriers, such as inadequate infrastructure and curriculum rigidity, exacerbated these differences, while the Extended BIUT Framework emphasized the importance of institutional support in enabling meaningful simulation use.

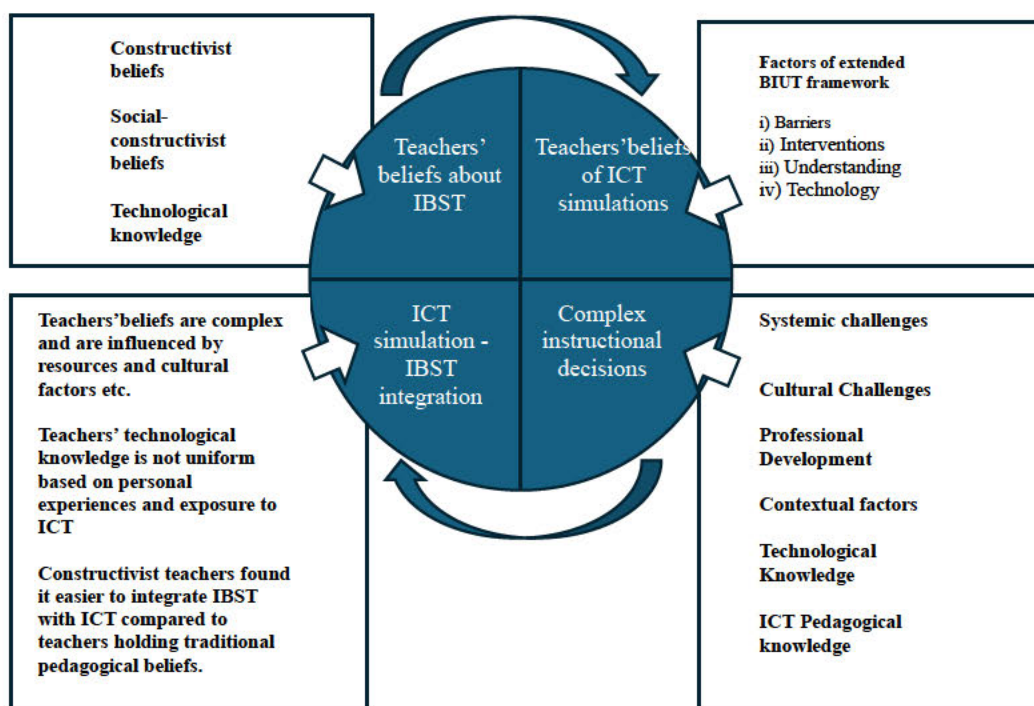
The findings underscore the need for targeted interventions to bridge the gap between teachers' beliefs and classroom practices. Professional development must be tailored to address both pedagogical and technological dimensions, building teachers' confidence in using ICT simulations and aligning their beliefs with IBST principles. Investments in ICT infrastructure and curriculum flexibility are essential to create environments where simulations can be effectively integrated into science teaching. Institutional support, including leadership that prioritizes inquiry-based learning and provides access to resources, is critical to fostering the sustained adoption of simulations. Finally, culturally responsive approaches are necessary to address contextual factors, such as standardized testing and cultural attitudes toward teacher control, which influence how simulations are perceived and utilized.

The extent to which teachers' beliefs about IBST and ICT simulations influence simulation use is determined by the alignment between constructivist ideals and systemic realities. Constructivist beliefs promote the comprehensive use of simulations, while traditionalist beliefs constrain their integration. Addressing systemic barriers, enhancing professional development, and fostering institutional support are critical for translating positive beliefs into effective practices.

Science teachers' beliefs about IBST and ICT simulations profoundly shape their use of simulations in teaching. Constructivist beliefs foster the adoption of simulations as central tools for inquiry, while traditional beliefs constrain their integration. The extent of influence is mediated by factors such as technological confidence, professional development, and systemic support. Bridging the gap between positive beliefs and effective practices requires a multifaceted approach, aligning teacher training, institutional resources, and policy frameworks to foster meaningful, inquiry-driven use of simulations in science education.

Figure 9.1

The complexity of science teachers' beliefs about IBST and ICT simulations shaping their instructional decisions in classroom practice



The conclusion of the study captures the profound and multifaceted relationship between science teachers' beliefs, their instructional practices, and the integration of Inquiry-Based Science Teaching (IBST) and ICT simulations in the classroom.

The conclusion of the study captured the relationship between science teachers' beliefs, their instructional practices, and the integration of ICT simulations and IBST in the classroom. The findings highlighted the importance of teachers' epistemological and pedagogical beliefs in shaping their decisions, particularly as these beliefs acted as both enablers and barriers to adopting innovative teaching methodologies. Constructivist and social-constructivist beliefs are emphasized as crucial in harmonizing teaching practices with inquiry-based pedagogies, enabling science teachers to view ICT simulations not merely as an extra pedagogical tool but as a transformative medium that fosters collaboration, critical thinking, and learner autonomy. However, the **complexity of teachers' beliefs** lies in their dynamism, deeply influenced by their personal experiences, cultural contexts, and systemic constraints, which collectively plays a big role on the extent to which ICT and IBST can be effectively integrated in the classrooms.

The **Extended BIUT Framework** revealed this complexity through a multidimensional lens. Teachers' beliefs about ICT simulations and IBST must navigate some intrinsic barriers, such as limited digital confidence or resistance to pedagogical change, and extrinsic barriers, including inadequate infrastructure, curriculum rigidity, and insufficient professional development. The influence of these factors demands interventions that are not only technical but also deeply reflective, targeting the transformation of teachers' mindsets. The frameworks used in this research underscored the need for systemic changes that address contextual realities, including policy alignment, equitable access to technology, and culturally relevant training programs. Additionally, the frameworks also focused on understanding and technology highlights the feedback loop between teachers' evolving instructional practices and their belief systems, where successful integration of ICT simulations fosters greater confidence and openness toward IBST.

The study also found out that addressing the complexity of science teachers' beliefs requires a paradigm shift in teacher education and systemic support. Professional development programs must transcend skill-building to foster critical reflection on beliefs, aligning teacher training with inquiry-based curricula, and provide sustained mentorship for navigating challenges. Moreover, systemic reforms must prioritize infrastructure development, policy flexibility, and institutional support to bridge the gap between aspirational curricula goals and classroom realities. The findings highlighted that without a holistic approach that integrates

belief transformation, technological fluency, and contextual adaptation the goal of IBST and ICT simulations in transforming science education will remain unfulfilled. This complexity, while challenging, also offers an opportunity to redefine science education as a dynamic, inquiry-driven, and technology-enhanced field that equips learners to meet the demands of the 21st century.

Figure 9.1 revealed that the integration of ICT simulations into IBST is a complex, multi-layered process where teachers' beliefs, knowledge, systemic challenges, and instructional decisions are deeply interconnected. Teachers' beliefs about IBST and ICT simulations provided the foundation, while technological knowledge and the BIUT framework mediate the process. Systemic challenges and professional development act as external forces that either support or hinder ICT simulation integration. Ultimately, the effective implementation of ICT simulations as a form of IBST implementation depends on aligning all these key elements to create a cohesive, inquiry-driven learning environment.

9.4 Contributions of this Research

This research contributes to the field of science education by providing a nuanced understanding of how science teachers' beliefs about IBST and ICT simulations influence pedagogical practices, particularly in resource-constrained environments. It advances theoretical, practical, and contextual insights into the integration of technology-enhanced inquiry-based learning in science classrooms.

9.4.1 Theoretical Contributions

The study extends the theoretical frameworks linking teachers' pedagogical and epistemic beliefs to instructional practices. It highlights the interplay between constructivist and traditional beliefs, demonstrating how these orientations shape teachers' acceptance and implementation of IBST and ICT simulations. By employing frameworks such as the Hew and Brush model and the Vickers Framework for understanding teacher beliefs, the research enriches our understanding of belief-driven decision-making in educational technology adoption. The emphasis on the relationship between intrinsic (beliefs) and extrinsic (systemic barriers) factors offers a comprehensive model for understanding ICT integration challenges.

9.4.2 *Practical Contributions*

The findings underscore the transformative potential of ICT simulations in fostering inquiry-based learning, particularly in promoting critical thinking, problem-solving, and conceptual understanding among learners. However, the study also identifies key barriers, including limited access to technology, insufficient professional development, and entrenched traditional beliefs. The research provides actionable recommendations for designing professional development programs that not only enhance teachers' technological and pedagogical skills but also address their beliefs about inquiry-based approaches. These insights are crucial for curriculum developers, policymakers, and teacher training institutions aiming to align teaching practices with 21st-century educational goals.

9.4.3 *Contextual Contributions*

By focusing on Mozambican science teachers, this research sheds light on the unique challenges and opportunities of implementing IBST and ICT simulations in developing countries. It highlights how systemic constraints such as resource disparities, curriculum rigidity, and infrastructural limitations impact teachers' instructional decisions. The study's context-sensitive approach contributes to the global discourse on educational equity and innovation, emphasizing the importance of tailoring interventions to local needs and realities.

9.4.4 *Methodological Contributions*

The research employs a robust qualitative methodology, integrating interviews, classroom observations, and document analysis through a crystallization strategy. This methodological rigor provides a holistic view of the factors influencing teachers' beliefs and practices, setting a precedent for future studies exploring similar themes. The focus on teacher narratives and real-world classroom practices adds depth to the analysis, bridging the gap between theoretical ideals and practical realities.

9.4.5 *Policy and Systemic Contributions*

The study highlights the critical role of institutional and systemic support in enabling the effective integration of ICT simulations into IBST. It calls for policies that prioritize investment

in technological infrastructure, teacher training, and supportive leadership to create an ecosystem conducive to inquiry-based science education. These recommendations have the potential to inform national and international strategies for enhancing Science, Technology, Engineering and Maths (STEM) education in resource-limited settings.

9.4.6 *Contribution to Literature*

This research addresses a significant gap in the literature on the intersection of ICT, IBST, and teacher beliefs, particularly in the context of developing countries. By focusing on ICT simulations a relatively underexplored area it provides fresh insights into their pedagogical value and the conditions necessary for their successful integration. The study adds to the growing body of knowledge advocating for inquiry-driven, technology-enhanced science education while offering practical pathways for overcoming implementation barriers.

9.5 Limitations

This research provides valuable insights into science teachers' beliefs about IBST and ICT simulations. However, several limitations highlight the constraints of its scope, methodology, and contextual applicability, offering avenues for future research and refinement.

The study's focus on Mozambican science teachers provides in-depth, contextualized insights but limits the generalizability of its findings. Variations in cultural norms, policy frameworks, and technological infrastructure across regions mean that teacher beliefs and practices identified here may not directly translate to other educational systems. This specificity, while valuable, highlights the need for comparative studies in diverse cultural and systemic contexts to understand broader trends and variations in teacher beliefs about IBST and ICT simulation integration.

Employing a qualitative methodology allowed for a nuanced understanding of teachers' beliefs and practices, but it inherently restricted the ability to quantify findings or establish statistical significance. The reliance on interviews, classroom observations, and document analysis, while providing depth, introduces potential researcher bias during data interpretation. The relatively small sample size, though methodologically justified for in-depth qualitative

research, may not fully represent the diversity of teacher experiences in Mozambique, thus constraining the breadth of the study's conclusions.

The reliance on self-reported data from teacher interviews introduces the possibility of social desirability bias, where participants may provide responses they believe align with the study's goals or portray them in a favourable light. This could result in an overrepresentation of positive attitudes toward IBST and ICT simulations, potentially obscuring underlying resistance, skepticism, or practical challenges. Triangulating these findings with alternative data sources, such as learner feedback or peer evaluations, could provide a more balanced perspective.

The systemic issues identified in the study, including limited access to technology and inadequate professional development, may have influenced the research process itself. Challenges such as insufficient ICT resources or infrastructural inconsistencies could have impacted classroom observations or constrained the availability of training programs for participating teachers. Addressing these resource limitations in future studies could enhance data collection and analysis.

The study captures teacher beliefs and practices at a specific point in time, providing a snapshot of the interplay between IBST and ICT simulation integration. However, beliefs and practices are inherently dynamic, shaped by ongoing professional development, curriculum changes, and advancements in technology. A longitudinal research design could offer a more comprehensive understanding of how these factors evolve over time and provide insights into the long-term impacts of interventions aimed at enhancing IBST and ICT simulation integration.

While the emphasis on ICT simulations provides valuable insights, it narrows the applicability of the findings to broader technology integration in science education. Teachers' experiences with other ICT tools, such as collaborative platforms, data analysis software, or virtual labs, may differ significantly, limiting the study's relevance to educational contexts that prioritize other forms of technology. Expanding the scope to include a broader range of ICT tools could provide a more holistic understanding of technology integration.

Although the study identifies systemic barriers such as curriculum rigidity, time constraints, and resource limitations, it does not explore these issues in depth. A more detailed

analysis of policy frameworks and institutional support systems could yield actionable recommendations for overcoming these challenges at a systemic level. Examining how policies influence teacher beliefs and practices would provide valuable insights for stakeholders aiming to foster inquiry-driven, technology-enhanced education.

While the research focuses on teachers' beliefs and practices, it does not extensively examine learner outcomes associated with IBST and ICT simulations. Understanding how these teaching approaches impact learner engagement, critical thinking, and scientific understanding could validate the study's findings and strengthen its practical implications. Future studies should prioritize learner-centric data to complement teacher-focused analyses.

The study was conducted during and shortly after the COVID-19 pandemic, the research may reflect atypical teaching environments influenced by disruptions and an increased reliance on virtual learning tools. These circumstances could have shaped teacher beliefs and practices in ways that differ from typical classroom settings. Acknowledging this limitation emphasizes the need for follow-up studies in post-pandemic contexts to assess the persistence of observed trends.

While these limitations contextualize the findings and underscore the study's constraints, they also highlight critical areas for future research. Mixed-method approaches that incorporate quantitative data, expanded geographic and demographic scopes, and longitudinal designs could address these gaps and enhance the generalizability of findings. Exploring the long-term impacts of IBST and ICT simulation integration, along with systemic and learner-centred perspectives, will further validate and extend this research. Despite these constraints, this study offers critical insights into the relationship between teacher beliefs, inquiry-based pedagogy, and technology integration, laying the foundation for more inclusive and effective science education practices.

9.6 Recommendations

Structured and sustained professional development programs are critical for empowering teachers to integrate ICT simulations within IBST effectively. These programs should focus on building both technological competence and pedagogical confidence, particularly for teachers transitioning from traditional to constructivist approaches. Practical, hands-on workshops should enable teachers to design and implement lesson plans incorporating simulations, while ongoing mentorship and peer collaboration provide continuous support. By addressing traditional beliefs and fostering a shift toward inquiry-based, learner-centred teaching, professional development can ensure lasting changes in teaching practices.

Resource allocation and technological infrastructure must be prioritized to address the systemic barriers identified in this research. Investments in hardware, software, and reliable internet access are necessary, particularly in underserved regions. To overcome connectivity issues, schools should adopt offline-compatible simulation tools that allow teachers and learners to engage in technology-enhanced learning regardless of location. Equipping classrooms with the necessary tools creates an enabling environment for integrating IBST and ICT simulations, fostering equity in science education.

Policy reforms and institutional support are essential for embedding IBST and ICT simulations into mainstream education. Science curricula should be revised to explicitly include IBST principles and activities that leverage simulations, reducing curriculum rigidity and allowing teachers the flexibility to adopt inquiry-based methods. School leadership plays a pivotal role in creating a culture that values innovation, supporting teachers in transitioning to technology-enhanced, inquiry-driven practices. Leadership involvement also ensures alignment between policy goals and classroom realities.

Collaboration and peer learning networks can mitigate teacher isolation and promote the sharing of best practices. Establishing communities of practice enables teachers to exchange strategies and resources for integrating IBST and ICT simulations. Interdisciplinary collaboration across science subjects can further enrich teaching approaches, while cross-school partnerships can facilitate resource sharing, particularly in resource-constrained environments. Such

collaborative efforts build collective capacity and foster a shared commitment to inquiry-driven, technology-enhanced education.

Systemic challenges must be addressed to ensure the seamless integration of IBST and ICT simulations. Sufficient time should be allocated for teachers to plan, implement, and reflect on inquiry-based lessons. Administrative support is needed to manage large class sizes and provide equitable access to ICT tools, ensuring all learners benefit from these innovations. Aligning assessment practices with IBST principles, de-emphasizing rote memorization, and promoting critical thinking will reinforce the adoption of inquiry-based teaching.

To enhance learner engagement and outcomes, simulation-based activities should be designed to reflect real-world scientific challenges, making them relevant and engaging for learners. Active learner participation in inquiry-based activities should be encouraged to develop critical thinking, collaboration, and problem-solving skills. Incorporating learner feedback into the design of IBST activities ensures alignment with their needs, fostering a more inclusive and effective learning environment.

Finally, the study highlights the importance of further research to support the sustainable integration of IBST and ICT simulations. Longitudinal studies can track the long-term impact of these tools on teaching practices and learner outcomes. Exploring cultural and contextual factors that influence teacher beliefs and ICT adoption can guide tailored interventions. Developing scalable models for integrating IBST and ICT simulations in resource-constrained settings is essential for addressing disparities and expanding access to quality science education.

The successful implementation of these recommendations requires collaboration among policymakers, teachers, researchers, and institutions. By addressing both intrinsic factors, such as teachers' beliefs, and extrinsic barriers, such as resource and policy constraints, these strategies can create a supportive environment for integrating IBST and ICT simulations. This transformation will empower teachers to adopt innovative practices, enhance learner learning, and ensure science education meets the dynamic needs of the 21st century.

9.7 Concluding Remarks

This research offers a critical exploration of the complex interplay between science teachers' beliefs, IBST, and the use of ICT simulations in science education. It provides valuable insights into how intrinsic factors, such as pedagogical beliefs, and extrinsic factors, such as systemic barriers, shape teachers' practices and their willingness to adopt innovative teaching strategies.

The study underscores the transformative potential of IBST and ICT simulations in enhancing learner engagement, inquiry skills, and conceptual understanding. Teachers with constructivist beliefs demonstrate greater alignment with IBST principles, integrating ICT simulations to promote learner-centred, inquiry-driven education. However, the study also reveals that traditional beliefs, coupled with systemic challenges such as limited resources, insufficient training, and rigid curricula, hinder the broader adoption of these approaches.

A key conclusion of this research is the critical role of professional development in bridging the gap between teacher beliefs and effective practice. By addressing entrenched traditional beliefs, building technological and pedagogical confidence, and fostering collaborative professional networks, targeted training can empower teachers to integrate ICT simulations more effectively into their inquiry-based teaching strategies.

The research also highlights the importance of systemic reforms, including improved technological infrastructure, flexible curricula, and supportive institutional policies, to enable the successful integration of ICT-enhanced inquiry-based teaching. Without addressing these systemic constraints, even the most innovative teaching strategies may fail to achieve their intended impact.

Furthermore, this study contributes to the global discourse on educational innovation, particularly in resource-constrained contexts like Mozambique. By examining the intersection of IBST, ICT, and teacher beliefs, it provides actionable insights for teachers, policymakers, and researchers seeking to foster equitable, technology-driven science education.

In conclusion, this research emphasizes that transforming science education to meet the demands of the 21st century requires a holistic approach. It calls for a concerted effort to align

teacher beliefs, professional development, and systemic support, thereby creating an ecosystem that empowers teachers to embrace inquiry-based, technology-enhanced pedagogies. The findings of this study not only bridge significant gaps in the literature but also lay the groundwork for future research and interventions aimed at fostering inclusive and effective science education worldwide.

9.8 Personal Reflection

Conducting this research has been a deeply enriching and transformative journey, both professionally and personally. Exploring the interplay between science teachers' beliefs, IBST, and ICT simulations has not only broadened my understanding of educational innovation but also allowed me to confront and challenge my own assumptions about teaching and learning in science education.

This study illuminated the profound impact of teacher beliefs on instructional practices. As an teacher, I have witnessed firsthand the challenges teachers face in balancing traditional pedagogical approaches with the demands of 21st-century education. Through this research, I have gained a deeper appreciation for the complexities of integrating ICT simulations into inquiry-based teaching, particularly in resource-constrained environments. The narratives and experiences shared by the participating teachers have reinforced the idea that meaningful educational change requires both systemic support and a shift in intrinsic beliefs.

One of the most impactful aspects of this journey has been engaging with the lived realities of Mozambican science teachers. Their stories highlighted the resilience and creativity they bring to their classrooms, often in the face of significant resource and systemic constraints. Their commitment to fostering inquiry and embracing technology, even amidst challenges, has been both humbling and inspiring. From a methodological perspective, this research has deepened my understanding of the value of qualitative inquiry. The process of conducting interviews, observing classrooms, and analyzing teacher practices provided a holistic lens through which to understand the interplay between beliefs, practices, and systemic factors. It also underscored the importance of reflexivity in research remaining mindful of my own biases and assumptions while interpreting the data.

On a personal level, this research journey has strengthened my resolve to advocate for equitable, technology-enhanced science education. It has reinforced my belief in the transformative potential of professional development as a tool to empower teachers and bridge the gap between aspirations and practice. Moreover, it has highlighted the need for sustained collaboration among teachers, policymakers, and researchers to create environments where inquiry-based, technology-driven education can thrive.

In conclusion, this research has not only contributed to the academic discourse but has also profoundly shaped my professional identity and commitment to educational innovation. It is my hope that the insights from this study will inspire meaningful changes in science education, particularly in contexts where resources are limited but the potential for impact is boundless. This journey has been a testament to the power of education as a catalyst for personal and societal transformation.

References

- Abbitt, J. T. (2011). An Investigation of the Relationship between Self-Efficacy Beliefs about Technology Integration and Technological Pedagogical Content Knowledge (TPACK) among Preservice Teachers. *Journal of Digital Learning in Teacher Education*, 27(4), 134-143.
<https://doi.org/10.1080/21532974.2011.10784670>
- Ainley, M., & Ainley, J. (2019). Motivation and learning: Measures and methods.
<https://doi.org/10.1017/9781316823279.028>
- Al Husaeni, D. N., & Rahmat, M. (2023). Computational Bibliometric Analysis: Can Digital Transformation Improve the Quality of Islamic Learning? *ASEAN Journal of Religion, Education, and Society*, 2(2), 123-138.
- Alake-Tuenter, E., Biemans, H. J., Tobi, H., Wals, A. E., Oosterheert, I., & Mulder, M. (2012). Inquiry-based science education competencies of primary school teachers: A literature study and critical review of the American National Science Education Standards. *International Journal of Science Education*, 34(17), 2609-2640.
<https://doi.org/https://doi.org/10.1080/09500693.2012.669076>
- Albugarni, S., & Ahmed, V. (2015). Success factors for ICT implementation in Saudi secondary schools: From the perspective of ICT directors, head teachers, teachers and students. *International Journal of Education and Development using Information and Communication Technology*, 11(1), 36-54.
<https://ukzn.idm.oclc.org/login?url=https://www.proquest.com/scholarly-journals/success-factors-ict-implementation-saudi/docview/1681507463/se-2?accountid=158225>
- Alshenqeeti, H. (2014). Interviewing as a data collection method: A critical review. *English linguistics research*, 3(1), 39-45. <https://doi.org/10.5430/elr.v3n1p39>
- Altinsoy, E., & Zuhail, O. (2017). The impact of contextual factors on English language teachers' beliefs. *Journal of Language and Linguistic Studies*, 13(2), 53-70.
<https://dergipark.org.tr/en/download/article-file/440754>
- Amineh, R. J., & Asl, H. D. (2015). Review of constructivism and social constructivism. *Journal of Social Sciences, Literature and Languages*, 1(1), 9-16.
- Ananiadou, K., & Claro, M. (2009). 21st Century Skills and Competences for New Millennium Learners in OECD Countries. <https://doi.org/https://doi.org/10.1787/218525261154>
- Anderson, R. D. (2007). Inquiry as an organizing theme for science curricula. *Handbook of research on science education*, 807-830.
- Anderson, R. D. (2013). Inquiry as an organizing theme for science curricula. In *Handbook of research on science education* (pp. 807-830). Routledge.
- Antoninis, M., Alcott, B., Al Hadheri, S., April, D., Fouad Barakat, B., Barrios Rivera, M., Baskakova, Y., Barry, M., Bekkouche, Y., & Caro Vasquez, D. (2023). Global Education Monitoring Report 2023: Technology in education: A tool on whose terms? <https://doi.org/10.54676/UZQV8501>
- Apostolou, A., & Koulaidis, V. (2010). Epistemology and science education: a study of epistemological views of teachers. *Research in Science & Technological Education*, 28(2), 149-166.
- Areepattamannil, S. (2012). Effects of inquiry-based science instruction on science achievement and interest in science: Evidence from Qatar. *The journal of Educational Research*, 105(2), 134-146.

- Areepattamannil, S., Cairns, D., & Dickson, M. (2020). Teacher-directed versus inquiry-based science instruction: Investigating links to adolescent students' science dispositions across 66 countries. *Journal of Science Teacher Education*, 31(6), 675-704.
<https://doi.org/10.1080/1046560X.2020.1753309>
- Atman-Uslua, N. (2022). Exploring Pre-service Teachers' Perception Regarding Factors in Technology Integration with Q Methodology. *Bartın Üniversitesi Eğitim Fakültesi Dergisi*, 11(3), 543-558.
<https://doi.org/10.14686/buefad.1001562>
- Bandura, A. (1997). Self Efficacy. The Exercise of Control, New York: W H. *Freeman & Co. Student Success*, 333, 484-61. <https://doi.org/10.1891/0889-8391.13.2.158>
- Barzilai, S., & Chinn, C. A. (2017). On the goals of epistemic education: Promoting apt epistemic performance. *Journal of the Learning Sciences*.
<https://doi.org/https://doi.org/10.1080/10508406.2017.1392968>
- Baxter, P., & Jack, S. (2008). Qualitative case study methodology: Study design and implementation for novice researchers. *The qualitative report*, 13(4), 544-559.
- Baylor, A. L., & Ritchie, D. (2002). What factors facilitate teacher skill, teacher morale, and perceived student learning in technology-using classrooms? *Computers & Education*, 39(4), 395-414.
- Becker, H. J. (2000). Findings from the teaching, learning, and computing survey. *Education policy analysis archives*, 8, 51.
- Becker, H. J., & Riel, M. M. (2000). Teacher Professional Engagement and Constructivist-Compatible Computer Use. Teaching, Learning, and Computing: 1998 National Survey. Report# 7.
- Bell, R. L., Smetana, L., & Binns, I. (2005). Simplifying inquiry instruction. *The science teacher*, 72(7), 30-33.
- Bell, R. L., & Smetana, L. K. (2008). Using computer simulations to enhance science teaching and learning. *National Science Teachers Association*, 3, 23-32.
- Berg, S., Benz, C. R., Lasley, T. J., & Daniel Raisch, C. (1998). Exemplary Technology Use in Elementary Classrooms. *Journal of research on computing in education*, 31(2), 111-122.
<https://doi.org/10.1080/08886504.1998.10782245>
- Biesta, G. (2018). Pragmatising the curriculum: Bringing knowledge back into the curriculum conversation, but via pragmatism. In *Creating Curricula: Aims, Knowledge and Control* (pp. 40-60). Routledge.
- Bingimlas, K. A. (2009). Barriers to the successful integration of ICT in teaching and learning environments: A review of the literature. *Eurasia Journal of Mathematics, Science and Technology Education*, 5(3), 235-245.
- Binns, I. C., & Popp, S. (2013). Learning to teach science through inquiry: Experiences of preservice teachers. *The Electronic Journal for Research in Science & Mathematics Education*, 17(1). (Retrieved from <http://ejse.southwestern.edu/article/view/11346/8116>.)
- Birt, L., Scott, S., Cavers, D., Campbell, C., & Walter, F. (2016). Member checking: a tool to enhance trustworthiness or merely a nod to validation? *Qualitative Health Research*, 26(13), 1802-1811.
<https://doi.org/10.1177/1049732316654870>
- Blackwell, C. K., Lauricella, A. R., Wartella, E., Robb, M., & Schomburg, R. (2013). Adoption and use of technology in early education: The interplay of extrinsic barriers and teacher attitudes. *Computers & Education*, 69, 310-319.

- Boghossian, P. (2006). Behaviorism, constructivism, and Socratic pedagogy. *Educational philosophy and theory*, 38(6), 713-722.
- Bogiannidis, N., Southcott, J., & Gindidis, M. (2023). An exploration of the possible educational opportunities and the challenges at the intersection of the physical and digital worlds occupied by 10–14 year-old students. *Smart Learning Environments*, 10(1), 26.
<https://doi.org/https://doi.org/10.1186/s40561-023-00246-w>
- Borg, M. (2001). Key concepts in ELT. Teachers' beliefs. *ELT journal*, 55(2), 186-188.
<https://doi.org/https://doi.org/10.1093/elt/55.2.186>
- Bowen, G. A. (2009). Document analysis as a qualitative research method. *Qualitative research journal*.
- Boz, Y., & Cetin-Dindar, A. (2023). Teaching concerns, self-efficacy beliefs and constructivist learning environment of pre-service science teachers: a modelling study. *European Journal of Teacher Education*, 46(2), 274-292. <https://doi.org/10.1080/02619768.2021.1919079>
- Bransford, J., Brophy, S., & Williams, S. (2000). When computer technologies meet the learning sciences: Issues and opportunities. *Journal of Applied Developmental Psychology*, 21(1), 59-84.
[https://doi.org/https://doi.org/10.1016/S0193-3973\(99\)00051-9](https://doi.org/https://doi.org/10.1016/S0193-3973(99)00051-9)
- Braun, V., Clarke, V., & Weate, P. (2016). Using thematic analysis in sport and exercise research. In *Routledge handbook of qualitative research in sport and exercise* (pp. 213-227). Routledge.
- Brown, J. S. (2005). New learning environments for the 21st century. In.
- Bruner, J. (2013). Culture, mind and education. In *Inclusion and Behaviour Management in Schools* (pp. 169-193). David Fulton Publishers.
- Buckingham, D. (2007). Digital Media Literacies: rethinking media education in the age of the Internet. *Research in comparative and international education*, 2(1), 43-55.
<https://doi.org/doi.org/10.2304/rcie.2007.2.1>
- Buehl, M., & Fives, H. (2009). Come From? Does It Change? *The Journal of Experimental Education*, 77(4), 367-407. <https://doi.org/https://doi.org/10.3200/JEXE.77.4.367-408>
- Burt, G., & van der Heijden, K. (2024). Towards a framework to understand purpose in Futures Studies: The role of Vickers' Appreciative System. *Technological Forecasting and Social Change*, 75(8), 1109-1127.
<https://doi.org/https://doi.org/10.1016/j.techfore.2008.03.003>
- Bybee, R. W. (2009). The BSCS 5E instructional model and 21st century skills. *Colorado Springs, CO: BSCS*, 24.
- Bybee, R. W. (2014). The BSCS 5E instructional model: Personal reflections and contemporary implications. *Science and Children*, 51(8), 10-13.
- Cakir, M. (2008). Constructivist approaches to learning in science and their implications for science pedagogy: A literature review. *International journal of environmental and science education*, 3(4), 193-206.
- Çakır, N. (2017). Effect of 5E Learning Model on Academic Achievement, Attitude and Science Process Skills: Meta-Analysis Study. *Journal of Education and Training Studies*, 5, 157.
<https://doi.org/10.11114/jets.v5i11.2649>
- Caulfield, F. (2019). *Qualitativ research in cardiology*
La recherche qualitative en cardiologie (Publication Number 2019UBFCE005) Université Bourgogne Franche-Comté]. Univ-fcomte Cardi Star. <https://theses.hal.science/tel-02499104>

- Chabalengula, V. M., & Mumba, F. (2012). Inquiry-based science education: A scenario on Zambia's high school science curriculum. *Science Education International*, 23(4), 307-327.
- Chai, C. S., Hwee Ling Koh, J., & Teo, Y. H. (2019). Enhancing and modeling teachers' design beliefs and efficacy of technological pedagogical content knowledge for 21st century quality learning. *Journal of Educational Computing Research*, 57(2), 360-384.
<https://doi.org/https://doi.org/10.1177/0735633117752453>
- Chan, K.-W., & Elliott, R. G. (2004). Relational analysis of personal epistemology and conceptions about teaching and learning. *Teaching and Teacher Education*, 20(8), 817-831.
<https://doi.org/https://doi.org/10.1016/j.tate.2004.09.002>
- Chen, R.-J. (2010). Investigating models for preservice teachers' use of technology to support student-centered learning. *Computers & Education*, 55(1), 32-42.
<https://doi.org/https://doi.org/10.1016/j.compedu.2009.11.015>
- Chen, X., Zou, D., Cheng, G., & Xie, H. (2020). Detecting latent topics and trends in educational technologies over four decades using structural topic modeling: A retrospective of all volumes of *Computers & Education*. *Computers & Education*, 151, 103855.
- Chinn, C. A., & Malhotra, B. A. (2002). Epistemologically authentic inquiry in schools: A theoretical framework for evaluating inquiry tasks. *Science education*, 86(2), 175-218.
<https://doi.org/https://doi.org/10.1002/sce.10001>
- Chiu, J. L., DeJaegher, C. J., & Chao, J. (2015). The effects of augmented virtual science laboratories on middle school students' understanding of gas properties. *Computers & Education*, 85, 59-73.
<https://doi.org/https://doi.org/10.1016/j.compedu.2015.02.007>
- Choi, S., & Ramsey, J. (2009). Constructing Elementary Teachers' Beliefs, Attitudes, and Practical Knowledge Through an Inquiry-Based Elementary Science Course. *School Science and Mathematics*, 109(6).
<https://doi.org/https://doi.org/10.1111/j.1949-8594.2009.tb18101.x>
- Cirik, İ., Colak, E., & Kaya, D. (2015). Constructivist learning environments: the teachers' and students' perspectives. *International Journal on New Trends in Education and Their Implications*, 6(2), 30-44.
- Clarke-Midura, J., & Dede, C. (2010). Assessment, technology, and change. *Journal of Research on Technology in Education*, 42(3), 309-328. <https://doi.org/10.1080/15391523.2010.10782553>
- Cohen-Blankshtain, G., Nijkamp, P., & van Montfort, K. (2004). Modelling ICT Perceptions and Views of Urban Front-liners. *Urban Studies*, 41(13), 2647-2667.
<https://doi.org/10.1080/0042098042000294600>
- Cohen, L., Manion, L., & Morrison, K. (2017a). Approaches to qualitative data analysis. In *Research methods in education* (pp. 643-656). Routledge.
- Cohen, L., Manion, L., & Morrison, K. (2017). Validity and reliability. In *Research Methods in Education* (pp. 245-284). Routledge.
- Compeau, D. R., & Higgins, C. A. (1995). Computer self-efficacy: Development of a measure and initial test. *MIS quarterly*, 189-211.
- Council, N. R. (2000). *Inquiry and the national science education standards: A guide for teaching and learning*. National Academies Press.
- Cox, M. (2003). ICT and Attainment : A Review of the Research Literature. ICT in Schools Research and Evaluation Series No.17. Becta/DfES.

http://www.becta.org.uk/page_documents/research/ict_attainment_summary.pdf.
<https://ci.nii.ac.jp/naid/10024734137/en/>

- Crawford, B. A. (2007). Learning to teach science as inquiry in the rough and tumble of practice. *Journal of Research in Science Teaching*, 44(4), 613-642. <https://doi.org/https://doi.org/10.1002/tea.20157>
- Crawford, B. A. (2014). From inquiry to scientific practices in the science classroom. In *Handbook of research on science education, volume II* (pp. 529-556). Routledge.
- Crawford, J., Butler-Henderson, K., Rudolph, J., Malkawi, B., Glowatz, M., Burton, R., Magni, P., & Lam, S. (2020). COVID-19: 20 countries' higher education intra-period digital pedagogy responses. <https://creativecommons.org/licenses/by/4.0/>
- Creswell, J. W., & Clark, V. L. P. (2017). *Designing and conducting mixed methods research*. Sage publications.
- Creswell, J. W., & Creswell, J. D. (2017). *Research design: Qualitative, quantitative, and mixed methods approaches*. Sage publications.
- Creswell, J. W., & Poth, C. N. (2017). *Qualitative inquiry and research design: Choosing among five approaches*. Sage publications.
- Crossman, S. (2017). *MIND ACTION SERIES Physical Sciences Gr 10 Textbook & Workbook* (A. Press, Ed. First ed.). ALLCOPY PUBLISHERS.
- Cuban, L. (2009). *Oversold and underused*. Harvard university press.
- Darling-Hammond, L., Hyler, M. E., & Gardner, M. (2017). Effective teacher professional development. *Palo Alto, CA: Learning Policy Institute*.
- De Jong, T., Linn, M. C., & Zacharia, Z. C. (2013). Physical and virtual laboratories in science and engineering education. *Science*, 340(6130), 305-308.
- De Vries, S., van de Grift, W. J., & Jansen, E. P. (2014). How teachers' beliefs about learning and teaching relate to their continuing professional development. *Teachers and Teaching*, 20(3), 338-357. <https://doi.org/https://doi.org/10.1080/13540602.2013.848521>
- Deng, F., Chai, C. S., Tsai, C.-C., & Lee, M.-H. (2014a). The relationships among Chinese practicing teachers' epistemic beliefs, pedagogical beliefs and their beliefs about the use of ICT [Report]. *Educational Technology & Society*, 17, 245+. <https://doi.org/https://link.gale.com/apps/doc/A374101890/AONE?u=anon~401eeef2&sid=googleScholar&xid=31af561f>
- Deng, F., Chai, C. S., Tsai, C.-C., & Lee, M.-H. (2014b). The relationships among Chinese practicing teachers' epistemic beliefs, pedagogical beliefs and their beliefs about the use of ICT. *Journal of Educational Technology & Society*, 17(2), 245-256. <https://doi.org/https://link.gale.com/apps/doc/A374101890/AONE?u=anon~401eeef2&sid=googleScholar&xid=31af561f>
- Dexter, S. L., Anderson, R. E., & Becker, H. J. (1999). Teachers' views of computers as catalysts for changes in their teaching practice. *Journal of Research on Computing in Education*, 31(3), 221-239.
- Dorier, J., & Maab, K. (2012). The PRIMAS Project: Promoting inquiry-based learning (IBL) in mathematics and science education across Europe PRIMAS context analysis for the implementation of IBL: International Synthesis Report PRIMAS—Promoting Inquiry-Based Learning in Mathemati (Vol. 1). *Lokaliseret på: www.primasproject.eu/servlet/supportBinaryFiles*.

- Dudu, W. T., & Vhurumuku, E. (2012). Teachers' Practices of Inquiry When Teaching Investigations: A Case Study. *Journal of Science Teacher Education*, 23(6), 579-600. <https://doi.org/10.1007/s10972-012-9287-y>
- Ellingson, L. L. (2009). *Engaging crystallization in qualitative research: An introduction*. Sage.
- Erduran, S., & Kaya, E. (2019). Epistemic beliefs and teacher education. In *Transforming Teacher Education Through the Epistemic Core of Chemistry* (pp. 51-80). Springer. https://doi.org/10.1007/978-3-030-15326-7_3
- Ertmer, & Ottenbreit-Leftwich. (2010). Teacher Technology Change. *Journal of Research on Technology in Education*, 42(3), 255-284. <https://doi.org/10.1080/15391523.2010.10782551>
- Ertmer, P., Anne, O.-L., & Tondeur, J. (2015). Teacher beliefs and uses of technology to support 21st century teaching and learning. In *International handbook of research on teachers' beliefs* (pp. 403-419). Routledge.
- Ertmer, P. A. (2005). Teacher pedagogical beliefs: The final frontier in our quest for technology integration? *Educational technology research and development*, 53(4), 25-39. <https://doi.org/10.1007/BF02504683>
- Ertmer, P. A., & Ottenbreit-Leftwich, A. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education*, 64, 175-182.
- Ertmer, P. A., & Ottenbreit-Leftwich, A. (2013). Removing obstacles to the pedagogical changes required by Jonassen's vision of authentic technology-enabled learning. *Computers & Education*, 64, 175-182. <https://doi.org/https://doi.org/10.1016/j.compedu.2012.10.008>
- Ertmer, P. A., Ottenbreit-Leftwich, A., & York, C. S. (2007). Exemplary technology-using teachers: Perceptions of factors influencing success. *Journal of Computing in Teacher Education*, 23(2), 55-61.
- Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2010). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, 42(3), 255-284.
- Ertmer, P. A., Ottenbreit-Leftwich, A. T., Sadik, O., Sendurur, E., & Sendurur, P. (2012). Teacher beliefs and technology integration practices: A critical relationship. *Computers & Education*, 59(2), 423-435. <https://doi.org/https://doi.org/10.1016/j.compedu.2012.02.001>
- Essalih, S., Ourahay, M., & Khzami, S.-e. (2024). Perceptions and practices of science teachers for the development of critical thinking through inquiry: a qualitative study of Moroccan primary schools. *Education 3-13*, 52(5), 662-677. <https://doi.org/https://doi.org/10.1080/03004279.2022.2116942>
- Fauzi, A., Damayanti, D., & Ilahi, T. (2017). A teacher's beliefs on the integration of video technology in teaching speaking: A case study. *International Journal of Pedagogy and Teacher Education*, 1(1), 46-54. <https://doi.org/https://doi.org/10.20961/ijpte.v1i1.4914>
- Fernandes, G. W. R., Rodrigues, A. M., & Ferreira, C. A. R. (2019). *Using ICT in Inquiry-Based Science Education*. Springer.
- Fitzgerald, M., Danaia, L., & McKinnon, D. H. (2019). Barriers inhibiting inquiry-based science teaching and potential solutions: perceptions of positively inclined early adopters. *Research in Science Education*, 49(2), 543-566.
- Forbes, C. T., & Davis, E. A. (2010). Beginning elementary teachers' beliefs about the use of anchoring questions in science: A longitudinal study. *Science education*, 94(2), 365-387. <https://doi.org/https://doi.org/10.1002/sce.20370>

- Freese, M., Teichrew, A., Winkelmann, J., Erb, R., Ullrich, M., & Tremmel, M. (2023). Measuring teachers' competencies for a purposeful use of augmented reality experiments in physics lessons. *Frontiers in Education*,
- Fullan, M. (2013). Great to excellent: Launching the next stage of Ontario's education agenda. Toronto: Ontario Ministry of Education. *Электронный ресурс*.—Режим доступа: <https://michaelfullan.ca/wp-content/uploads/2016/06/13599974110.pdf>.—Дата доступа, 23, 2018.
- Fullan, M. (2015). *The new meaning of educational change*. Teachers college press.
- Furtak, E., Shavelson, R., Shemwell, J., & Figueroa, M. (2012). To teach or not to teach through inquiry: Is that the question. *The journey from child to scientist: Integrating cognitive development and the education sciences*, 227-244. <https://doi.org/https://doi.org/10.1037/13617-011>
- Gilakjani, A. P., Lai-Mei, L., & Ismail, H. N. (2013). Teachers' use of technology and constructivism. *International Journal of Modern Education and Computer Science*, 5(4), 49.
- Goldkuhl, G. (2012). Pragmatism vs interpretivism in qualitative information systems research. *European journal of information systems*, 21(2), 135-146. <https://doi.org/10.1057/ejis.2011.54>
- Graham, M., Kruger, G., & Van Ryneveld, L. (2024). Developing a Novel Model for ICT Integration in South African Education: Insights from TIMSS. *Education Sciences*, 14, 865. <https://doi.org/10.3390/educsci14080865>
- Gurcay, D., Wong, B., & Chai, C. S. (2013). Turkish and Singaporean Pre-service Physics Teachers' Beliefs about Teaching and Use of Technology. *The Asia-Pacific Education Researcher*, 22(2), 155-162. <https://doi.org/10.1007/s40299-012-0008-2>
- Guskey, T. R. (2002). Professional Development and Teacher Change. *Teachers and Teaching*, 8(3), 381-391. <https://doi.org/10.1080/135406002100000512>
- Hammond, M., Reynolds, L., & Ingram, J. (2011). How and why do student teachers use ICT? *Journal of Computer Assisted Learning*, 27(3), 191-203. <https://doi.org/https://doi.org/10.1111/j.1365-2729.2010.00389.x>
- Haney, J. J., Czerniak, C. M., & Lumpe, A. T. (1996). Teacher beliefs and intentions regarding the implementation of science education reform strands. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 33(9), 971-993.
- Harris, C. J., & Rooks, D. L. (2010). Managing inquiry-based science: Challenges in enacting complex science instruction in elementary and middle school classrooms. *Journal of Science Teacher Education*, 21(2), 227-240. <https://doi.org/10.1007/s10972-009-9172-5>
- Harris, J. B. (2016). In-service teachers' TPACK development: Trends, models, and trajectories. In *Handbook of technological pedagogical content knowledge (TPACK) for educators* (pp. 191-206). Routledge.
- Harwood, W. S., Hansen, J., & Lotter, C. (2006). Measuring teacher beliefs about inquiry: The development of a blended qualitative/quantitative instrument. *Journal of Science Education and Technology*, 15(1), 69-79.
- Hatlevik, O. E. (2017). Examining the relationship between teachers' self-efficacy, their digital competence, strategies to evaluate information, and use of ICT at school. *Scandinavian Journal of Educational Research*, 61(5), 555-567. <https://doi.org/10.1080/00313831.2016.1172501>
- Hattie, J. (2008). *Visible learning: A synthesis of over 800 meta-analyses relating to achievement*. routledge. <https://doi.org/https://doi.org/10.4324/9780203887332>

- Hegarty, M. (2018). Advances in cognitive science and information visualization. *Score reporting research and applications*, 19-34. <https://doi.org/https://doi.org/10.4324/9781351136501>
- 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. <https://pdfs.semanticscholar.org/56ec/8d2248a546352fed0f520972b57034334a45.pdf>
- Hennessy, S., Ruthven, K., & Brindley, S. (2005). Teacher perspectives on integrating ICT into subject teaching: commitment, constraints, caution, and change. *Journal of Curriculum Studies*, 37(2), 155-192. <https://doi.org/https://doi.org/10.1080/0022027032000276961>
- Hermans, R., Tondeur, J., Van Braak, J., & Valcke, M. (2008). The impact of primary school teachers' educational beliefs on the classroom use of computers. *Computers & Education*, 51(4), 1499-1509. <https://doi.org/https://doi.org/10.1016/j.compedu.2008.02.001>
- Herrington, J., Reeves, T. C., & Oliver, R. (2014). *Authentic learning environments*. Springer. https://doi.org/10.1007/978-1-4614-3185-5_32
- Hess, F., Kelly, A., & Meeks, O. (2011). The case for being bold: A new agenda for business in improving STEM education. *Institute for a Competitive Workforce, Washington, DC*.
- Hew, K. F., & Brush, T. (2007). Integrating technology into K-12 teaching and learning: Current knowledge gaps and recommendations for future research. *Educational technology research and development*, 55(3), 223-252. <https://doi.org/https://doi.org/10.1007/s11423-006-9022-5>
- Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundations for the twenty-first century. *Science education*, 88(1), 28-54.
- Holden, H., & Rada, R. (2011). Understanding the influence of perceived usability and technology self-efficacy on teachers' technology acceptance. *Journal of Research on Technology in Education*, 43(4), 343-367. <https://doi.org/https://doi.org/10.1080/15391523.2011.10782576>
- Holland, D. D., & Piper, R. T. (2016). A technology integration education (tie) model for millennial preservice teachers: Exploring the canonical correlation relationships among attitudes, subjective norms, perceived behavioral controls, motivation, and technological, pedagogical, and content knowledge (TPACK) competencies. *Journal of Research on Technology in Education*, 48(3), 212-226.
- Honebein, P. C. (1996). Seven goals for the design of constructivist learning environments. *Constructivist learning environments: Case studies in instructional design*, 11(12), 11.
- Howard, B. C., McGee, S., Schwartz, N., & Purcell, S. (2000). The experience of constructivism: Transforming teacher epistemology. *Journal of research on computing in education*, 32(4), 455-465.
- Howard, S. K., Chan, A., & Caputi, P. (2015). More than beliefs: Subject areas and teachers' integration of laptops in secondary teaching. *British Journal of Educational Technology*, 46(2), 360-369. <https://doi.org/https://doi.org/10.1111/bjet.12139>
- Huang, K., Ge, X., & Eseryel, D. (2017). Metaconceptually-enhanced simulation-based inquiry: effects on eighth grade students' conceptual change and science epistemic beliefs. *Educational technology research and development*, 65(1), 75-100. <https://doi.org/https://doi.org/10.1007/s11423-016-9462-5>
- Hudgins, B. B. (1977). Learning and thinking: A primer for teachers. (No Title).
- Hultén, M., & Björkholm, E. (2016). Epistemic habits: primary school teachers' development of pedagogical content knowledge (PCK) in a design-based research project. *International Journal of Technology and Design Education*, 26(3), 335-351. <https://doi.org/https://doi.org/10.1007/s10798-015-9320-5>

- Inan, F. A., & Lowther, D. L. (2010). Factors affecting technology integration in K-12 classrooms: A path model. *Educational Technology Research and Development*, 58(2), 137-154.
<https://doi.org/https://doi.org/10.1007/s11423-009-9132-y>
- Ivankova, N. V., & Stick, S. L. (2007). Students' persistence in a distributed doctoral program in educational leadership in higher education: A mixed methods study. *Research in Higher Education*, 48(1), 93.
- Jiang, F., & McComas, W. F. (2015). The effects of inquiry teaching on student science achievement and attitudes: Evidence from propensity score analysis of PISA data. *International Journal of Science Education*, 37(3), 554-576. <https://doi.org/https://doi.org/10.1080/09500693.2014.1000426>
- Johnson, R. B., & Onwuegbuzie, A. J. (2004). Mixed methods research: A research paradigm whose time has come. *Educational researcher*, 33(7), 14-26.
- Jonassen, D. H., & Carr, C. S. (2020). Mindtools: Affording multiple knowledge representations for learning. In *Computers as cognitive tools* (pp. 165-196). Routledge.
- Juggernath, A. (2017). *Exploring Grade 8 Natural Science Teachers' Use of Information, Communication Technology (ICT) In Teaching Natural Sciences: A Case Study In A Public School In Kwazulu-Natal* [Masters, University of KwaZulu-Natal]. Durban.
- Juggernath, A., & Govender, N. (2020). Natural sciences teachers' beliefs as barriers for integrating ICTs in a technology-rich context. *African Journal of Research in Mathematics, Science and Technology Education*, 24(1), 105-115.
- Kalina, C., & Powell, K. (2009). Cognitive and social constructivism: Developing tools for an effective classroom. *Education*, 130(2), 241-250.
- Kanselaar, G. (2002). Constructivism and socio-constructivism. *Constructivism and socio-constructivism*, 1-7.
- Karaseva, A., Siibak, A., & Pruulmann-Vengerfeldt, P. (2015). Relationships between teachers pedagogical beliefs, subject cultures, and mediation practices of students' use of digital technology. *Cyberpsychology: Journal of Psychosocial Research on Cyberspace*, 9(1).
[https://doi.org/https://cyberpsychology.eu/article/view/4331#:~:text=1\)%2C%20Article%206,-.https%3A//doi.org/10.5817/CP2015-1-6,-Keywords](https://doi.org/https://cyberpsychology.eu/article/view/4331#:~:text=1)%2C%20Article%206,-.https%3A//doi.org/10.5817/CP2015-1-6,-Keywords)
- Ketelhut, D. J., Nelson, B. C., Clarke, J., & Dede, C. (2010). A multi-user virtual environment for building and assessing higher order inquiry skills in science. *British Journal of Educational Technology*, 41(1), 56-68.
- Keys, C. W., & Bryan, L. A. (2001). Co-constructing inquiry-based science with teachers: Essential research for lasting reform. *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, 38(6), 631-645.
<https://doi.org/https://doi.org/10.1002/tea.1023>
- Kim, C., Kim, M. K., Lee, C., Spector, J. M., & DeMeester, K. (2013). Teacher beliefs and technology integration. *Teaching and teacher education*, 29, 76-85.
<https://doi.org/https://doi.org/10.1016/j.tate.2012.08.005>
- Kim, H.-J., & Rha, J.-Y. (2018). Predicting the drivers of the intention to use mobile learning in South Korea. *International Journal of Interactive Mobile Technologies*, 12(1). <https://doi.org/10.3991/ijim.v12i1.7688>
- Kim, H. (2011). Inquiry-based science and technology enrichment program: Green earth enhanced with inquiry and technology. *Journal of Science Education and Technology*, 20(6), 803-814.

- Kim, M. C., & Hannafin, M. J. (2011). Scaffolding problem solving in technology-enhanced learning environments (TELEs): Bridging research and theory with practice. *Computers & Education*, 56(2), 403-417.
- Kock, Z.-J., Taconis, R., Bolhuis, S., & Gravemeijer, K. (2015). Creating a culture of inquiry in the classroom while fostering an understanding of theoretical concepts in direct current electric circuits: A balanced approach. *International Journal of Science and Mathematics Education*, 13(1), 45-69. <https://doi.org/https://doi.org/10.1007/s10763-014-9535-z>
- Koehler, M. J., Mishra, P., Akcaoglu, M., & Rosenberg, J. (2013). The technological pedagogical content knowledge framework for teachers and teacher educators. In M. Panigrahi (Ed.), *ICT integrated teacher education: A resource book* (pp. 20-31). CEMCA.
- Korstjens, I., & Moser, A. (2018). Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1), 120-124. <https://doi.org/10.1080/13814788.2017.1375092>
- Kotsis, K. T. (2024). The Significance of Experiments in Inquiry-based Science Teaching. *European Journal of Education and Pedagogy*, 5(2), 86-92.
- Kozma, R. B. (2003). Technology and classroom practices: An international study. *Journal of Research on Technology in Education*, 36(1), 1-14. <https://doi.org/10.1080/15391523.2003.10782399>
- Kreijns, K., Van Acker, F., Vermeulen, M., & Van Buuren, H. (2013). What stimulates teachers to integrate ICT in their pedagogical practices? The use of digital learning materials in education. *Computers in Human Behavior*, 29(1), 217-225. <https://doi.org/https://doi.org/10.1016/j.chb.2012.08.008>
- Kuang, X., Eysink, T. H., & De Jong, T. (2020). Effects of providing partial hypotheses as a support for simulation-based inquiry learning. *Journal of Computer Assisted Learning*, 36(4), 487-501. <https://doi.org/https://doi.org/10.1111/jcal.12415>
- Kumar, R. (2018). Research methodology: A step-by-step guide for beginners. *Research methodology*, 1-528.
- Kunnath, B., & Kriek, J. (2018). Exploring effective pedagogies using computer simulations to improve Grade 12 learners' understanding of the photoelectric effect. *African Journal of Research in Mathematics, Science and Technology Education*, 22(3), 329-339.
- Laurillard, D. (2007). Modelling benefits-oriented costs for technology enhanced learning. *Higher Education*, 54, 21-39.
- Laurillard, D. (2013). *Rethinking university teaching: A conversational framework for the effective use of learning technologies*. Routledge.
- Lederman, J. S., Lederman, N. G., Bartos, S. A., Bartels, S. L., Meyer, A. A., & Schwartz, R. S. (2014). Meaningful assessment of learners' understandings about scientific inquiry-The views about scientific inquiry (VASI) questionnaire. *Journal of Research in Science Teaching*, 51(1), 65-83. <https://doi.org/10.1002/tea.21125>
- Lehesvuori, S., Ratinen, I., Moate, J., & Viiri, J. (2018). Inquiry-Based Approaches in Primary Science Teacher Education. *Professional Development for Inquiry-Based Science Teaching and Learning*, 121-134. https://doi.org/10.1007/978-3-319-91406-0_7
- Lehtinen, A., Lehesvuori, S., & Viiri, J. (2019). The connection between forms of guidance for inquiry-based learning and the communicative approaches applied—a case study in the context of pre-service teachers. *Research in Science Education*, 49(6), 1547-1567. <https://doi.org/10.1007/s11165-017-9666-7>
- Levin, B., Datnow, A., & Carrier, N. (2012). Changing school district practices. *Jobs for the Future, Boston, MA*.

- Levitt, K. E. (2002). An analysis of elementary teachers' beliefs regarding the teaching and learning of science. *Science education*, 86(1), 1-22.
- Lim, C. P., Tondeur, J., Nastiti, H., & Pagram, J. (2014). Educational innovations and pedagogical beliefs: The case of a professional development program for Indonesian teachers. *Journal of Applied Research in Education*, 18, 1-14.
- Lin, W.-S., & Wang, C.-H. (2012). Antecedences to continued intentions of adopting e-learning system in blended learning instruction: A contingency framework based on models of information system success and task-technology fit. *Computers & Education*, 58(1), 88-99.
<https://doi.org/https://doi.org/10.1016/j.compedu.2011.07.008>
- Liu, F., Ritzhaupt, A. D., Dawson, K., & Barron, A. E. (2017). Explaining technology integration in K-12 classrooms: A multilevel path analysis model. *Educational technology research and development*, 65(4), 795-813.
- Liu, X., & Zhang, L. (2024). Exploring the relationship between teachers' professional capital and technology-enhanced teaching innovation: The mediating role of constructivist belief. *Teaching and teacher education*, 139, 104434. <https://doi.org/10.1016/j.tate.2023.104434>
- Livingstone, S., & Sefton-Green, J. (2016). *The class: Living and learning in the digital age*. New York University Press. <https://doi.org/10.18574/nyu/9781479884575.001.0001>
- Lotter, C. R., Thompson, S., Dickenson, T. S., Smiley, W. F., Blue, G., & Rea, M. (2018). The impact of a practice-teaching professional development model on teachers' inquiry instruction and inquiry efficacy beliefs. *International Journal of Science and Mathematics Education*, 16(2), 255-273.
- Maggioni, L., & Parkinson, M. M. (2008). The role of teacher epistemic cognition, epistemic beliefs, and calibration in instruction. *Educational Psychology Review*, 20(4), 445-461.
<https://doi.org/10.1007/s10648-008-9081-8>
- Maigari Mohammed, S., Amponsah, K., Ampadu, E., & Kumassah, E. (2020). Extent of Implementation of Inquiry-based Science Teaching and Learning in Ghanaian Junior High Schools. *Eurasia Journal of Mathematics, Science and Technology Education*, 16, em1928.
<https://doi.org/10.29333/ejmste/9373>
- Makki, T. W., O'Neal, L. J., Cotten, S. R., & Rikard, R. (2018). When first-order barriers are high: A comparison of second-and third-order barriers to classroom computing integration. *Computers & Education*, 120, 90-97.
- Mama, M., & Hennessy, S. (2013). Developing a typology of teacher beliefs and practices concerning classroom use of ICT. *Computers & Education*, 68, 380-387.
<https://doi.org/https://doi.org/10.1016/j.compedu.2013.05.022>
- Mansour, N. (2008). The experiences and personal religious beliefs of Egyptian science teachers as a framework for understanding the shaping and reshaping of their beliefs and practices about science-technology-society (STS). *International Journal of Science Education*, 30(12), 1605-1634.
<https://doi.org/https://doi.org/10.1080/09500690701463303>
- Markic, S., & Eilks, I. (2012). A comparison of student teachers' beliefs from four different science teaching domains using a mixed methods design. *International Journal of Science Education*, 34(4), 589-608.
<https://doi.org/https://doi.org/10.1080/09500693.2011.608092>
- Mathevu, M. D., & Uwizemana, D. E. (2014). The challenges facing the integration of ICT in teaching and learning activities in South African rural secondary schools. *Mediterranean Journal of Social Sciences*, 5(20), 1087-1087. <https://doi.org/http://dx.doi.org/10.5901/mjss.2014.v5n20p1087>

- Mayer, R. E., & Fiorella, L. (2022). The Cambridge handbook of multimedia learning. In: Cambridge University Press.
- McChesney, K., & Aldridge, J. (2019). Weaving an interpretivist stance throughout mixed methods research. *International journal of research & method in education*, 42(3), 225-238. <https://doi.org/10.1080/1743727X.2019.1590811>
- McMillan, J. H., & Schumacher, S. (2010). Research in Education: Evidence-Based Inquiry, MyEducationLab Series. *Pearson*.
- Means, B., Bakia, M., & Murphy, R. (2014). *Learning online: What research tells us about whether, when and how*. Routledge.
- Mei, B., Brown, G. T., & Teo, T. (2018). Toward an understanding of preservice English as a Foreign Language teachers' acceptance of computer-assisted language learning 2.0 in the People's Republic of China. *Journal of Educational Computing Research*, 56(1), 74-104. <https://doi.org/https://doi.org/10.1177%2F0735633117700144>
- Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.
- Meyer, I., & Gent, P. (2016). The status of ICT in education in South Africa and the way forward. *National Education Collaboration Trust*.
- Miles, M. B., Huberman, A. M., & Saldana, J. (2014). *Qualitative Data Analysis: A Methods Sourcebook*. SAGE Publications Ltd (CA).
- Milner, A. R., Sondergeld, T. A., Demir, A., Johnson, C. C., & Czerniak, C. M. (2012). Elementary teachers' beliefs about teaching science and classroom practice: An examination of pre/post NCLB testing in science. *Journal of Science Teacher Education*, 23(2), 111-132. <https://doi.org/https://doi.org/10.1007/s10972-011-9230-7>
- Miranda, H. P., & Russell, M. (2012). Understanding factors associated with teacher-directed student use of technology in elementary classrooms: A structural equation modeling approach. *British Journal of Educational Technology*, 43(4), 652-666. <https://doi.org/https://doi.org/10.1111/j.1467-8535.2011.01228.x>
- Mirzajani, H., Mahmud, R., Ayub, A. F. M., & Wong, S. L. (2016). Teachers' acceptance of ICT and its integration in the classroom. *Quality Assurance in Education*.
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers college record*, 108(6), 1017-1054.
- Mishra, S. B., & Alok, S. (2022). Handbook of research methodology. In: Educreation publishing.
- Moll, L. C. (2001). Through the mediation of others: Vygotskian research on teaching. *Handbook of research on teaching*, 4, 111-129. <https://doi.org/10.4324/9780203156773>
- Moote, J. (2019). Investigating the longer-term impact of the CREST inquiry-based learning programme on student self-regulated processes and related motivations: Views of students and teachers. *Research in Science Education*, 49(1), 265-294. <https://doi.org/https://doi.org/10.1007/s11165-017-9621-7>
- Morse, J. M. (2015). Using qualitative methods to access the pain experience. *British journal of pain*, 9(1), 26-31. <https://doi.org/10.1177/2049463714550507>

- Mugabo, R. L. (2012). Introduction of Inquiry-based Science Teaching in Rwandan Lower Secondary Schools: Teachers' attitudes and perceptions.
- 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.
- Nelson, M. J., & Hawk, N. A. (2020). The impact of field experiences on prospective preservice teachers' technology integration beliefs and intentions. *Teaching and teacher education*, 89, 103006. <https://doi.org/10.1016/j.tate.2019.103006>
- Newman, M., & Gough, D. (2020). Systematic reviews in educational research: Methodology, perspectives and application. *Systematic reviews in educational research: Methodology, perspectives and application*, 3-22.
- Nikolopoulou, K., & Gialamas, V. (2016). Barriers to ICT use in high schools: Greek teachers' perceptions. *Journal of Computers in Education*, 3, 59-75.
- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, 16(1), 1609406917733847. <https://doi.org/10.1177/1609406917733847>
- Olsen, B. (2019). Does Cultural Capital Matter in Professional Settings? Educational Value Profiles among the Personnel in Kindergartens. *International Research in Early Childhood Education*, 9(1), 1-22.
- Ongowo, R. O., Indoshi, F. C., & Ayere, M. A. (2015). Perception of constructivist learning environment: Gender and school type differences in Siaya County, Kenya.
- Opre, D. (2021). Teachers' Pedagogical Beliefs and Technology Integration. *European Proceedings of Educational Sciences*. <https://doi.org/10.15405/epes.22032.10>
- Osborne, J. (2014). Teaching Scientific Practices: Meeting the Challenge of Change. *Journal of Science Teacher education*, 25(2), 177-196. <https://doi.org/10.1007/s10972-014-9384-1>
- Österholm, M. (2010). Relationships between epistemological beliefs and properties of discourse: Some empirical explorations. MADIF 7, the 7th Swedish Mathematics Education Research Seminar, Stockholm, January 26-27, 2010,
- Ottenbreit-Leftwich, A. T., Glazewski, K. D., Newby, T. J., & Ertmer, P. A. (2010). Teacher value beliefs associated with using technology: Addressing professional and student needs. *Computers & Education*, 55(3), 1321-1335. <https://doi.org/https://doi.org/10.1016/j.compedu.2010.06.002>
- Pajares, M. F. (1992). Teachers' beliefs and educational research: Cleaning up a messy construct. *Review of educational research*, 62(3), 307-332. <https://doi.org/https://doi.org/10.3102%2F00346543062003307>
- Palak, D., & Walls, R. T. (2009). Teachers' beliefs and technology practices: A mixed-methods approach. *Journal of Research on Technology in Education*, 41(4), 417-441. <https://doi.org/https://doi.org/10.1080/15391523.2009.10782537>
- Pandey, P., & Pandey, M. M. (2021). *Research methodology tools and techniques*. Bridge Center.
- Patton, M. Q. (2014). *Qualitative research & evaluation methods: Integrating theory and practice*. Sage publications.
- Peck, C. L., Herriot, L., Fives, H., & Gill, M. (2015). Teachers' beliefs about social studies. *International Handbook of Research on Teachers' beliefs*, 387-402.

- Peck, C. L., & Herriot, L. A. (2014). Teachers' beliefs about social studies. In *International handbook of research on teachers' beliefs* (pp. 399-414). Routledge.
- Pelgrum, W. J. (2001). Obstacles to the integration of ICT in education: results from a worldwide educational assessment. *Computers & Education*, 37(2), 163-178. [https://doi.org/https://doi.org/10.1016/S0360-1315\(01\)00045-8](https://doi.org/https://doi.org/10.1016/S0360-1315(01)00045-8)
- Pellegrino, J. W., Goldman, S. R., Bertenthal, M., & Lawless, K. (2007). Teacher education and technology: Initial results from the "what works and why" project. *Yearbook of the National Society for the Study of Education*, 106(2), 52-86. <https://doi.org/https://doi.org/10.1111/j.1744-7984.2007.00115.x>
- Piaget, J. (1973). Problems of genetic psychology: The child and reality. New York: Grossman Publishers. Salajan, FD, Perschbacher, S., Cash, M., Talwar, R., El-Badrawy, W., & Mount, GJ (2009). Learning with web-based interactive objects: An investigation into student perceptions of effectiveness. *Computers & Education*, 53, 632-647.
- Pischetola, M., Albuquerque, P., Heinsfeld, B. D., SantoS, E. R. d. B., & Corrêa, J. G. (2019). Naira Silva. *Tecnologias, pensamento sistêmico e os fundamentos da inovação pedagógica*. Curitiba: CRV. <https://doi.org/10.24824/978854443795.7>
- Plass, J. L., Milne, C., Homer, B. D., Schwartz, R. N., Hayward, E. O., Jordan, T., Verkuilen, J., Ng, F., Wang, Y., & Barrientos, J. (2012). Investigating the effectiveness of computer simulations for chemistry learning. *Journal of Research in Science Teaching*, 49(3), 394-419. <https://doi.org/https://doi.org/10.1002/tea.21008>
- Plumb, M., & Kautz, K. (2016). Barriers to the integration of information technology within early childhood education and care organisations: A review of the literature. *arXiv preprint arXiv:1606.00748*.
- Ponelis, S. R. (2015). Using Interpretive Qualitative Case Studies for Exploratory Research in Doctoral Studies: A Case of Information Systems Research in Small and Medium Enterprises. *International Journal of Doctoral Studies*, 10, 535-550. (Retrieved from <http://ijds.org/Volume10/IJDSv10p535-550Ponelis0624.pdf>)
- Prestridge, S. (2017). Examining the shaping of teachers' pedagogical orientation for the use of technology. *Technology, Pedagogy and Education*, 26(4), 367-381. <https://doi.org/https://doi.org/10.1080/1475939X.2016.1258369>
- Prestridge, S. (2019). Categorising teachers' use of social media for their professional learning: A self-generating professional learning paradigm. *Computers & Education*, 129, 143-158. <https://doi.org/10.1016/j.compedu.2018.11.003>
- Priestley, M., Biesta, G., & Robinson, S. (2015). *Teacher agency: An ecological approach*. Bloomsbury Publishing.
- Quinlan, C. (2011). *Business research methods*. South-Western Cengage Learning Andover.
- Rafiq, M., Batool, S. H., Ali, A. F., & Ullah, M. (2021). University libraries response to COVID-19 pandemic: A developing country perspective. *The Journal of Academic Librarianship*, 47(1), 102280. <https://doi.org/10.1016/j.acalib.2020.102280>
- Ramnarain, U. (2016). Understanding the influence of intrinsic and extrinsic factors on inquiry-based science education at township schools in South Africa. *Journal of Research in Science Teaching*, 53(4), 598-619.
- Ramnarain, U., & Hlatswayo, M. (2018). Teacher beliefs and attitudes about inquiry-based learning in a rural school district in South Africa. *South African Journal of Education*, 38(1), 1-10. <https://doi.org/10.15700/saje.v38n1a1431>

- Reynolds, D., Treharne, D., & Tripp, H. (2003). ICT—the hopes and the reality. *British Journal of Educational Technology*, 34(2), 151-167. <https://doi.org/https://doi.org/10.1111/1467-8535.00317>
- Richardson, L. (2003). Writing: A method of inquiry. *Turning points in qualitative research: Tying knots in a handkerchief*, 2, 379.
- Richardson, L., & St. Pierre, E. A. (2005). Writing: A Method of Inquiry. In *The Sage handbook of qualitative research*, 3rd ed. (pp. 959-978). Sage Publications Ltd.
- Ripple, R. E., & Rockcastle, V. N. (1964). Piaget Rediscovered. A Report Of The Conference On Cognitive Studies And Curriculum Development.
- Roehrig, G. H., & Luft, J. A. (2004). Constraints experienced by beginning secondary science teachers in implementing scientific inquiry lessons. *International Journal of Science Education*, 26(1), 3-24. <https://doi.org/https://doi.org/10.1080/0950069022000070261>
- Rohaani, E. J., Taconis, R., & Jochems, W. M. (2012). Analysing teacher knowledge for technology education in primary schools. *International Journal of Technology and Design Education*, 22(3), 271-280. <https://doi.org/10.1007/s10798-010-9147-z>
- Rutten, K., & Soetaert, R. (2015). Attitudes toward education: Kenneth Burke and new rhetoric. *Studies in Philosophy and Education*, 34, 339-347. <https://doi.org/https://doi.org/10.1007/s11217-014-9432-5>
- Rutten, N., van Joolingen, W. R., & van der Veen, J. T. (2012). The learning effects of computer simulations in science education. *Computers & Education*, 1(58), 136-153. <https://doi.org/10.1016/j.compedu.2011.07.017>
- Saad, R., & BouJaoude, S. (2012). The relationship between teachers' knowledge and beliefs about science and inquiry and their classroom practices. *Eurasia Journal of Mathematics, Science and Technology Education*, 8(2), 113-128.
- Saadati, F., Cerda, G., Giaconi, V., Reyes, C., & Felmer, P. (2019). Modeling Chilean Mathematics Teachers' Instructional Beliefs on Problem Solving Practices. *International Journal of Science and Mathematics Education*, 17(5), 1009-1029. <https://doi.org/10.1007/s10763-018-9897-8>
- Sandoval, W. A., & Reiser, B. J. (2004). Explanation-driven inquiry: Integrating conceptual and epistemic scaffolds for scientific inquiry. *Science education*, 88(3), 345-372. <https://doi.org/https://doi.org/10.1002/sce.10130>
- Santos, E., & Pischetola, M. (2020). A percepção da eficácia coletiva nas práticas pedagógicas com as tecnologias digitais. *Escritos sobre Educação e Tecnologias: entre provocações, percepções e vivências*. São Paulo: Artesanato Educacional, 95-108.
- Sarabando, C., Cravino, J. P., & Soares, A. A. (2014). Contribution of a computer simulation to students' learning of the physics concepts of weight and mass. *Procedia Technology*, 13, 112-121. <https://doi.org/https://doi.org/10.1016/j.protcy.2014.02.015>
- Scherer, R., & Siddiq, F. (2015). Revisiting teachers' computer self-efficacy: A differentiated view on gender differences. *Computers in Human Behavior*, 53, 48-57.
- Schramm, J., Jin, H., Keeling, E. G., Johnson, M., & Shin, H. (2018). Improved student reasoning about carbon-transforming processes through inquiry-based learning activities derived from an empirically validated learning progression. *Research in Science Education*, 48(5), 887-911. <https://doi.org/https://doi.org/10.1007/s11165-016-9584-0>
- Schunk, D. H., & DiBenedetto, M. K. (2016). Self-efficacy theory in education. *Handbook of motivation at school*, 2, 34-54.

- Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). *Helping students make sense of the world using next generation science and engineering practices*. NSTA Press.
- Scrimshaw, P. (2004). Enabling teachers to make successful use of ICT. <http://www.becta.org.uk>
- Sexton, S. S. (2020). Meaningful Learning—David P. Ausubel. *Science education in theory and practice: An introductory guide to learning theory*, 163-175. https://doi.org/10.1007/978-3-030-43620-9_12
- Shenton, A. K. (2004). Strategies for ensuring trustworthiness in qualitative research projects. *Education for information*, 22, 63-75. <https://doi.org/10.3233/EFI-2004-22201>
- Shifflet, R., & Weilbacher, G. (2015). Teacher beliefs and their influence on technology use: A case study. *Contemporary issues in technology and teacher education*, 15(3), 368-394.
- Sikko, S. A., Lyngved, R., & Pepin, B. (2012). Working with Mathematics and Science teachers on inquirybased learning (IBL) approaches: Teacher beliefs. *[VISIONS 2011: Teacher Education*, 6(1), 1-17.
- Singh, S., & Yaduvanshi, S. (2015). Constructivism in science classroom: Why and how. *International Journal of Scientific and Research Publications*, 5(3), 1-5.
- Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. *Journal of Business Research*, 104, 333-339.
- Squire, K. (2011). *Video Games and Learning: Teaching and Participatory Culture in the Digital Age. Technology, Education--Connections (the TEC Series)*. ERIC.
- Ssempala, F. (2017). *Science Teachers' Understanding and Practice of Inquiry-Based Instruction in Uganda* [Syracuse University].
- Stake, R. E., Denzin, N., & Lincoln, Y. (1998). Strategies of qualitative inquiry. *Case studies*.
- Steyn, G. M. (2008). Continuing professional development for teachers in South Africa and social learning systems : conflicting conceptual frameworks of learning : research article. *Koers : Bulletin for Christian Scholarship* = *Koers : Bulletin vir Christelike Wetenskap*, 73(1), 15-31. <https://doi.org/10.10520/EJC59354>
- Stipek, D. J., Givvin, K. B., Salmon, J. M., & MacGyvers, V. L. (2001). Teachers' beliefs and practices related to mathematics instruction. *Teaching and teacher education*, 17(2), 213-226.
- Taber, K. S. (2013). Revisiting the chemistry triplet: drawing upon the nature of chemical knowledge and the psychology of learning to inform chemistry education. *Chemistry education research and practice*, 14(2), 156-168. <https://doi.org/10.1039/C3RP00012E>
- Tamim, S. R., & Grant, M. M. (2013). Definitions and uses: Case study of teachers implementing project-based learning. *Interdisciplinary Journal of Problem-Based Learning*, 7(2), 3. <https://doi.org/10.7771/1541-5015.1323>
- Tang, H., Qiu, C., Meng, L., Li, Y., & Zhang, J. (2020). Factors Predicting Inquiry-Based Teaching in Science Across One Belt One Road Countries and Regions: A Multilevel Analysis. *SAGE Open*, 10(2), 2158244020932511.
- Teddle, C., & Tashakkori, A. (2011). Mixed methods research. *The Sage handbook of qualitative research*, 4(1), 285-300.
- Teo, T. (2011). Technology acceptance research in education. In *Technology acceptance in education* (pp. 1-5). Springer.

- Thacker, I., & Sinatra, G. M. (2019). Visualizing the greenhouse effect: Restructuring mental models of climate change through a guided online simulation. *Education Sciences*, 9(1), 14. <https://doi.org/https://doi.org/10.3390/educsci9010014>
- Thakur, G. R. (2014). Training and Effectiveness of Multimedia E-Content Based on ADDIE Model Prepared by Student Teachers in Economics for the Students of STD. IX. *Online Submission*.
- Thisgaard, M., & Makransky, G. (2017). Virtual Learning Simulations in High School: Effects on Cognitive and Non-cognitive Outcomes and Implications on the Development of STEM Academic and Career Choice. *Frontiers in Psychology*, 8, 805. <https://doi.org/10.3389/fpsyg.2017.00805>
- Timotheou, S., Miliou, O., Dimitriadis, Y., Sobrino, S. V., Giannoutsou, N., Cachia, R., Mones, A. M., & Ioannou, A. (2023). Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. *Education and Information Technologies*, 28(6), 6695-6726.
- Tobin, G. A., & Begley, C. M. (2004). Methodological rigour within a qualitative framework. *Journal of Advanced Nursing*, 48(4), 388-396. <https://doi.org/10.1111/j.1365-2648.2004.03207.x>
- Tondeur, J. (2020). Teachers' pedagogical beliefs and technology use. *M. Peters. Encyclopedia of Teacher Education*. Springer. https://doi.org/10.1007/978-981-13-1179-6_111-1.
- Tondeur, J., Scherer, R., Baran, E., Siddiq, F., Valtonen, T., & Sointu, E. (2019). Teacher educators as gatekeepers: Preparing the next generation of teachers for technology integration in education. *British Journal of Educational Technology*, 50(3), 1189-1209. <https://doi.org/10.1111/bjet.12748>
- Tondeur, J., Van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017a). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, 65, 555-575.
- Tondeur, J., Van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: a systematic review of qualitative evidence. *Educational technology research and development*, 65(3), 555-575. <https://doi.org/https://doi.org/10.1007/s11423-016-9481-2>
- Tondeur, J., Van Braak, J., Sang, G., Voogt, J., Fisser, P., & Ottenbreit-Leftwich, A. (2012). Preparing pre-service teachers to integrate technology in education: A synthesis of qualitative evidence. *Computers & Education*, 59(1), 134-144. <https://doi.org/https://doi.org/10.1016/j.compedu.2011.10.009>
- Tuwoso, T. (2016). The implementation of constructivism approach for physics learning in vocational high school. *AIP Conference Proceedings*,
- Ültanir, E. (2012). An epistemological glance at the constructivist approach: Constructivist learning in Dewey, Piaget, and Montessori. *International Journal of Instruction*, 5(2).
- Vaismoradi, M., Jones, J., Turunen, H., & Snelgrove, S. (2016). Theme development in qualitative content analysis and thematic analysis. <http://dx.doi.org/10.5430/jnep.v6n5p100>
- 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.
- Voogt, J., Fisser, P., Roblin, N. P., Tondeur, J., & van Braak, J. (2013). Technological pedagogical content knowledge—a review of the literature. *Journal of Computer Assisted Learning*, 2(29), 109-121. <https://doi.org/10.1111/j.1365-2729.2012.00487.x>
- Vygotsky, L. S. (1987). *The collected works of LS Vygotsky: The fundamentals of defectology* (Vol. 2). Springer Science & Business Media.

- Vygotsky, L. S., & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Harvard university press.
- Wallace, C. S., & Kang, N. H. (2004). An investigation of experienced secondary science teachers' beliefs about inquiry: An examination of competing belief sets. *Journal of Research in Science Teaching*, 41(9), 936-960. <https://doi.org/https://doi.org/10.1002/tea.20032>
- Wallace, J., & Loughran, J. (2012). Science teacher learning. *Second international handbook of science education*, 295-306. https://doi.org/10.1007/978-1-4020-9041-7_21
- Wang, J., & Zhao, Y. (2016). Comparative research on the understandings of nature of science and scientific inquiry between science teachers from Shanghai and Chicago. *Journal of Baltic Science Education*, 15(1), 97.
- Wanjala, M. (2016). Information Communication Technology Pedagogical Integration in Mathematics Instruction among Teachers in Secondary Schools in Kenya. *Journal of Education and Practice*, 7(2), 66-73. (retrieved from: <http://kerd.ku.ac.ke/123456789/1572>)
- Warschauer, M. (2004). Technology and social inclusion: Rethinking the digital divide. In: MIT press.
- Watson, D. (2006). Understanding the relationship between ICT and education means exploring innovation and change. *Education and information technologies*, 11(3), 199-216. <https://doi.org/https://doi.org/10.1007/s10639-006-9016-2>
- Watson, S. (2020). Virtual Chemistry: Using the PhET Simulation Scale and the 5E Model to Enhance Students' pH Understandings. https://doi.org/10.2505/4/tst19_087_02_25
- Wen, C.-T., Liu, C.-C., Chang, H.-Y., Chang, C.-J., Chang, M.-H., Chiang, S.-H. F., Yang, C.-W., & Hwang, F.-K. (2020). Students' guided inquiry with simulation and its relation to school science achievement and scientific literacy. *Computers & Education*, 149, 103830. <https://doi.org/10.1016/j.compedu.2020.103830>
- Williams, P. J., Nguyen, N., & Mangan, J. (2017). Using technology to support science inquiry learning. *JOTSE*, 7(1), 26-57.
- Windschitl, M., & Sahl, K. (2002). Tracing teachers' use of technology in a laptop computer school: The interplay of teacher beliefs, social dynamics, and institutional culture. *American Educational Research Journal*, 39(1), 165-205. <https://doi.org/https://doi.org/10.3102%2F00028312039001165>
- Winn, W. (2013). Cognitive perspectives in psychology. In *Handbook of research on educational communications and technology* (pp. 90-123). Routledge.
- Winn, W., Stahr, F., Sarason, C., Fruland, R., Oppenheimer, P., & Lee, Y. L. (2006). Learning oceanography from a computer simulation compared with direct experience at sea. *Journal of Research in Science Teaching*, 43(1), 25-42. <https://doi.org/https://doi.org/10.1002/tea.20097>
- Wood, D. (2003). The why? what? when? and how? of tutoring: The development of helping and tutoring skills in children. *Literacy teaching and learning*, 7, 1-30.
- Wood, D. (2010). *How Children Think and Learn, eTextbook*. John Wiley & Sons.
- Yesudhas, R., Lalit, P., Josy, A., & Impana, S. (2014). Water and Sanitation in Mumbai's Slums: Education through Inquiry Based Learning in Social Work. *Qualitative Report*, 19(45). <https://doi.org/https://doi.org/10.46743/2160-3715/2014.1110>
- Yin, R. K. (2009). *Case study research: Design and methods* (Vol. 5). sage.

- Yin, R. K. (2018). Case study research and applications. In: Sage Thousand Oaks, CA.
- Zacharia, Z., & Anderson, O. R. (2003). The effects of an interactive computer-based simulation prior to performing a laboratory inquiry-based experiment on students' conceptual understanding of physics. *American Journal of Physics*, 71(6), 618-629. <https://doi.org/https://doi.org/10.1119/1.1566427>
- Zhao, Y., & Frank, K. A. (2003). Factors affecting technology uses in schools: An ecological perspective. *American Educational Research Jjournal*, 40(4), 807-840.
<https://doi.org/https://doi.org/10.3102%2F00028312040004807>
- Zhou, Y., Zhang, H., & Stodolska, M. (2018). Acculturative stress and leisure among Chinese international graduate students. *Leisure Sciences*, 40(6), 557-577. <https://doi.org/https://doi.org/10.1080/01490400.2017.1306466>

ANNEXURES

Appendix A 1 - Ethical Clearance Certificate



22 March 2022

Luis Jose Bras (220109618)
School Of Education
Edgewood Campus

Dear LJ Bras,

Protocol reference number: HSSREC/00003719/2021

Project title: Science Teachers' Beliefs about the Use of Information and Communication Technology Simulations as a Form of Inquiry Based Science Teaching

Degree: PhD

Approval Notification – Expedited Application

This letter serves to notify you that your application received on 10 December 2021 in connection with the above, was reviewed by the Humanities and Social Sciences Research Ethics Committee (HSSREC) and the protocol has been granted **FULL APPROVAL**.

Any alteration/s to the approved research protocol i.e. Questionnaire/Interview Schedule, Informed Consent Form, Title of the Project, Location of the Study, Research Approach and Methods must be reviewed and approved through the amendment/modification prior to its implementation. In case you have further queries, please quote the above reference number. PLEASE NOTE: Research data should be securely stored in the discipline/department for a period of 5 years.

This approval is valid until 22 March 2023.

To ensure uninterrupted approval of this study beyond the approval expiry date, a progress report must be submitted to the Research Office on the appropriate form 2 - 3 months before the expiry date. A close-out report to be submitted when study is finished.

All research conducted during the COVID-19 period must adhere to the national and UKZN guidelines.

HSSREC is registered with the South African National Research Ethics Council (REC-040414-040).

Yours sincerely,



Professor Dipane Hlalele (Chair)

/dd

Humanities and Social Sciences Research Ethics Committee

Postal Address: Private Bag X54001, Durban, 4000, South Africa

Telephone: +27 (0)31 260 8350/4557/3587 Email: hssrec@ukzn.ac.za Website: <http://research.ukzn.ac.za/Research-Ethics>

Founding Campuses: ■ Edgewood ■ Howard College ■ Medical School ■ Pietermaritzburg ■ Westville

INSPIRING GREATNESS

Appendix A 2 - Declaration of Editing

Declaration of editing

Dr Nishaal Bhaw

BSc Chmical Engineering, MSc Phsyics Education, PhD

[REDACTED]

[REDACTED]

Title of edited text: Science Teachers' Beliefs about the Use of Information and Communication Technology Simulations as a Form of Inquiry-Based Science Teaching

Author/s: Luís José Brás

Date of editing: 4 December 2024

The editing service includes english editing and proofreading of the entire text, uniformity of layout. I also commnetd on aspects of language, academic style, content, contradictions or sentence construction.

Notes to the author:

- Changes and recommendations have been inserted by means of track changes.
- It is the responsibility of the author to ensure that all my recommendations are considered and either accepted or rejected to clear the track changes.

My best wishes for the successful completion of your PhD.

[REDACTED]

Nishaal Bhaw

Date: 5 December 2024

Appendix B 1 – Schools' Principal Consent Form



TRICHARDT SCHOOL
FOR
CHRISTIAN EDUCATION



Av. Base de N'Tchinga, N.º 55 - Maputo - Moçambique - Telefones/Faxes (258) 21 417688 / 21 416281 - Celular: [REDACTED] E-mail: office@trichardt.ac.mz

SCHOOL PERMISSION TO CONDUCT RESEARCH

September 15, 2021

Dear UKZN Institutional Review Committee

The purpose of this letter is to inform you that I give Luis José Bras permission to conduct the research titled **Science Teachers' Beliefs on the Use of Simulations as a Form of Inquiry Based Science Teaching** at Trichardt School for Christian Education in Mozambique. This also serves as assurance that this school complies with requirements of the Family Educational Rights and Privacy Act (FERPA) and the Protection of Pupil Rights Amendment (PPRA) (see back for specific requirements) and will ensure that these requirements are followed in the conduct of this research.

Sincerely,

[REDACTED]

Paulo Vijarona
Trichardt School General Director

Appendix B 2- Informed Consent Document – Teachers

Teachers Consent Letter

Dear Sir / Madam

15 September 2021

My name is **Luis José Brás** (student number 220109610). I am a PhD candidate studying at the University of KwaZulu-Natal, Edgewood Campus. Am studying under the department of Mathematics, Science and Technology Education. I am holder of BSc Ed (Eduardo Mondlane University) and Master of Science in Physics (Eduardo Mondlane University). My supervisor is Professor Nadaraj Govender in teaching and research in the discipline of Mathematics, Science and Technology. He can be contacted be on email: Govendern37@ukzn.ac.za.

You are being invited to consider participating in a study that involves exploring **Science Teachers' Beliefs on the Use of Simulations as a Form of Inquiry Based Science Teaching**. This research aims to explore teachers' beliefs on the use of simulations in teaching contexts and also explore how those beliefs are related to teacher pedagogical teaching activities on various factors teachers consider when deciding whether to integrate technology into their pedagogy. This involves exploring teachers' formative assessment practice and experiments using simulations to the grade 11 learners. This also involves observing teachers and pupils' interaction while using simulations and their teaching approaches.

Teachers will be observed during teaching through video recording to capture the behavior of the learners when engaging with simulations, how teachers assess the students' understanding of inquiry-based science teaching activities using ICT simulations and teachers teaching styles. Video recording is expected to complement interview data and give a much deeper understanding of the topic. All these activities will take place during the period for physical science grade 11 and is expected to last for three weeks. This study is funded by the University of KwaZulu Natal.

This study also involves learners in high school at FET level between 17 and 18 years. The major risk is learners participating in the study without their knowledge and consent. A consent form for their guardians explaining the involvement of their

child will have to be signed as they cannot consent on their own. Some teachers are not comfortable having their lessons video recorded and the issue of confidentiality will be observed to avoid any harm to privacy of practice. Their participation will have to be voluntary and they can choose to opt out of the study at any time. Another risk is exposure to Covid 19 to learners and study participants. Hence Covid 19 protocol has to be observed during the study. Additional information on Covid 19 can be found on this link [Safety in the workplace | South African Government \(www.gov.za\)](https://www.gov.za/safety-in-the-workplace) as well as [Education - Coronavirus COVID-19 | South African Government \(www.gov.za\)](https://www.gov.za/education-coronavirus-covid-19).

This study is expected to have the following benefits: Firstly, teachers will be exposed to a more robust way of using inquiry-based science approach when performing practical experiments. Secondly, teachers will have a better understanding of their pedagogical beliefs and how these beliefs can influence the use of simulations to enhance inquiry-based science. This study has been ethically reviewed and approved by the UKZN Humanities and Social Research Ethics Committee and the approval number is _____

In the event of any problems or concerns, you may contact the researcher at email: 220109618@stu.ukzn.ac.za cell number [REDACTED] Alternatively the following contact details can be used:

Humanities & Social Sciences Research Ethics Administration

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001

Durban

4000

KwaZulu-Natal, SOUTH AFRICA

Tel: [REDACTED]

Email: HSSREC@ukzn.ac.za

Please note that the information that you provide will be used for scholarly research only and that your participation is entirely voluntary. You have a choice to participate, not to participate or stop participating in the research at any time and no victimization or coercion will be used to make you participate. You will not be penalized for taking such an action. Video and audio recordings will be kept confidential and only used to generate data for this research project. Your views will be presented anonymously and neither your name nor identity will be disclosed in any form during and after the study. The records as well as other items associated with the research will be held in a password-protected file accessible only to me and my supervisor. After a period of 5 years, in line with the rules of the university, it will be disposed by deleting it permanently from all storage devices.

This project is designed not to give participants a cost. This is because data collection happens during normal school timetable. Participants are free to indicate if they need to be compensated for any costs incurred during the process of data collection. They are free to state and when they need the financial compensation.

Yours sincerely,

15-09-2021

Luis José Brás

Date

Teacher Consent Form

I _____ have been informed about the study entitled: **Science Teachers' Beliefs on the Use of Simulations as a Form of Inquiry Based Science Teaching**. The researcher is Luis José Brás.

I understand the purpose and procedures of the study.

I have been given an opportunity to answer questions about the study and have had answers to my satisfaction.

I declare that my participation in this study is entirely voluntary and that I may withdraw at any time without affecting any of the benefits that I usually am entitled to.

I have been informed about any available compensation or medical treatment if injury occurs to me as a result of study-related procedures.

If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher at (provide details).

If I have any questions or concerns about my rights as a study participant, or if I am concerned about an aspect of the study or the researchers then I may contact:

Humanities & Social Sciences Research Ethics Administration
Research Office, Westville Campus
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I hereby provide consent to:

Audio-record my interview / focus group discussion	YES / NO
Video-record my interview / focus group discussion	YES / NO
Use of my photographs for research purposes	YES / NO

Teachers Signature

Date

INSTRUMENTS

Appendix C 1- The Semi-Structured Interview Guideline

SEMI-STRUCTURED INTERVIEW GUIDE

Science teacher's background information

Participant's name					
1. Gender					
2. Age (Please tick)	Below 20 Years	20-25 Years	25-30 Years	Above 30 Years	
3. What are your academic qualifications?					
4. Your major subject area in your qualification.					
5. Years of Teaching Experience. (Please tick)	0-5	6-10	11-15	16-20	21 & above
6. How often do you use ICT simulations to teach science? (Please tick the most appropriate one).	Once in a week	Once in a month	Daily	Other	
7. How long have you been using ICT simulations in a classroom for?					
8. What Kind of ICT simulations are familiar with?					

Section A: Inquiry-Based Science Teaching (IBST)

1. Understanding IBST

- 1.1 How would you describe inquiry-based science teaching?
- 1.2 Do you think this approach to teaching is valuable? Why?
- 1.3 Do you believe that inquiry-based science teaching can be supported effectively with technology? Why?

2. Applications and Outcomes

- 2.1 What is your vision for ICT use within the school?
- 2.2 How do you make use of ICT in the classroom?
- 2.3 What kind of ICT simulation-enhanced inquiry-based science teaching activities have you done with your students?
 - Describe the activities and their specific outcomes.
- 2.4 How well do the ICT tools align with instructional strategies and content?

Section B: Technology Integration

3. Current Practices

- 3.1 What are some technology tools you use in your classroom?
- 3.2 Describe the ways you use these tools and how they support teaching and learning.
- 3.3 Which technology tool do you use the most, and why?
- 3.4 How has the classroom environment affected your integration of technology?

4. Barriers and Challenges

- 4.1 Can you describe situations where technology use was limited due to:
 - Lack of devices or technical support?
 - Insufficient time or knowledge?
 - Students' skills or classroom management challenges?

Section C: Teachers' Epistemological and Pedagogical Beliefs

5. Reflection on Teaching Practices

- 5.1 Briefly describe the last science lesson you taught.
- 5.2 What were the main teaching strategies used?

5.3 Was the lesson effective? Why or why not?

5.4 Was this lesson typical of your usual teaching style? If not, describe a typical lesson.

6. Beliefs Driving Practice

6.1 What are your pedagogical beliefs driving classroom practices?

6.2 What motivates you to use technology in teaching?

6.3 How do you assess students' understanding of IBST activities supported by ICT simulations?

Section D: Inquiry-Based Learning and ICT Simulations

7. Characteristics and Effectiveness

7.1 What are the key elements of a good IBST lesson?

7.2 What are the characteristics of effective inquiry-based science teaching?

7.3 How do you believe ICT simulations promote IBST? Please explain.

8. Assessment and Scaffolding

8.1 How do you assess students' understanding of IBST activities using ICT simulations?

8.2 What scaffolds do you provide (teacher-guided or ICT-supported)?

Section E: Curriculum and Policy Alignment

9. Science Curriculum Perspectives

9.1 Do you believe the science curriculum emphasizes content knowledge or methods of inquiry more?

9.2 Should the curriculum be relevant to students' environments and societal issues?

10. Influences on Teaching

10.1 How do policies and curriculum requirements affect your teaching methods?

10.2 What changes would you suggest to align policies with IBST practices?

Section F: Reflection and Future Directions

11. Challenges and Improvements

11.1 What are the biggest challenges you face in integrating IBST and ICT in your teaching?

11.2 What additional knowledge or skills would help you improve in this area?

Appendix C 2 – The Classroom Teaching Observation sheet

Classroom Teaching Observation Guide Sheet

1. Time of visit: _____
2. Date of visit: _____
3. Teacher: _____
4. School: _____
5. Visit No: _____
6. Class observed: _____
7. Description of science lesson: _____
8. Focus on lesson observation: _____

Time	Teacher's activities	Students' activities	Teachers teaching styles	Researcher's notes

Appendix C 3 – Reflection Session Schedule

Agenda Item	Description
Introduction & Purpose of Reflection	Briefly explain the purpose of the reflection session.
Overview of the Lesson	Ask the teacher provides a brief summary of the observed lesson, including its objectives and goals.
Teacher's Activities Reflection	Teacher reflects on their own actions during the lesson what went well, what could be improved.
Students' Activities Reflection	Discuss learners' engagement, participation, and responses. How did the learners interact with the lesson?
Teaching Styles and Methods Reflection	Teacher reflects on the teaching methods and strategies used. Were they effective in achieving the lesson's goals?
Researcher's Observations	The researcher shares their notes and provides feedback on the observed teaching practices and learners' engagement.
Strengths and Areas for Improvement	Discussion of the lesson's strengths and weaknesses. What went well, and what could be done differently?
Actionable Insights	Discuss specific strategies for improving future lessons. Set actionable goals for the teacher.
Closing & Summary	Summarize key takeaways from the reflection session and outline any follow-up actions or observations.

TEACHERS' ORIGINAL LESSON PLANNING SHEET

Appendix D 1 - Teacher António's Lesson Plan

Lesson Plan: Conservation of Mechanical Energy.^①

High School: Physics.

Duration: 90 minutes

Lesson Objectives

By the end of the lesson students should be able to:

- Analyze, Understand and apply how mass, friction and gravity affects energy, ~~mechanical energy and knowledge~~
- to predict and calculate energy changes in a simulated environment.

Materials

- Computer, Projector, Whiteboard, Paper, Pencil and Markers

Introduction

- ①
- List the main objectives of the lesson.

② Recap of previous knowledge. (10)

- Teacher asks learners to recall and define kinetic energy and gravitational energy.

1. Introduction to the PhET simulation (10)

- Explain how the simulation will be used to explore energy conservation.

2. Demonstration (10)

- Show how to change variable like mass, friction and gravity.
- Ask questions ~~to learners~~ like:
 - What happens to the skater's energy when we increase the mass?
 - How does adding friction affects ~~the~~ skater's energy?
 - What if we increase the gravitational force?

③

Guided Exploration (20)

3.1 Energy observation

- Have the learners observed the energy bar graph and pie chart in the simulation; ask the them.

Prediction and Validation

Encourage and guide learners to predict the skater's position or speed based on energy shown.

Calculation and Analysis (20)

- Provide information about the skater's energy at one position
- Ask learners to calculate the speed or height at a different position

Conclusion (10)

(4)

Discussion and Clarification

- Clarify any misconceptions and ensure learners understand the relationship between variables.
- Demonstrate the impact of changing the reference height on potential energy.

④ Independent Experimentation (20)

4.1 Designing a Skate Park

- Ask learners to design their own skate park using the stimulation.
- Instruct them to create a track and encourage consideration of height, mass, and friction in their designs.

4.2 Exploration and Engagement

- Allow learners to experiment with different designs and variables.

Conclusion : (10)

(5)

- Recap key concepts learned during the lesson.

Assessment

- Have learners submit their skate park designs along with explanations on how they used the concepts of energy conservation.

Homework.

Ask learners to write a short essay on the importance of energy conservation in real-life applications.

Appendix D 2 -Teacher Shantel's Lesson Plan

High School
Physics: Exploring Coulomb's Law
90 min

Objectives:

- (1) Understand the Principles of Coulomb's law with focus on charge magnitude, distance, and electrostatic force
- (2) Use PhET as an assisting visual

Key materials:

- Laptop for each student
- PhET simulation
- Projector

Introduction:

1. Introduce plan and objectives
2. recap Previous knowledge & Reinforce core concepts:
 - what makes a force attractive / repulsive?
 - Newton's 3rd law applied to electrostatic interactions?

Lesson outline:

1. Emphasize the relationship between charge magnitude, distance and electrostatic force.
2. Project the PhET simulation- Demonstrate how to manipulate variables and Pos questions. Allow learners to test hypotheses

Activities:

1. Learners explore simulation, ~~Test~~ scenarios and make observations
Key questions- what do you observe when increasing charge or adjusting distance?
2. Group discussion, share findings and guide learners through analysis

of observations: * Describe relationship between charge and electrostatic force as seen in the simulation.

* Explain the impact of distance on force

3. Provide scenarios for applied knowledge, encourage learners to design experiments to test their answers.

Conclusion:

recap key concepts, highlight real world application.

Assessment:

Submit summary of findings, include: observations, hypotheses and conclusion as well as answering the key questions discussed.

Homework:

1. Assign problems involving calculations of electrostatic forces using Coulomb's law.
2. Ask learners to write short essay on the significance of electrostatic forces in everyday life.

Appendix D 3 -Teacher Abel's lesson plan Topic

Grade: 10	
Teacher: [REDACTED]	
Electricty and Cincuits - chapter 16	
Topic: Circuit Construction using Phet	
Parameters	Description
Chapter Covered	Chapter 12: Electricty and Cincuits
Name of the Book	MIND ACTION SERIES, PHYSICAL SCIENCES
Learning Objective	By the end of this lesson students should be able to: → Identify different types of Electrical components and their Symbols using Phet → Differentiate between series and Parallel circuits. → Describe how to measure voltage, current and resistance.
Time Required	2 Periods of 45' each

Classroom Arrangement.	Seating arrangement → Flexible (for groups).
Materials Required	→ Smart class setup. → Whiteboard and marker. → Computers. → Good internet connectivity.
Pre-Preparation Activities	Keep the following resources ready before the session: → Circuit construction kit: AC-virtual lab.
Previous knowledge	Basic knowledge of the use of Electricity.
Methodology	→ Explaining Electrical Circuit by simulating on the website. → Explain the Basics of Electrical components. → Explain the science behind glowing of Bulbs. → The Teacher will cover the working of an Electrical switch. → The difference between series and Parallel circuits.

Appendix D 4 -Teacher José's lesson plan



Teacher:

Subject: Physics.

Grade Level: High school, middle school.

Duration: 90 minutes.

Keyword: Projectile motion, initial velocity, launch angle, Gravity
PhET Simulation.

Objectives:

By the end of the lesson learners should be able to:

- Understand the factors affecting projectile motion.
- Develop critical thinking and inquiry skills.
- Explore and visualize the trajectory of a projectile.

Materials:

- Laptops
- PhET simulation: Projectile motion
- Data projector
- Whiteboard.

Classroom Setup.

- Desks and chairs: arranged facing the front

Lesson outline (10 minutes)

Introduction (10 minutes)

- List main objectives of the lesson
- Engage prior knowledge, by asking engaging questions.

Activity procedure: Step 1: Concept explanation (15 minutes)

- Explain key concepts of projectile motion.
- Emphasize the importance of these factors in predicting and analyzing the path of a projectile.
- Provide real-life examples to contextualize the concepts.

Step 2: Simulation demonstration (10 minutes): Introduction to PhET simulation.

- Project the PhET Projectile Motion simulation on screen.
- Demonstrate how to manipulate variables.
- Demonstrate how to record observations and use simulation interface.

Step 3: Guided exploration (30 minutes): Hands-on activity

- Instruct learners to use
- ~~Instruct~~ Instruct learners to access the PhET simulator.
- Provide the steps for the initial experimentation.
- ~~Encourage~~ Encourage learners to record their observations and compare them to their predictions.

Step 4: Group discussion and analysis (20 minutes): Class-wide discussion.

- Facilitate a discussion to share findings.
- Analyze the results collectively

Step 5: Concept application (10 minutes)

- Ask application question.
- Provide scenarios for learners to apply their knowledge.
- Encourage groups to design their own circuits.

Conclusion (5 minutes).

- Recap concepts. - Summarize main points discussed during the lesson.
- Homework assignment: assign problems related to AC circuits for further practice.

Assessment.

- Monitor group activities and discussions.
- collect reflections for evaluation.
- Include a quiz or worksheet to test comprehension of key concepts.

Appendix D 5 -Teacher Paulo's lesson plan

DAILY LESSON PLAN

TEACHER	██████████
SUBJECT	PHYSICS
GRADE	HIGH SCHOOL
DURATION	90 MINUTES
TOPIC	EXPLORING ATOMIC INTERACTIONS USING PHET SIMULATION
Key Terms	Atomic interaction, Ionic Bonds, Van der Waals Forces, PhET Simulation
Lesson objectivesn	1. Understand different types of atomic interactions, including ionic bonds, covalent bonds and van der Waals forces. 2. Use the Phet Atomic Interactions simulation to explore Atomic interactions 3. Use the PhET Atomic interactions to visualize atomic interactions. 4. Develop critical thinking in exploring atomic interaction using group discussion 5. Enhance collaboration skills through group activities and presentation.
Teaching Aids	• Laptops (one per group of 4-5 learners) • PhET simulation: Atomic interactions • Data Projector • Whiteboard and Markers • Molecular model kits • Handouts with notes and lesson outline.
Teaching Methods	• Group discussion Method. • Lecture Method and Collaborative Learning

1. INTRODUCTION

(10 Minutes)

- The educator introduces the lesson by explaining atomic interaction and key terms.
- The educator divides the class into groups of 4 to 5 learners.
- The educator asks the question "What do you know about atoms interaction?"

2. LESSON DEVELOPMENT

	Activity	Material	Time
Step 1: Concepts in atoms interactions explained (Using the key terms)	• Explaining different types of atomic interaction: Ionic bonds, covalent bonds, and van der Waals bonds. • Each group assigned specific type of atomic interaction to investigate.	• PhET Simulation	10 Minutes
Step 2: Group Investigation	• Groups discuss their assigned atomic interaction. • Groups Prepares a short presentation	• PhET Simulation	20 Minutes
Step 3: Group Presentation	• Each group present their findings to class. • Learners ask questions and offer feedback	• PhET Simulation	20 Minutes

2

	• Compare and contrast different types of atomic interactions.		
Step 4: Practical Task: Molecular Kits	• Constructing models of atoms and molecules. • Probing: Show how an ionic bond is formed between sodium and Chlorine? • Probing: How does the shape of a molecule affect its interactions with other molecules?	• Molecular model kits	15 Minutes
Step 5: Phet Simulation and Interaction (Demonstration)	• Project the PHET Atomic interactions simulation onto the screen. • Probing: What do you think will happened if we increase temperature?	• Projector/Screen	10 Minutes

3. Conclusion:

- The educator summarizes the main points.
- The educator highlights practical application of understanding atomic interactions.
- The educator gives learners task to solve.

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4. Class Evaluation

- **Learners recorded observation are collected.**
- **Learners need to answer quiz or worksheet to test comprehension of key concepts.**

5. Educators Evaluation

- **The educator will give feedback (next class)**
- **The educator will monitor the progress of the groups and grade their presentations.**