EXPLORING THE DEVELOPMENT OF TSPCK OF GRADE SIX NATURAL SCIENCE AND TECHNOLOGY PRE-SERVICE TEACHERS: A CASE FOR MATTER AND MATERIALS

by

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This thesis is submitted in fulfilment of the requirements for the degree of Master's in education, in the Cluster of Science and Technology Education, University of KwaZulu-Natal, Durban, South Africa

Supervisor: Prof. B.P. Alant

June 2021

DECLARATION

I, **Ms Rosann Chantel Naidoo**, declare that

1. The research reported in this thesis, except where otherwise indicated, is my original research.

2. This thesis has not been submitted for any degree or examination at any other university.

3. This thesis does not contain other persons' data, pictures, graphs, or other information, unless specifically acknowledged as being sourced from other persons.

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Rosann Chantel Naidoo

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Student Name

June 2021

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Date

Professor Busisiwe Precious Alant

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Name of Supervisor

[redacted]

Signature

ETHICAL CLEARANCE LETTER

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

11 September 2019

Ms Rosann Chantel Naidoo (9401119)
School of Education
Edgewood Campus

Dear Ms Naidoo,

Protocol reference number : HSS/0439/019M
Project title: Exploring the development of TSPCK of Grade Five Natural Science and Technology pre-service teachers : A case for matter and materials

Approval Notification – Expedited Application

With regards to your response received on 03 September 2019 to our letter of 01 August 2019, the Humanities & Social Sciences Research Ethics Committee has considered the abovementioned application 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.

The ethical clearance certificate is only valid for a period of 3 years from the date of issue. Thereafter Recertification must be applied for on an annual basis.

I take this opportunity of wishing you everything of the best with your study.

[redacted]

Yours faithfully

[redacted]

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ABSTRACT

The literature suggests that pre-service teachers lack an integrated Natural Science and Technology pedagogical content knowledge and as a result cannot make good pedagogical decisions in classroom practice. This study argues for the place and space of adequately trained Natural Science and Technology specialists with an integrated understanding of Natural Science and Technology, who can plan, design, implement, and reflect on suitable instructional strategies and classroom activities that would promote the envisioned integrated curriculum for the Intermediate Phase. It therefore endeavoured to understand the process of engagement and the types of understandings that come to the fore when pre-service Natural Science and Technology teachers are exposed to active learning aimed to develop their topic-specific pedagogical content knowledge in an integrated way. The focus was on Matter and Materials and Processing in the knowledge strands of Natural Science and Technology. Using an exploratory case study methodology, the study addressed the following two questions:

(i) How do we engage Grade 6 Natural Science and Technology pre-service teachers to elicit their understanding of an integrated Natural Science and Technology curriculum through concept mapping? and

(ii) *How do Grade 6 Natural Science and Technology pre-service teachers represent their understanding of an integrated Natural Science and Technology curriculum through concept mapping?*

W.r.t. Research Question 1, the four-phase engagement process of using concept mapping by Wang which was adapted to three for the purposes of this study, showed that when these phases are combined with a framework of Topic specific Pedagogical Content Knowledge as proposed by in the literature, does indeed, promote the graphical representation of facts, concepts, and relationships; aids in the construction and retainment of knowledge as well as clarity and a deeper meaning of knowledge through communication. After the concept mapping activity was completed, the Grade 6 Natural Science and Technology pre-service teachers had a full view of their prior Grade 4 to 6 Content Knowledge in topics and concepts pertaining to Matter and Materials and Processing. This holistic view of the concept maps also exposed to the Grade 6 Natural Science and Technology pre-service teachers' various gaps in their prior Grade 4 to 6 Content Knowledge and misconceptions that may have possibly formed earlier on in primary school. The findings suggest that Natural Science and Technology pre-service teachers' understanding of an integrated Natural Science and Technology curriculum could be elicited

by engagement using instructional strategies and a concept mapping activity to promote the development of an integrated Topic Specific Pedagogical Content Knowledge in Matter and Materials in Natural Science and Processing in Technology.

W.r.t. Research Question 2, two understandings of integration were elicited which were spread through the eight categories.

- Understanding 1: Integration of two processes: the scientific and design processes
- Understanding 2: Integration of various Natural Science and Technology topics and concepts.

Understanding 1 was held by nine (22,5%) pre-service teachers, whilst Understanding 2 was held by 31 (77,5%). The first understanding was derived from one category where an integrated NST was perceived as an: Integration of two processes: Scientific and Design processes. The second understanding was derived from seven categories, where an integrated Natural Science and Technology was perceived as the integration of Grade 4 to 6 Natural Science and Technology topics and concepts. It is significant to note that it is these nine pre-service teachers in Category 1, who successfully identified the problematic (lack of provisions of clean water in rural contexts) and applied their understanding of an integrated NST curriculum to solve an authentic, real-world context (in this case, the water and sanitation problems in the uGu district in the KZN region).

This study offers a glimpse into the opportunities that could be afforded when Natural Science and Technology pre-service teachers acquire a deep conceptual understanding of these two subject disciplines. They could, make good pedagogical decisions on designing effective activities related to evolving Content Knowledge to teach the integration of *Natural Science and Technology*. In teaching practice, Natural Science and Technology pre-service teachers who have developed a strong Pedagogical Content Knowledge of integrated Natural Science and Technology will begin to motivate Intermediate Phase learners to see relevance and importance of studying science and technology in high school and higher education. Consequently, these learners will follow science and technology career paths and may possibly become prolific citizens who could contribute to our country's science, technology and innovation in the future.

DEDICATION

This thesis is dedicated to my parents, Paul and Rumila Valayudum, and my son, Keenan Joshua Naidoo, who gave me the motivation, encouragement, and time to complete this study.

Thank you, Lord, for my wonderful family.

I feel truly blessed to have them in my life. I am eternally grateful to you for all that you have done for us over the years.

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First and foremost, I would like to thank the Almighty God for his wisdom and grace during my study. He has been my strong tower and my fortress on both good and bad days, and I am forever grateful to him for his guidance and love that he has shown me in all areas of my life.

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I am grateful to have worked with Dr. Lee-Anne Roux who assisted me with the final editing of my thesis. May you be blessed in all your future endeavours.

I want to acknowledge the Independent Institute of Education for providing funding and Mrs Yenusha Ramluggan, for her support during my study.

I want to thank the Grade 6 NST pre-service teachers who willingly participated in my study. Also, for their participation in the classroom discussions, concept mapping activity, and suggested NST activities. The Grade 6 NST pre-service teachers' contributions to my study have been significant and invaluable to the development of an integrated NST curriculum in the future.

A sincere appreciation goes to my siblings, Rochelle, and Christopher, as well as close friends and colleagues who encouraged and motivated me throughout my studies. May you grow from strength to strength and achieve all your goals and aspirations in the future.

A special thanks is extended to my father, Paul Valayudum, who always listened and believed in my future goals and aspirations. Both my parents made many sacrifices to ensure that I followed my passion for Chemistry and my development in the field of science and technology education. I would also like to thank both my parents for instilling within me Christian morals and values so that I could use my knowledge to become an empowered individual, and hence, make a meaningful contribution to society in the field of science and technology education. May God Almighty bless you both and fulfil your wishes.

I also want to thank you, my son, Keenan Joshua Naidoo, for your understanding and the many sacrifices that we endured during my studies. Life has been challenging. I believe that God has blessed me with a son like you so that you could be my pillar of strength. I am hoping that we will spend many more happy days together and I have faith that God will grant us the desires of our hearts in the future.

LIST OF ABBREVIATIONS/ACRONYMS

ALC	Active Learning Classrooms
ASTA	Australian Science Teachers Association
B.Ed.	Bachelor in Education
C2005	Curriculum 2005
CAPS	Curriculum and Assessment Policy Statement
CBC	Content Based Curriculum
CK	Content Knowledge
CM	Concept Mapping
DoBE	Department of Basic Education
DTE	Design, Technology and Engineering
GAC	Granulated Activated Carbon
HE	Higher Education
HEI	Higher Education Institution
ICASE	International Council of Associations Science Education
IDMEC	Investigate Design Make Evaluate Communicate
KZN	Kwa-Zulu Natal
MLT	Meaningful Learning Theory
MSE	Materials Science and Engineering
NCS	National Curriculum Statement
NPC	National Planning Commission
NS	Natural Science
NST	Natural Science and Technology

OBE	Outcomes-based education
PCK	Pedagogical Content Knowledge
PST	Pre-service Teacher
RNCS	Revised National Curriculum Statement
ROSE	Relevance of Science Education
SAFI	select-and-fill-in
SASA	South African Sugar Mill Association
STEM	Science Technology Engineering and Mathematics
TECH	Technology
TIMMS	Trends in International Mathematics and Science Study
TNST	Teaching Natural Science and Technology
TSPCK	Topic specific Pedagogical Content Knowledge
UKZN	University of Kwa-Zulu Natal
UNESCO	United Nations Educational, Scientific and Cultural Organization
USA	United States of America
ZPD	Zone of Proximal Development

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CHAPTER 1

CONTEXTUAL BACKGROUND TO THE STUDY

Introduction

The South African education system has undergone many curriculum changes over the years. These changes include a shift, after the dawn of the new political dispensation in South Africa in 1994, from a content-based curriculum (CBC) towards an outcomes-based education (OBE) in 1995 to Curriculum 2005 (C2005) launched in March 1997 and NCS in 2004 to the introduction of CAPS (2011) in 2012. While C2005, on the one hand, was launched to shift the outdated content-based and exam-oriented curriculum of the past to OBE, as described by Killen (2016) in an attempt to encourage scientific literacy and critical thinkers in the country. CAPS, on the other hand, aimed to provide equal access to basic education for all citizens (Killen, 2016). Furthermore, the introduction of Technology in 1998 as a subject discipline was meant to address the shortage of skills and the need for professionals in the fields of science, technology, mathematics, and engineering (STEM) in South Africa. According to a report by Taylor and Schindler (2016) in South Africa, Grade 9 and 11 learners drop-out from high school and are either absorbed into technical colleges or are employed in the labour market. Consequently, these learners do not even reach completion of Grade 12 for entry into higher education (HE).

When Technology was introduced into the South African schools, a recommendation was made that it should be offered for the first nine years of pre-tertiary education as a compulsory subject and for the last three years as an optional subject (Ankiewicz, 1995). Ankiewicz (1995, p. 245) argued that technology education can make an important contribution to South African education "if the so-called 'technological process' is the major emphasis as this can be transformative and promote quality education". Potgieter (2004) pointed out that the implementation of technology education could impact the lives of teachers and learners by improving their problem solving and communication skills in relevant contexts. However, he emphasised the need for more research to be done on the inclusion of technology education in teacher training programmes as technology education was not included in past teacher training programmes. As a result, many in-service teachers could not engage learners in conceptual understanding of technology topics and concepts, such as the design process.

Thus, the change to CAPS in 2012 to redress past injustices, brought about a paradigm shift in primary schools. The implementation of Natural Science and Technology (NST) previously taught separately in primary schools had to be taught as one integrated subject in Grades 4 to 6 according to Linn et al., (2016). According to Linn et al., (2016) an integrated curriculum was introduced to combine NST in primary schools as one subject discipline, and thus, develop holistic learners in this way. In the Senior Phase (Grades 7 to 9), NST are taught separately so that learners would choose science or technologically oriented courses for subject specialisation in Grades 10 to 12, which would prepare them to enter the science and engineering disciplines in HE. Since the introduction of an integrated NST curriculum in South Africa in 2012, many researchers across the world (Booi & Khuzwayo, 2018; Linn et al., 2016; Mesutoglu & Baran, 2020; O'Grady, 2014; Stears et al., 2011) have welcomed the integration of TECH and NS into the curriculum. It was anticipated that if NST were taught in primary schools as one subject discipline by suitably qualified and trained specialist NST primary school in-service teachers, then primary school learners in Grades 4 to 6 may have a deeper conceptual grasp of NST and later want to study academic disciplines such as science and engineering in HE.

Khanyile's (2016) study which explored Grade 6 educators' understanding of an integrated NST revealed that although the Grade 6 educators understood, to some extent, the term 'integration', they lacked a basic understanding of the principles and ideas upon which the NST can be integrated to become one learning area. This was due to NST pre-service teachers (PSTs) not being trained in prior teacher training programmes on how to design and implement effective integrated NST lesson plans by "expert pedagogues" (Khanyile, 2016, p. 3). Arguing along the same lines, Booi and Khuzwayo (2018) assert that many in-service NST teachers in South Africa are not qualified as specialists in both Natural Science (NS) and Technology (TECH), and thus find it challenging to teach these two subject disciplines in an integrated way. In addition, in the past, these "underqualified" in-service teachers received their training in the teaching of either NS or TECH disciplines only, and were unskilled in the teaching of an integrated NST curriculum to Intermediate Phase learners which required that both NS and TECH be taught as one subject (Bantwini, 2010). Maryani and Martaningsih (2015) opine that in-service teachers' understanding of the curriculum depends on their PCK. They further argue that most in-service teachers might not have been suitably trained as experts in PCK to teach difficult topics in NST, leading to a lack of topic-specific pedagogical content knowledge (TSPCK). Without gaining proper training and specialisation in an integrated NST curriculum, in-service teachers presently cannot critically assess the NS and TECH topics and concepts contained in any policy documents or learning resources (Mathai, 2014) to help learners to gain a deeper understanding of the integrated NS and TECH curriculum.

This study thus aimed to understand the process of engagement and the types of understandings that come to the fore when NST PSTs are exposed to active learning which helps them develop the necessary TSPCK in thinking about an integrated NST, with a particular focus on Matter and Materials and Processing. The study tested the waters with NST PSTs to see the kind of understanding of an integrated NST that is brought to bear if these PSTs are engaged in active learning through peer interaction focussed on TSCK in a lecture setting.

1.1 Problem Statement

Mavhunga (2014) as well as Mavhunga and Rollnick (2013) assert that PSTs lack integrated NST pedagogical content knowledge (CK) and therefore cannot make good pedagogical decisions in classroom practice. Taylor and Schindler (2016) thus urge higher education institutions (HEIs) to review their initial teacher training programmes where PSTs could be trained in the teaching of NST as a field of specialisation (Taylor & Schindler, 2016). The argument is that initial teacher training programmes at South African HEIs are not equipping PSTs with the required PCK, and thus, the quality of primary and high school education is compromised (Mentz & Steyn, 2008; Taylor & Schindler, 2016). According to Pitjeng (2014), PSTs need to be trained in TSPCK which may lead to an understanding of how to teach topics in NST in an integrated way. Researchers such as Mavhunga and Van der Merwe (2017) opine that TSPCK in Matter and Materials and Processing can be further developed by NST specialists using instructional tools such as concept mapping activities (Romero et al., 2017) and co-operative learning (Malatji, 2016) to promote the understanding of an integrated NST curriculum for Grades 4 to 6 (Department of Basic Education (DoBE), 2011) in future NST PSTs in HE in South Africa.

The problem of the NST PSTs' lacking prior NST CK in topics and concepts in Grades 4 to 6, is seen in this study as having the potential to affect their development of PCK in teaching NST as an integrated subject discipline when they become in-service teachers in the future. It is in this regard that this study embarked on exploring the development of TSPCK of Grade 6 NST PSTs', with a particular focus on Matter and Materials and Processing.

1.2 Rationale

I am a teacher trainer and lecturer of the Bachelor of Education (B.Ed.) programme at an independent private HEI in Westville, KwaZulu-Natal (KZN). Prior to entering higher education (HE), I was a NST educator with a background in Chemistry and taught in primary and high schools in the Durban South area in KZN. I noticed that in primary schools, the Intermediate Phase Grade 4 to 6 learners were eager to learn NST topics and concepts that involved Life and Living and Earth and Beyond. However, the Grade 4 to 6 primary school learners expressed difficulties in learning NST topics in Matter and Materials, Processing and Systems and Control possibly due to the abstract nature of the topics and concepts contained within these knowledge strands. In the General and Education Training (GET) band in high schools, I discovered that the problem of negative perceptions towards the learning of NST topics and concepts in Matter and Materials and Processing continued into Grade 7 to 9. The Grade 7 to 9 learners whom I taught both NS and TECH, reported to me that they had no intentions of studying science and technology in HE. I concluded from my interaction with the Grade 7 to 9 learners during the NST lessons, that their negative perceptions and disinterest in pursuing careers in the science and technology field, may have resulted from a lack of Grade 4 to 6 foundational primary school NST prior knowledge of topics and concepts in chemistry and processing. I started exploring and implementing interactive learner-centred teaching and learning strategies during my NST lessons. The purpose was to assist the Grade 7 to 9 NST learners to build on their Grade 4 to 6 NST prior knowledge and promote an integrated understanding of Grade 4 to 6 NST topics and concepts.

When I transitioned into HE as a teacher-educator at a private independent HEI, I realised that the NST PSTs studying the B.Ed. degree, also held similar negative perceptions to NST as the learners that I had taught in high schools. The NST PSTs also found it challenging to recall prior knowledge in NST topics and concepts from Grades 4 to 6. This was concerning as many of the NST PSTs reported to me that they had not been taught NST topics and concepts in an integrated way. It was challenging to recall and apply their NST CK to assessments and that their NST teachers used direct instruction and only taught either NS or TECH separately.

1.3 Significance of the Study

Future teacher training programmes must prepare and develop Grade 6 NST PSTs to become NST specialists who are able to introduce conceptual understanding of an integrated NST curriculum to Intermediate Phase learners in primary schools across South Africa (Bantwini, 2010; Fraser, 2015). If an integrated NST TSPCK is also developed successfully in these qualified Grade 6 NST PSTs, then this may assist in reducing the early formation of negative attitudes and misconceptions in primary school learners in South Africa (Bantwini, 2010; Botha & Rens, 2018; Taylor, 2011; Taylor & Schindler, 2016).

Grade 6 NST pre-service teachers' TSPCK can be developed in the topic of Matter and Materials in NST in an integrated way by implementing suitable instructional strategies, like using a concept map (CM) (Wang, 2019), whole class and small group discussion, and peer interaction through co-operative learning (Arthurs & Kreager, 2017; Mapplebeck & Dunlop, 2019). The various instructional strategies combined with a good integrated TSPCK in Matter and Materials and Processing could equip Grade 6 NST PSTs to better prepare primary school learners to understand other difficult topics and concepts relating to the particle nature of matter and structures in an integrated way. An improved conceptual understanding of the topic of Matter and Materials and Processing will not only benefit Grade 6 NST teachers but also the primary school learners that they teach during their teaching experience period in schools.

Grade 6 NST PSTs will also be better equipped to teach other topics in NST, such as particle nature of matter and structures in an integrated way, which means that they need to develop a strong integrated TSPCK in topics such as Matter and Materials first. Overall success in the improvement of Intermediate Phase primary school learners' TSPCK in topics such as Matter and Materials and Processing could also be assessed and monitored in the TIMMS global assessment and the South African NST Olympiads. The annual matric National Senior Certificate (NSC) diagnostic results in subjects such as physical science, engineering, and graphics design would also report on the progress of primary school learners in high school and whether the development of an integrated TSPCK in NST in primary school was successfully established in primary school. HE institutions would experience a "ripple effect" where more matriculants would want to take up studies in the science and engineering disciplines, hence making South Africa a global competitor in the field of science and technology.

1.4 Aim and Objectives of the Study

The main **aim** of the study was to use a case study to explore the development of TSPCK in Grade 6 NST PSTs in the topics and concepts pertaining to Matter and Materials in NS and Processing in TECH as stipulated in the CAPS for Grades 4 to 6 (DoBE, 2011).

The **objectives** of this study were to**:**

a) To facilitate the engagement of NST PSTs in a CM activity to elicit their understanding of an integrated NST curriculum.
b) To obtain insights into how NST PSTs' understand an integrated NST curriculum using a CM activity.

1.5 Research Questions

The following research questions were formulated for this study:

1) How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?

2) How do NST pre-service teachers represent their understanding of an integrated NST curriculum?

1.6 Research Methods/Approach to the Study

1.6.1 Qualitative inquiry

A qualitative approach with an exploratory case study design was employed in this study. Qualitative methods, as suggested by Merriam (2009), are used to gain a deeper understanding of individuals' perceptions regarding a particular phenomenon. Merriam (2009) defines a case study as an in-depth description and analysis within a bounded system (pp. 40-41).

A case study design was deemed suitable as it seeks to explore and understand the meaning individuals ascribe to a social or human problem (Creswell, 2014; Maree, 2016). In this study, Grade 6 NST PSTs' understanding of an integrated NST curriculum was elicited through a process of engagement using active learning and peer interaction. The results of the data from the eight categories of the Grade 6 NST individual CMs were analysed. The findings also provided a description of how the Grade 6 NST PSTs represented their understanding of an integrated Grade 6 NST curriculum using CMs as an instructional tool. The study was based on the TSPCK model and studies proposed by Mavhunga and van der Merwe (2017) in the exploration of Grade 6 NST PSTs' development of an integrated TSPCK in topics and concepts pertaining to Matter and Materials and Processing of an integrated Grade 6 NST curriculum as laid out in the CAPS document for the Intermediate Phase (DoBE, 2011).

An exploratory case study methodology (Creswell, 2014) was also followed for data collection and thematic analysis of the NST PSTs' understanding of an integrated NST curriculum and how they represented their understanding using CMs. Braun and Clarke (2006) advocate that thematic analysis is a flexible and widely used approach in qualitative research studies. It is used to identify, analyse, organise, describe, and report on themes and emerging patterns from the data collection set.

1.6.2 Research protocol

All necessary procedures and protocol were observed in line with the University of KwaZulu-Natal's (UKZN) ethical requirements to conduct this study.

1.6.3 Data collection

According to Maree (2016), qualitative research uses "purposive sampling" (p. 198) where participants are chosen for a case study have a particular purpose and criteria in mind and represent a "phenomenon, group, incident and location" (p. 85). The participants for the study initially consisted of 48 male and female Grade 6 NST PSTs from a diverse cultural and socio-economic background who attended both public and private schools around the Durban area. However, data was collected from only 40 who submitted their CMs.

1.6.3.1 Phase one

To explore how we can develop the PSTs' understanding of an integrated NST curriculum. Phase one explored the various stages of engagement which were aimed at eliciting the PSTs understanding of an integrated NST curriculum.

In line with Wang's (2019) model of the practical application of a CM activity, the following three phases were used:

- the preparation phase;
- the interactive phase;
- the feedback and evaluation phase.

The first phase requires the teacher to plan and prepare by setting clear objectives for the activity. A suitable structure of the CM must be prepared by the teacher before the activity containing the concepts under the theme of the learning unit that students should know to form the concepts. The content, concepts and themes must be aligned to the textbook content. The second phase is where the teacher explicitly explains the objectives and the intended purpose and meaning of the activity. In the last phase, students engage in a peer review process where students mark each group's CM according to a rubric or rating scale provided by the teacher. The data from the first phase was collected during the elicitation of Grade 6 NST PSTs' understanding of an integrated NST curriculum through a process of engagement using active learning, peer interaction, and a CM activity. Data was collected during 2-hour lecture sessions over five weeks (from the 1 October 2019 to 1 November 2019). Data was collected during the following 4 activities:

Activity 1: Eliciting Prior knowledge of Term 2 Grade 6 NST topics on Matter and Materials and Processing through peer interaction in groups of three on 4 October 2019.
Activity 2: Whole class Feedback on Activity 1 on the 4, 7 and 8 October 2019.
Activity 3: Construction of PSTs' understanding of an integrated NST curriculum as derived from CM – on the 18th October 2019.
Activity 4: Feedback on the construction of PSTs' understanding of an integrated NST curriculum as derived from CM – on the 24, 25 and 31 October 2019.

1.6.3.2 Phase two

To explore how Grade 6 NST PSTs teachers organised, connected, and synthesised their integrated knowledge of the Grade 6 NST curriculum through the use of CMs. This phase used a "select-and-fill-in" (SAFI) qualitative approach to concept mapping was used. A qualitative approach had to be taken because of the nature of topic explored: Grade 6 NST PSTs' understanding of an integrated NST curriculum. We explored the qualitatively different ways in which the 40 NST PSTs conceptualised the integration by looking at the following questions:

(i) What was foregrounded in terms of what is being integrated?
(ii) Which NS and TECH topics and concepts are foregrounded i.t.o. CAPS and OTHER?
(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

Table 1.1 below represents the rubric that was used to collect the data for Research Question 2.

Table 1.1 Rubric used to elicit NST PSTs understanding of an integrated Science and Technology curriculum

Category 1	Integrated NS and TECH	NS Strand - CAPS	NS Strand - OTHER	TECH Strand - CAPS	TECH Strand - OTHER	Linking NS to TECH
PST CM Response	What is being integrated?	Topics/concepts w.r.t. CAPS	Topic/concepts w.r.t. OTHER	Topics/concepts w.r.t. CAPS	Topics/concepts w.r.t. OTHER	How are the two being linked?

1.6.4 Data analysis

Thematic analysis was conducted using Braun and Clarke's (2006) six step process in which Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing as contained in CAPS were analysed. The six steps involved:

(i) The initial familiarisation of the Grade 4 to 6 NST topics and concepts that were written in the CMs.

(ii) Coding was used to identify NST topics and concepts pertaining to Matter and Materials and Processing in Grade 6 Term 2

(iii) The NST topics and concepts in Matter and Materials and Processing were then organised according to the themes, sub-themes, and codes.

(iv) Themes were checked against the sub-themes and codes to gain a deeper meaning of the 40 CMs.

(v) Ongoing revision of the themes, sub-themes, and codes generated defined themes and names for the data set.

(vi) A final report on the eight categories from the data analysis was compiled and presented by the use of graphical representations and narratives in relation to the themes, research questions, and literature presented in the study.

The presentation and analysis of the Grade 6 NST PSTs understanding of an integrated NST curriculum was carried out in two phases:

Table 1.2. below provides a presentation of the summary of the findings that emerged from the data analysis of the eight categories of the Grade 6 NST PSTs contained in their 40 CMs with regards to their understanding of an integrated curriculum.

Table 1.2 Presentation of the summary of the findings that emerged from the data analysis of the eight categories of the Grade 6 NST PSTs contained in their 40 CMs

SUMMARY OF FINDINGS

2	3	4	5	6	7	8
Matter and Materials (NS) and Processing (TECH)	Matter and Materials (NS) and Processing (TECH)	Matter and Materials (NS) and Water Pollution (TECH)	Arrangement of Particles (NS) and Processing (TECH)	Raw Materials (NS) and Man-made or Manufactured Materials (TECH)	Raw Materials (NS) and Man-made or Manufactured Materials (TECH)	Various Topics (NS) and Various Topics (TECH)
It is an integration of the Grade 6 NS topics of Dissolving , Mixtures and water resources and Grade 6 TECH topic of processes to purify water and the concept of clean water.	It is an integration of the Grade 6 NS topic of Solids, liquids and gases , Mixtures and water resources, concepts of the arrangement of particles and Grade 6 TECH topic of processes to purify water and concept of clean water supply.	It is an integration of Grade 6 NS topic of Mixtures and Solutions as special mixtures, concepts of soluable substances and saturated solutions and Water Pollution with a particular focus on the topic of Separation. Also, includes the integration of Grade 6 TECH topic of processes to purify water.	It is an integration of Grade 6 NS concepts of arrangement of particles, mixtures of materials, solutions and the Grade 6 TECH topic of processing with a particular focus on the concept of crystallisation	It is an integration of NS & TECH Grade 5 topics and concepts	It is an ntegration of NS & Tech Grade 5 topics and concepts	It is an integration of different NS & Tech topics and concepts from Grades 4 to 6
7,5%	10%	10%	10%	17,5%	12,5%	10%

Phase one explicated Research Question 1 which set out to explore: **"How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?"**

Grade 6 NST PSTs' understanding an integrated NST curriculum was explored during phase one as stipulated in the NST CAPS for the intermediate phase Grades 4 to 6 (DoBE, 2011). Instructional strategies involved a constructivist principle and student-centred approach of facilitation and mediation using whole class and small group discussions, co-operative learning, and a concept mapping activity. Grade 6 NST pre-service teachers' TSPCK in Matter and Materials and Processing, as well as the misconceptions and gaps in prior knowledge of an integrated Grade 4 to 6 NST curriculum was further explored using a three-phase practical concept mapping activity (Wang, 2019). Two understandings of integration were elicited which were spread through the eight categories.

- *Understanding 1: Integration of two processes: the scientific and design processes*

- *Understanding 2: Integration of NST – there is a variation in the way the groupings of PSTs described the topics and concepts on their CMs.*

Understanding 1 was held by nine (22,5%) PSTs, whilst understanding 2 was held by 31 (77,5%) PSTs. The first understanding was derived from one category where an integrated NST was perceived as an: Integration of two processes: Scientific and Design processes. The second understanding was derived from 7 categories, where an integrated NST was perceived as the integration of Grade 4 to 6 NST topics and concepts.

Phase two expounded Research Question 2 intended to explore "How do NST pre-service teachers represent their understanding of an integrated NST curriculum?"

During phase two, a SAFI approach was taken in which the Grade 6 NST PSTs where the Grade 6 NST PST, 40 CMs were collected and the Grade 4 to 6 topics and concepts pertaining to Matter and Materials and Processing were analysed. The Grade 6 NST PSTs' individual CMs were analysed to determine how the Grade 6 NST derived and represented their understanding of an integrated NST curriculum in the teaching of topics and concepts pertaining to Matter and Materials and Processing. The Grade 4 to 6 NST topis and concepts and propositions were arranged hierarchically from basic to more complex. Using linking words and crosslinks an understanding of the relationships between two or more NST topics and concepts (Novak, 2008), resulted in a meaningful visual representation of a SAFI CM. The data from the 40 CMs were read repeatedly to gain a better understanding of the participants' responses and the identification of key topics, concepts, and possible gaps in their Grade 6 CK of Matter and Materials and Processing. The important Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing from CAPS were ordered and categorised, then organised and sorted into categories to reveal the various themes and the NST PSTs' understandings of an integrated NST curriculum. My supervisor assisted me in the validation of the presentation and analysis of the eight categories of data as described and explained in detail in Chapters 5 and 6. It must be highlighted that the data validation process with my supervisor took a long time as we had to go back and forth to read and analyse the themes, sub-themes, and codes carefully until we were satisfied with the alignment of the data with the respective categories that emerged. The categories represented two understandings of integration that were elicited and there were variations in the two understandings through the eight categories.

1.7 Outline of The Study

This study consists of seven chapters, which are organised as follows:

Chapter 1: Contextual background to the study

Chapter 1 provides an overview of the purpose and rationale for carrying out this study. Included is an explanation of the problem statement, the significance of the study, and research methodology employed to answer the research questions and achieve the aim and objectives of the study. The forthcoming chapters are also outlined, providing a 'roadmap' of what is to come.

Chapter 2: Literature review

Chapter 2 presents the literature review of the study pertaining to integration and case studies of integrated NST curricula both locally and internationally. In addition to discussing the historical context of Beane's integrated democratic curriculum, the chapter also explores the use of instructional strategies that could promote the implementation of an integrated NST curriculum in the future.

Chapter 3: Theoretical framework

Chapter 3 provides the theoretical framework of the development of TSPCK in Grade 6 NST PSTs.

Chapter 4: Research methodology

Chapter 4 gives a detailed description of the research design and methodology employed in this study. A qualitative approach was adopted because of the nature of the topic explored: Grade 6 NST PSTs' understanding of an integrated NST curriculum. Herein, the qualitatively different ways in which the NST PSTs conceptualised the integration of topics and concepts pertaining to Matter and Materials and Processing were explored further.

Chapter 5: Process of eliciting Grade 6 NST pre-service teachers' understanding of an integrated NST curriculum

Chapter 5 deals with the presentation and analysis of the data obtained using the individual CM during a three-phase engagement process using social peer interaction, whole class and small group discussion, and co-operative learning. Each Grade 6 NST pre-service teacher's CM was analysed and placed into eight categories to answer the research questions in this study.

Chapter 6: Presentation of the results of the concept maps

Chapter 6 provides a description and discussion of the interpretation of all sources of data relating to answering both research questions posed in this study. The results were presented using graphical representations of eight categories. A "select-and-fill-in" (SAFI) qualitative approach to concept mapping had to be taken because of the nature of the topic explored: *Grade 6 NST PSTs' understanding of an integrated NST curriculum*. The qualitatively different ways in which the NST PSTs conceptualised their understanding of integration in Matter and Materials and Processing was explored in detail.

Chapter 7: Researcher's Reflections on the findings

This chapter seeks to provide a case for the teaching of difficult topics in NST. It provides my reflections as a researcher on the affordances and challenges of the process of engagement that was used to elicit the NST PSTs' understanding of an integrated NST. It argues for the place and space for a trained specialist NST teacher with an integrated understanding of Matter and Materials and Processing that could plan, design, implement, and reflect on using suitable instructional strategies and classroom activities that would promote an understanding of the required NST concepts of matter and materials, and processing to PSTs, as contained in CAPS (DoBE, 2011) for the Intermediate Phase.

Chapter 8: Discussion of findings, recommendations, limitations & conclusion

Chapter 8 presents the findings, implications, recommendations, limitations and conclusions of the study to a wider educational context. It indicates whether the Grade 6 NST PSTs in this study reached an understanding of an integrated Grade 6 NST curriculum and how they represented their understanding in the topics and concepts of Matter and Materials in NS and Processing in TECH using a concept mapping activity. Chapter 8 also highlights how the findings could be beneficial in providing future insights into the development of an integrated NST curriculum that is envisioned for primary schools in South Africa.

1.8 Conclusion

Chapter 1 introduced the topic under study and comprised the background, context, aim and objectives, rationale, and research questions. Included was a brief description of the research design and methodology utilised in this study. The penultimate section provided an overview of the forthcoming chapters, followed by a brief conclusion to wrap up the chapter.

The next chapter presents the literature that guided the research on NS and TECH education and the use of CMs in the development of an integrated TSPCK in this study.

CHAPTER 2

LITERATURE REVIEW

Introduction

A growing body of research globally supports the shift from science education taught in isolation to one of teaching science in combination with technology education, also called "integration" (Dowden, 2007; Khanyile, 2016; Linn et al., 2016; Loepp, 1999; Mesutoglu & Baran, 2020; Snyder, 2018; Stears et al., 2011). This chapter reviews the literature on NS and TECH education in order to address the aim of the study which is to explore Grade 6 NST PSTs' understanding of an integrated NST curriculum.

The structure of the chapter is as follows. The first part considers the various understandings of the integrated curriculum as presented in the literature (section 2.1). This is followed by a review of the three models of integration (section 2.2). Attention then shifts to teaching an integrated NST curriculum in South Africa (section 2.3); NST academic achievement (2.4); instructional strategies (section 2.5); and the use of CMs as an instructional tool (section 2.6). Thereafter, technology education is introduced (section 2.7). The chapter concludes with a brief summary (section 2.8).

2.1 An Integrated Curriculum as Defined in the Literature

The term "integration" originated in the 1800s and was termed "integrated studies" by followers of the German educator, Johann Herbart. In the 1920s, the concept of "integration" was based on the integration of human personality with behaviours, values, and the environment by Gestalt psychologists. Later in 1927, a dissertation by Meredith Smith helped to change the concept of integration into a child-centred approach which focused on interactive, practical activities through co-operative learning. The change resulted in the term "democratic integrated process" in the 1930s, 1950s, and 1960s, which focused on the social interaction of individuals in groups solving social issues (Beane, 1997). In the late 1980s, policies advocated an interdisciplinary approach for all subjects in school. It was later taken up again in the 1990s as a result of growing concerns over teacher practice and assessment (Drake et al., 2015).

According to Wallace et al. (2007), the concept "integration" has been around since the 19th century and was later introduced by John Dewey. Dewey suggested that by teaching across subject disciplines and learners working in communities, learners would be more inclined to see the relevance of studying such disciplines as beneficial (Wallace et al., 2007). Beane (1995) supported Dewey's view on an interdisciplinary approach to the curriculum by pointing out that for learners to see the relevance of such a curriculum, learners' future needs in these subject disciplines must be considered. In 1937, Hopkins put forward his practical and theoretical arguments for including integration into the school curriculum, which were taken up further by Apple and Bean (1995) and Beane (1995, 1997, 1998, 2002, 2013). Beane further advocated that the curriculum must be one that is "unified, experiential, democratic and relevant" (as cited in (Wallace et al., 2007, p. 30). Researchers like Fraser (2000) and Dowden (2011) also support the view that curriculum integration is important in bridging the divide between the teaching and learning of subject matter knowledge in various subjects. However, they point out that curriculum integration in the literature has confused many teachers and researchers about its meaning and relevance in education. According to Apple and Bean (1995), the challenge is mostly felt in countries with democratic schools. "Democracy", according to the English Dictionary, refers to "a system of running organizations, businesses, and groups in which each member is entitled to vote and take part in decisions". Apple and Bean (1995) noted further that democratic schools allow for planned collaboration of teachers and learners in learning communities to participate in the teaching and learning activities of a school to achieve academic success and the holistic development of the individual into a capable citizen of a country. However, Apple (2000) argues that curriculum reform has become more politicised and teacher training programmes have become more competitive in countries such as the USA. In the USA, students are merely viewed as "consumers" and education as a "consumer product" (p. 60).

Beane (1997) supported the view of integration as the linking of all types of knowledge and experiences contained within the curriculum plan. He further noted that curriculum integration consists of four dimensions, namely: (a) integration of experiences, (b) social integration, (c) knowledge, and (d) curriculum design. To unpack these further, *integrative learning*, he notes, takes place when new knowledge is internalised, and past experiences are used to solve new contextual problems. *Social integration* is referred to as general education where all learners participate in curriculum planning and are taught in a democratic way, irrespective of their cultural and historical backgrounds. Beane also argues that the *integration of knowledge* is linked to solving a problem in a context that is relevant to the learners' lives. This type of knowledge integration is also referred as "contextualisation" as suggested by a review carried out by Perin (2011). The review suggested that there are two forms of contextualisation. Firstly, contextualised basic skills instruction involved the teaching of the academic writing skills rather than subject content in an attempt to assist non-language proficient student's scientific and mathematical literacy. Secondly, integrated basic skills instruction could be used to promote scientific and mathematical literacy across subject disciplines so that students are prepared for the workplace. However, Perin (2011) also highlights that there is insufficient evidence in the literature on the efficacy of contextualisation in HE and that more needs to be explored in this area, especially among non-proficient students. Finally, Beane suggests that integration relates to *curriculum design* where the curriculum must be organised to include learners as participants in solving real-life societal problems in a democratic way.

In their study, Drake et al. (2015) state that the term "curriculum integration" refers to the various forms of disciplines emerging in the educational sector. According to Drake et al. (2015), interdisciplinary, multidisciplinary and transdisciplinary were the central forms of disciplinary collaborations. Integration, as described, thus indicates the collaboration of different disciplines within the school curriculum and includes the transference of CK, skills, and values across and between disciplines. According to Dowden (2007; 2011), the two predominant models currently in practice are the student-centred integrative model by Beane (1997) and the subject-centred interdisciplinary model by Jacobs (1989). The disadvantage of the subject-centred interdisciplinary model suggested by Jacobs (1989) is that even though learners develop specialised subject matter knowledge and skills, learners cannot apply these aspects to other subjects and make valuable connections. Beane's integrative model is therefore advantageous, as it allows teachers and learners to collaboratively plan the curriculum according to both individual and community needs. Beane's integrative model is based on a democratic philosophy in which power is shared between the teacher and learners (Beane, 1995; 1997; 1998; 2002; 2013). This democratic orientation is apparent in how teachers and learners collaborate in shared teaching and learning activities. Consequently, collaborative planning creates shared and supportive settings that enable early adolescents to develop strong teacher and peer relationships. The integrative model is based on well-developed or thick ethical principles that focus on the student. Beane designed his integrative model specifically to meet the diverse needs of early teenagers. His model respects everyone's dignity by assuming that not all young people are the same, and thus, have different educational needs. By supporting Dewey's view on learners being actively involved in producing their own knowledge and being able to participate in democratic citizenship, Beane's integrative model ensures that primary schools engage in developing "democratic communities" where learners attain the social and academic skills needed to make good decisions for the future growth of a country (Brough, 2012, p. 346).

The concept of an "integrative curriculum" has been widely studied and is presently adopted and implemented in Australia in primary schools (Dowden, 2007, p. 17). Wallace et al., (2007) further state that even though there is literature spanning 40 years on curriculum reform, the literature also indicates that there are challenges in carrying out change in primary school classrooms. The challenges are twofold. First, there is an ongoing need for curriculum integration in the primary schools, and second, curriculum change requires the educational community to support this change so that it can be sustained over a long period. The move towards creating a democratic school curriculum of an integrated NST curriculum is summed up by Apple and Bean (1995, p. 13) as follows: "Democratic schools need to be based on a broad definition of 'we,' a commitment to building a community that is both of the school and of the society in which the school exists".

Having described the integrated curriculum in the section above, attention now shifts to the three models of integration – a multidisciplinary, interdisciplinary, and transdisciplinary – curriculum, which are unpacked below.

2.2 Three Models of Integration

Drake et al. (2015) and Pretorius (2017) describe a *multidisciplinary curriculum* as studying a topic from the viewpoint of more than one discipline and solving a problem using a different disciplinary approach. On the other hand, an *interdisciplinary curriculum* involves the understanding of theories that cut across disciplines and highlight the process and meaning rather than combining the content of different discipline (Jacobs, 1989; Klaassen, 2018). A *transdisciplinary curriculum* is removing the boundaries between the core disciplines, integrating them to construct new contexts of real-world themes, and introducing a sub-major stream course (Drake et al., 2015; Stock & Burton, 2011). In comparison, of the three models of integration, the transdisciplinary approach is termed the "holy grail" by Stock and Burton (2011, p. 1102), as it aims to create a holistic approach beyond problem-solving to synthesising new knowledge to address complex systems. It appears that the transdisciplinary approach supersedes the interdisciplinary and multidisciplinary approaches as it has no boundaries and is a more holistic, student-centred approach. A transdisciplinary approach also focuses on problematisation and contextualisation to solve the problem (Drake et al., 2015). The three models of integration are illustrated in Figure 2.1 below.

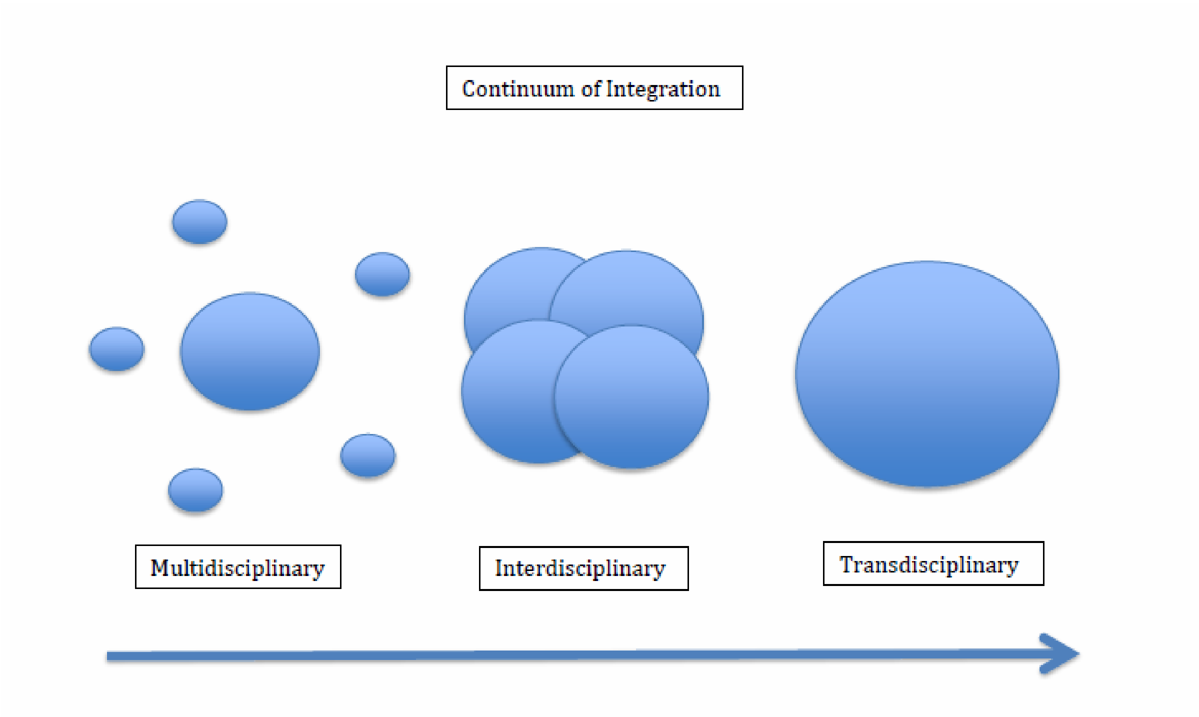


Figure 2.1: Illustration of the Progression of the Three Models of Integration (Drake et al., 2015, p. 13)

2.3 Teaching in an Integrated NST Curriculum in South Africa

Teaching in an integrated NST curriculum in primary schools is a critical component of democratic schools in which cultural-historical communities can establish shared opportunities for teaching and learning (Beane, 1997; Dowden, 2007; 2011).

Edwards (2015, p. 160) also emphatically emphasises the need for improving PSTs' conceptual understanding in NST in the following statement: "The country has to produce more scientists and engineers in a globally competitive environment while the declining uptake of students into these disciplines at tertiary level should be addressed as a matter of urgency".

The section below looks at the inclusion of an integrated NST curriculum in various countries across the globe, followed by a consideration of the inclusion of an integrated NST curriculum in the South African context in the section thereafter.

2.3.1 International studies

A few studies about the implementation of an integrated science curriculum are highlighted in the proceedings of a UNESCO consultation together with a worldwide conference in Canberra in 1988 on Science Education and the Quality of Life. After a ten-year period, another conference was held in Nijmegen in 1978, this conference in Canberra was organised by International Council of Associations Science Education (ICASE) and the Australian Science Teachers Association (ASTA). The focus of the proceedings is based on the recent trends on the teaching of integrated science and its challenges (Chisman et al., 1990). The proceedings also reported on trends of an integrated science curriculum in countries such as the Africa, the Arab States, Asia and the South Pacific, Europe, North America, Latin America, and the Caribbean. Examples of an integrated science curriculum also included Botswana, Netherlands, Philippines, Sierra Leone, and the United Kingdom. The aim of the report is to promote an awareness of the importance of the integration of primary school science and technology education. To address the challenges with possible solutions for future implementation of an integrated science curriculum in the world was also highlighted in a literature review by Winarno et al., (2020).

Africa experienced many challenges with regards to the implementation of an integrated science curriculum. For instance, many students are not interested in studying integrated science disciplines in HE; there is also a lack of suitably trained integrated science specialists in education; it is uncertain how to evaluate learner's integrated science knowledge in national examinations, so many teachers still use the traditional teacher-centred approach in their teaching of physical science, for example, and there is a need for cross-cultural studies to be carried out in classrooms. It is interesting to note that Botswana has a dry climate and water is scarce. In the implementation of an integrated science curriculum, learners are made aware of the importance of water as a topic by engaging in laboratory work on water which includes observing the different states of water and the changes of state, determining the boiling and melting points of water, plotting heating curves, and measuring rate of evaporation for different conditions. Field trips and projects on making a water filter are also undertaken. Technology education includes the designing of solar powered appliances and systems, as well as designing structures, such as traditional homes (Chisman et al., 1990).

In the Arab states of Egypt, Jordan, Qatar, and Saudi Arabia, science units are still taught separately to technology, and there is little attempt of integration of NS and TECH. Also, practical work is in the form of teacher demonstrations. In-service teacher training in the Arab states of Egypt, Jordan, Qatar, and Saudi Arabia must aim to change teacher perceptions about an integrated NS curriculum in the future. In the 1970s, the integrated NS curriculum was introduced in Brunei Darussalam, Singapore, Malaysia, and Hong Kong with the advocation of the scientific enquiry and discovery of teaching methods. Since Brunei Darussalam produced liquid natural gas, the syllabus included Earth and its Resources (including oil and gas) and Conservation for the Environment. Hong Kong introduced electronics whereas Singapore focused on energy themes. In Malaysia, the focus was based on the use of the scientific process in practical scientific investigations. In the Philippines, science and health are not taught together so that science complements health and health reinforce science. In the Netherlands, integrated science reforms occurred after 1983 in comparison to the United Kingdom which introduced an integrated science curriculum which has been in place since the 1950s and 1960s. However, after many revisions, teachers still find it challenging to adapt to teaching an integrated NS curriculum. North America and Canada were the first countries to implement thematic integrated NS curricula containing topics within biology, chemistry, physics, earth, and space science in an interdisciplinary or multidisciplinary approach. Latin America and the Caribbean have not implemented curriculum reform in the teaching of integrated science due to resistance of teachers to change their teaching practices and the shortage of suitably trained and skilled specialist teachers who are not paid well by the government (Chisman et al., 1990).

It is evident for the above reports that there are various factors that inhibit the implementation of an integrated NS curriculum in countries throughout the world. Even though changes have taken place, NS and TECH integration has not been successful in most countries due to the resistance of teachers in adopting active learning approaches; inadequate pre-service and in-service training programmes to train and support teachers in developing sound integrated CK and pedagogy; and economic limitations that devalue the teaching profession and make it unattractive for specialist science and technology specialists to be retained within the education system of a country (Chisman et al., 1990).

Having surveyed the international context above, attention is now given to the South African context in the discussion below.

2.3.2 South African studies

According to Jansen (cited in (Maodzwa–Taruvinga, 2017), integration was introduced in South Africa on two levels. Firstly, school subjects were grouped together into learning areas, and secondly, the introduction of outcomes so that subject knowledge could be applied to real-life contexts of the learner. The Revised National Curriculum Statement (RNCS) was developed and accepted in 2002 and was introduced and implemented in schools in 2004. However, on implementation of the RNCS, educators were burdened with an increase in their workload. Thus, in 2009, the Minister of Education called for a review of the RNCS, as content was not clearly specified in all the grades. Amendments were made to the RNCS by a review panel, which gave rise to the CAPS. The latter stipulated that NST be taught as a combined learning area in 2012 (Killen, 2016). One of the possible reasons for this transformation in NST education is the adoption of the world-wide science, technology, engineering, and mathematics (STEM) educational approach (Asunda & Mativo, 2016; Hudson et al., 2015; Kranzfelder et al., 2019), which is aimed at producing learners who can integrate all four subject knowledge disciplines to become scientifically literate and technologically capable citizens who can make better decisions for their country's future growth and development (Buckley et al., 2019; English, 2017; Rannikmäe, 2016).

A study was conducted by Bantwini (2010) on under-resourced schools that faced educational challenges in the Eastern Cape. The study included non-specialist NS primary school teachers from rural, urban, and township schools who received their qualifications before 1994. For the study, they participated in questionnaires and interviews about the RNCS. The findings indicated that 96% of the teachers did not implement the new curriculum by 2006, whereas 5% suggested that group work and independent learning was taking place. However, lesson observations revealed that this was not the case and that many of the teachers in the study, due to increased learner numbers and workloads, felt disempowered and did not have the confidence to implement curriculum reforms. Hence, they disregarded the CAPS document and resorted to using direct instruction as their teaching practice.

The case study by Maharajh et al. (2016) explored three primary school teachers' experiences in under-resourced schools and their implementation of the CAPS in the Kwa Ndengezi ward Pinetown district in KZN. The findings were similar to the findings in the study conducted by Bantwini (2010) in the Eastern Cape. However, the three teachers in the primary schools in KZN reported that CAPS cannot be properly implemented without the provision of resources such as Learning and Teaching Support Materials, laboratories, libraries, and ongoing support from specialist subject advisors and curriculum developers from the DoBE. This implies that in-service teachers need to be supported by the DoBE and the senior management team in primary schools in their understanding and implementation of CAPS in the future.

In another study, Khanyile (2016) established that some primary school in-service teachers in the eThekwini region in KZN could not understand and apply their PCK of NST concepts in an integrated way when teaching Grade 6 learners. He suggested that in-service teachers could not understand the term "integration" and attached to it different interpretations. Furthermore, he found that in-service teachers viewed and taught NST as separate subjects and used the traditional textbook bound direct instructional methods to teach NST in isolation. This is a problem as learners may not be able to apply their conceptual understanding of NST in real-life scenarios and may not see the relevance of learning both subjects together. The CAPS document for Intermediate Phase NST clearly guides PSTs in their teaching of the integration of NST concepts by providing conceptual links and recommended activities across the knowledge strands so as to "complement" each other (DoBE, 2011, p. 9).

The sections above explored teaching an integrated NST curriculum in South Africa. Attention now shifts to factors influencing learning and NST academic achievement.

2.4 NST Academic Achievement

In a report in Trends in International Mathematics and Science Study (TIMSS) for Grade 4 and 8 learners' performance in subjects such as mathematics and science in the world, Reddy et al. (2016a) highlighted that South Africa still underperforms in subjects such as mathematics and science. The TIMMS report was first conducted in 1995 by the Department of Education and Human Research Council to assess whether primary school learners in South Africa have developed a conceptual understanding of mathematics and science compared to other countries in the world. The TIMMS achievement scale is set at 500; South Africa scored 372 for mathematics and 358 for science. This indicates that it is a low-performing country in these two subject disciplines when compared to the top five ranked countries in mathematics from East Asia [Singapore (621), the Republic of Korea (606), Chinese Taipei (599), Hong Kong SAR (594), and Japan (587)] and science [Singapore (597), Japan (571), Chinese Taipei (569), the Republic of Korea (556), and Slovenia (551)] (p. 2). The TIMMS assessment framework aims to assess knowledge domains in both the mathematics and science curricula. Reddy et al., (2016) also point out that South African Grade 9 learners performed well in reasoning items in both mathematics and science and below the average points on science knowledge in chemistry and earth sciences (p. 14).

The TIMMS report suggests that many factors are influencing how primary school learners might learn and develop skills in mathematics and science. Reddy et al., (2016a) found that learner achievement in both subject disciplines is dependent on learner motivation, attitude, and confidence towards studying these subjects further. Scholars also highlight that South Africa must employ suitably trained and qualified mathematics and science teachers to motivate and teach learners the knowledge and skills required for these two disciplines to improve the quality of the economy in the future.

A possible reason for South Africa underperforming in especially NST education could be due to the lack of prior knowledge of an integrated conceptual understanding of NST, which was not properly established in primary school (Mesa, 2014; Permatadewi et al., 2019; Van Lloyd, 2017). The lack of conceptual understanding could be because of primary school learners who also view NST as separate subjects and difficult to learn (Linn et al., 2016). South African primary school learners before 1994 were possibly taught by inadequately trained in-service teachers who used the traditional content-driven direct instruction teaching method and relied heavily on textbooks (Mathai, 2014; Philander, 2015) to teach NST in isolation (Linn et al., 2016). The above statements imply that these in-service teachers might have also received instruction in NST as separate subjects that required rote learning and the memorisation of facts (Malatji, 2016; Ozfidan, 2017). Instructional strategies are considered next.

2.5 Instructional Strategies

Instructional approaches revolve around two schools of teaching approaches, namely, *a teacher-centred/traditional* and *student-centred/constructivist approach* (Dejene, 2020). According to Dejene (2020), teachers resorted to using direct instruction in their teaching practice due to being exposed to this type of teacher-centred instruction in school. Hence, teacher trainers in HE should change PSTs' beliefs of the teacher-centred approach by creating a student-centred/constructivist learning environments, modelling interactive teaching strategies, and providing multiple opportunities for PSTs to link theory to practice. Student-centred/constructivist approaches, on the other hand, include inquiry learning, laboratory sessions, computer simulations, and field trips (Arthurs & Kreager, 2017). A suggestion made Fitzgerald et al. (2020) on the use of inquiry-based teaching by PSTs would also promote practical activities and a student-centred approach in the teaching of science. From the above statements it appears that in the future, student-centred/constructivist approaches are more effective for understanding an integrated NST curriculum. A student-centred constructivist teaching approach suggests that learners would be actively engaged in constructing their own meaning of integrated NST content and would be able to apply this understanding to difficult concepts in other topics (Arthurs & Kreager, 2017).

In a report by Chisman et al. (1990), an integrated science curriculum requires teachers who focus on achieving the learners goals by assisting and facilitating activities. In Western countries like the USA, Australia, India and Malaysia, STEM education has taken off with a focus on the adoption of constructivist principles of student-centred teaching strategies to promote the integration of science, technology, engineering, and mathematics, and when compared to developing countries like Africa, the uptake of STEM education has been slow (Asunda & Mativo, 2016; Bibi & Watters, 2015).

A comparative study between Turkish and American teachers conducted by Ozfidan et al., (2017) found that both Turkish and American teachers hold reformed beliefs on science education. American teachers, however, were more advanced in academic writing skills such as paraphrasing and the critical analysis of text, lesson design, and implementation of technology than their Turkish counterparts. The above study shows that once science teachers change their beliefs about science and technology education, they could design effective science lessons and use technology that would promote conceptual understanding and "assist students to improve their reasoning habits and skills of mind necessary to do science" (p. 28). The consequence of teaching NST in isolation in South Africa resulted in demotivated primary school Intermediate Phase learners who viewed these two disciplines as too complex and difficult to study further (Bantwini, 2010; Reddy et al., 2016b). In-service teachers in primary school must change their beliefs about the complexity and difficulty of teaching NST by designing interactive and engaging lessons to bring about an integrated deep conceptual understanding in both disciplines (Booi & Khuzwayo, 2018).

2.5.1 Whole class discussions

Researchers (Reisman et al., 2017) that draw on Piaget's theory of constructivism suggest that teachers use class discussions to allow students to make sense of the text and use questions to prompt their ability to formulate new ideas and be creative. Classroom interaction, on the other hand, is based on the work of Vygotsky who advocates for a more sociocultural approach (Lehesvuori et al., 2019). In the particular case study of a science teacher in Finland conducted by Lehesvuori et al., (2019), it was found that verbal communication triggered higher-order thinking skills (Krathwohl, 2002) and understanding during teacher-led whole class discussions through the dialogic approach. The dialogic approach, according to Lehesvuori et al., (2019), involves a back-and-forth student teacher verbal dialogic interaction in which the teacher uses questioning prompts and sequencing of ideas to elicit prior knowledge from learners' past and everyday experiences. However, it is suggested that more research be done to explore the use of various communication strategies to enhance teacher-led whole class discussions in other science classrooms. Thirteen faculty teaching undergraduate biology courses were evaluated in a study conducted by Kranzfelder et al., (2019) in a reformed undergraduate STEM institution in the United States. The study took place in a biology department where the aim was focussed on transforming teaching approaches towards more usage of active learning strategies. The findings suggested that the instructors limited lectures to segments of no longer than 10 minutes and less than 34% of the total class session was devoted to lectures. Instructors in the study guided and interacted with their students three times more in the following ways: one-on-one discussions with individual students, small groups, and engaged with students in the asking and answering of questions during whole class discussions. It was interesting to note that the study also revealed that their students worked individually or in small groups on guided inquiry and asked and participated in whole class discussions 1.5 times more than being passive. Kranzfelder et al., (2019) also argue for active learning classrooms (ALC) which allow for students to engage in interactive activities with their peers and instructors. Active learning also involves guiding students in their learning of content rather than merely presenting a lecture (Zoller, 1993).

2.5.2 Small group discussions

In a literature review undertaken by Arthurs and Kreager (2017), they discovered that there are a variety of in-class group activities that promote active learning. However, more research is needed to be conducted on how instructors can use these integrative activities in their teaching of science in HE. In Sweden, teacher education programmes support problem-solving skills in PSTs by the use of group work to collaborate and increase self-confidence in their teaching and learning of science (Williams & Svensson, 2020). The study included three groups of 4 to 5 PSTs from two science teacher education programmes at the University of Gothenburg, in collaboration with a science centre in the City of Gothenburg, Sweden. The one programme was a 4-year primary school teacher programme preparing student teachers to teach primary school learners. The second teacher programme was a year-long programme preparing future teachers for teaching in high school and aimed for the student teachers to develop scientific knowledge and self-reflection on contextual problems in society and the environment. The findings from the study indicated that small group discussions in the three student teacher groups provided opportunities for a discussion or exploratory talk of the science content. The content-focused discussions in Group 1 can be characterised as *independent statements moving toward confirmatory talks* whereas in Group 2 the content-focussed discussions moved from *confirmatory to cumulative talk,* and in Group 3, there was a progression from *content-focussed discussion to exploratory talk* which lent itself to various patterns of variations (p. 11). The study also highlighted three implications for the use of small group discussions to be used in the future teaching of science content, namely, teacher trainers need to be aware of the nature and quality of student interactions within small groups (university students) and understand how to support students in their science discourse. It is hoped that by teacher trainers modelling small group discussions with student teachers, that these student teachers would carry this out in teaching practice with their learners. However, small group discussions present some challenges where students can become reliant on each other's contributions and can experience difficulties in learning together as well as being tolerant of each other's ideas and experiences.

2.5.3 Cooperative learning teaching strategy

Cooperative learning was favoured in many of the earlier core schools and the child-centred programmes (Buchs et al., 2017; Liebech-Lien, 2020; Malatji, 2016; Ogunleye, 2013). Apple and Bean (1995) concur that cooperative learning is a key component of a democratic curriculum and is not to be popularised as a teaching strategy aimed only at attaining academic achievement. However, according to Liebech-Lien (2020), cooperative learning remains a challenge since whole class discussions and individual tasks are still the most popular teaching strategies.

As suggested by Malatji (2016), cooperative learning is a teaching strategy that allows the teacher to guide learners with an expectation of learners to do the activities on their own with guided assistance from the teacher. Hence, cooperative learning allows learners to have face-to-face interaction and apply CK to problem-solving relevant issues in society. According to Malatji (2016) and Ogunleye (2013), cooperative learning, however, could be beneficial to students, as creativity and the development of the zone of proximal development (ZPD) is enhanced, hence supporting the learning theory of Vygotsky. Vygotsky's ZPD suggests that PSTs have the hidden potential to develop an understanding of complex topics and concepts in NST with the guidance of an instructor. Thus, cooperative learning also enhances the ZPD and develops student accountability of the task, increasing social and collaborative skills as well as self-reflection and analysis of the task at hand.

In a recent nine month professional development study by Liebech-Lien (2020), the author suggested that cooperative learning be used more in teaching as it is linked to student achievement and social skills needed for collaboration, as advocated by Kuhn (2015), in the workplace and society. Liebech-Lien (2020) in her study carried out the implementation of cooperative learning in the Senior Phase of a high school in Norway. The teacher team who participated in the study also taught the same learners from years 8 to 10 and taught one to three subjects in an interdisciplinary approach. The aim of the study was to ascertain how these teams of teachers implemented cooperative learning on a daily basis which instigated a change in her teaching practice of using and generating more insights in cooperative learning as an instructional strategy. The findings from the three stages of implementation of cooperative learning by the author and the team of teachers suggested that the teachers viewed the workshop as beneficial to them. The workshop gave them knowledge of the theory of cooperative learning and how they could implement this strategy in their classrooms. The team of teachers also used action research to implement cooperative teaching and develop student accountability, collaborated with each other on challenges experienced, and hence, formed a community of practice. However, the author also highlights that in order for cooperative learning to be effective, teachers must improve students' interpersonal skills for collaboration through small group discussions. The team of teachers were confident in their implementation of cooperative learning and felt empowered through active engagement in actional research and participation in a community of practice. The author, however, draws attention to a limitation in this study, namely, time constraints. More research needs to be done on extending the time for the implementation of the cooperative teaching strategy and to determine if this teaching practice is constant in interdisciplinary teamwork.

The next section looks at the use of CMs as a means to understand and make sense of difficult concepts in the curriculum.

2.6 Using Concept Maps as an Instructional Tool

Science curricula contain complex concepts that are difficult to understand. Many learners resort to rote learning and memorisation to learn these complex concepts without gaining a conceptual understanding of how to apply these concepts to real-life contexts. CMs are alternative tools to rote learning and memorisation and could provide meaningful learning of complex and abstract concepts, not only in science education but also in various other disciplines, such as concepts in technology education.

CMs are designed to use a cognitive structure of a hierarchical organisation with more general concepts occupying higher levels and more specific concepts at lower levels (Novak & Cañas, 2007; Ruiz-Primo, 1996; Schau, 2001; Vanides et al., 2005). The map is a diagram that graphically and visually represents conceptual and verbal knowledge. CMs can be conducted using cooperative learning in small groups. Novak and Cañas (2006) conducted extensive research regarding meaningful learning and concepts. When learners do not understand concepts, it could lead to the development of misconceptions; hence, making learning new concepts even more difficult, as the short-term memory can only hold two or three concepts at a time. Tümay (2016) and Üce and Ceyhan (2019) reiterate that chemistry is a difficult topic in science to teach, with many teachers not understanding the key concepts, vocabulary, and relationships, making it difficult to understand the concepts. CMs could be used as a powerful metacognitive tool to promote meaningful learning and conceptual understanding of difficult concepts in chemistry.

Novak's (1984) ideas on meaningful learning progressed from Ausubel's (1963) Meaningful Learning Theory (MLT) on cognitive development. According to Valadares (2013) and Novak and Gowin (1984), Ausubel viewed the development of new meanings as being based on prior relevant propositions and concepts. Ausubel regarded cognitive structure as a hierarchical organisation with more general concepts occupying higher levels and more specific concepts at lower levels. Ausubel believed that learning is meaningful when relationships between concepts become more precise, explicit, and better integrated with other concepts. In the 1960s, Novak studied children in Grades 1 to 12 for their understanding of the concepts of "matter", "energy", and "living systems" (Cañas & Novak, 2008). Ausubel's ideas on progressive differentiation and integrative reconciliation to design lessons and lesson sequences was further described by Novak (1993). The idea of *progressive differentiation* involves students building on their prior knowledge and elaborating on concepts acquired in earlier lessons. *Integrative reconciliation* is the clarification of ideas that might have been initially confusing to a child or where meanings acquired might have been distorted. Learners often hold misconceptions that must be modified, and this process requires meaningful learning (Romero et al., 2017).

The science of map-making – cartography – since 2500 B.C. to the thirteenth century A.D. has a long history stretching from Western Europe to the Persian Gulf, with Italy, Greece, Asia Minor, Egypt, and Mesopotamia. Humans have explored and mapped their travels and known geographies throughout history (Dilke, 1987). As humans used maps to graphically communicate their discoveries, Wandersee (1990) suggests that so can CMs be used in science classrooms to promote understanding of abstract topics and concepts. Along the same lines, Trochim (1989) states that CMs provide "detailed, visual, pattern-based representations of concepts (p. 110). Interestingly, Vanides et al., (2005) studied maps by giving students eight to twelve key terms from the unit. The students were given free opportunities to draw, organise, and redraw the maps. The open-ended construct-a-map style gave maximum insight into students' understanding, as the ideas came from the student, not the teacher. Vanides et al. (2005) contended that students could create their phrases and map structure, demonstrating their understandings or misunderstandings. Vanides et al., (2005, p. 31) further indicated that open-ended CMs "accurately reflect the differences across students' knowledge structures". Students worked in groups and branched out from the main concept while they discussed the subject matter. The groups brainstormed keywords from the unit without the teacher's help and identified related concepts on their own. Figure 2.2. provided a description of how the topic and concepts of a CM could be generated.

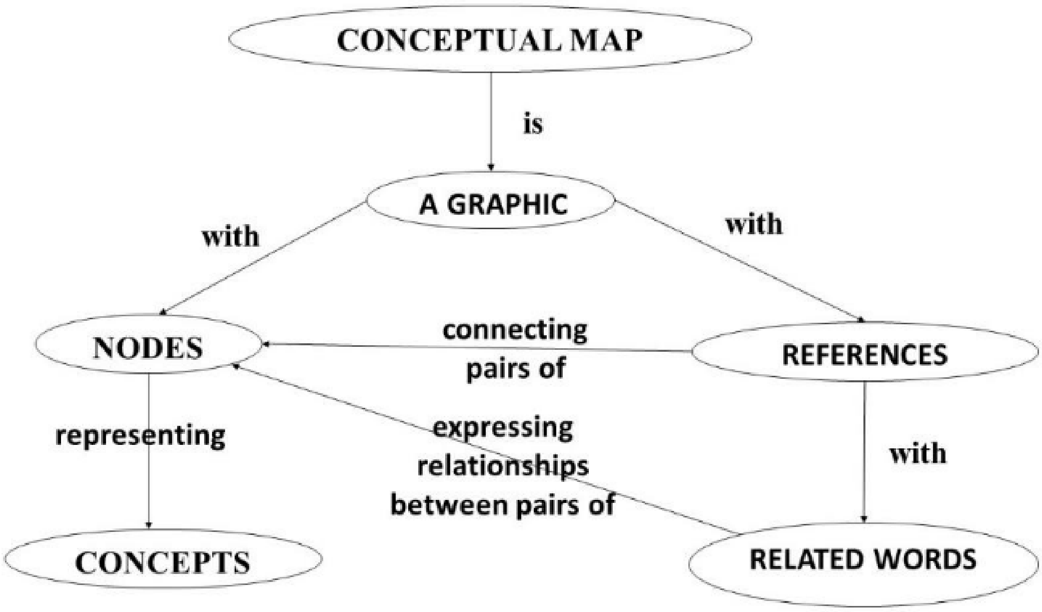


Figure 2.2: Concept Map and its components

(Source: Lăcrămioara, 2015, p. 903)

Another style of mapping started the students with a partially completed concept map and asked the group to fill in the empty boxes or circles. This contrasts with the belief of Vanides et al., (2005) that the map structure should not be a predefined tool. The fill-in-the-blank map had the teacher select three to six challenging words from the curriculum material that the students have studied, and the group added other related words to the map. Then, as the unit progressed and the students expanded their knowledge, they added the linking words and propositions. After the individual maps are created, the maps should be shared and discussed in small groups. When every student is familiar with the process of making a map, CMs can be prepared in groups of two to three students. Restructuring concepts while in small groups can greatly enhance the learning process with social interaction, as the students discuss, organise, and think about the concepts. The students can also use online resources to participate in peer collaborative discussions about concepts and learn from each other.

A literature review from 2010–2017 of ten articles from the United States of America, Taiwan, Iran, Sweden, Turkey, Egypt, and Brazil was undertaken by Khrais and Saleh (2017) to determine the effectiveness of CMs to the nursing profession. Four themes emerged from the review. The first theme was generated from seven studies which focussed on the use of CM to move students from being passive to active students who were able to learn independently. Findings from the Egyptian study also suggested that concept mapping assisted students in the storage of knowledge in their long-term memory and motivated them to become independent thinkers. The second theme focused on the linking of prior knowledge with the construction of new knowledge and was evidenced in six studies. The third theme revealed improvement in cognitive abilities. Many studies advocated that concept mapping assisted students in achieving higher order thinking skills as well as metacognitive skills. The fourth theme focused on developing clinically competent nurses who could integrate concept mapping with real-life scenarios of their patients' diseases and thus, provide a holistic approach to treatment of specific patients' diseases.

The disadvantages of using CMs are that compared to multiple-choice or fill-in-the-blank's tests, CMs take more time to evaluate (Schau, 2001). A rubric could assist in the evaluation of key features of the CM and speed up the evaluation process. Second, due to students resorting to rote learning and memorisation, there could be resistance to engage in CM activities. Researchers suggest that teachers allow students to become more familiar with the tool before assessing the CM. The advantages of using CMs outweigh the disadvantages as they provide students with a big picture of the topic or topics. It could be used as an assessment tool to evaluate the level of conceptual learning of concepts in subject disciplines and thus improve the quality of knowledge in students (Novak, 2007; Schau, 2001; Wang, 2019). Students share ideas and discuss complex concepts with their peers and promoting peer learning and cooperative learning. CMs are now used by textbook publishers to provide learners with a summary of key concepts of a specific topic at the end of a chapter which was proposed by Soyibo (1995).

In a recent study conducted by Wang (2019), he suggests that a practical application of a concept mapping activity should entail the following three phases: (1) preparation, (2) interactive and feedback, and (3) evaluation phase. Wang proposes that CM is not just a visual organiser of how knowledge is constructed but is also a powerful instruction tool that can be used by teachers to promote understanding of difficult concepts. Students can also find out gaps in their prior knowledge during self-reflection. Another advantage of concept mapping is the promotion of dialogue between individuals and in groups as well as with the reconstruction of topics within the text. He also points out that there are many disadvantages of using CMs, such as they are time consuming; tend to become a simple arrangement of concepts; the meaning of concepts is often vague in the explanations; and the assessment of CMs can be subjective as it is more focused on the structure. However, Wang also emphasises that concept mapping has more advantages than disadvantages in that students can present a complete picture of their knowledge and not just use single statements. It makes students recognise that understanding and sharing their knowledge and ideas is more important than rote learning and memorising.

In continuing the discussion and review, the next section takes a closer look at the design process in technology and technology education. This is done to highlight and distinguish aspects central to technological knowledge.

2.7 Integration of TECH into the NST Curriculum

The design process is complex and challenging and thus requires using higher-order thinking skills such as application and synthesis (DoBE, 2011; 2012). The lack of prior understanding of integration (Khanyile, 2016) is another limiting factor in PSTs' understanding and application of the design process. The integration of NST implies understanding the application of integrated NST concepts to the design process to produce a design structure or model. The current prevalent problem in primary schools in South Africa is that many technology in-service teachers were not adequately trained in HE (Potgieter, 2004). Hence, they may possibly lack the required conceptual understanding of an integrated NST curriculum for Grades 4 to 6 and cannot teach difficult technological topics such as processing.

The design process in Technology education is challenging to teach, as teachers view the design process as linear rather than problem-solving because they do not understand the design process themselves (Fantz et al., 2011). According to the CAPS document for Technology in Grades 7 to 9, the design process is non-linear and involves finding solutions to problems in society. In a study conducted by Hsu et al., (2011), 192 elementary teachers participated in a Design, Technology and Engineering (DTE) Professional development programme and were introduced to engineering content. Data from a survey on teacher perceptions was also used; the findings suggested that most of the elementary teachers were receptive to learning DTE and viewed DTE as important subjects to be introduced into the school curriculum. However, the elementary teachers also stated that they did not feel confident in their understanding of DET concepts and did not feel prepared to teach DET to learners in a classroom. Hsu et al., (2011) indicated that this is a concern in the introduction of DET into the science curriculum, particularly in the United States of America, and suggested professional development in DET both for pre-service and in-service teachers to improve the teachers' misconceptions and familiarity with careers in engineering, motivating students in maths, science, and engineering, and the application of 21st century skills, such as problem solving, and collaboration to promote effective decision making in the future.

Literature highlights aspects of scientific and technological knowledge within these two subject disciplines, as suggested by Buckley et al., (2019), Herschbach (1995), Hsu et al., (2011) and Tulley (2008). Learning, therefore, is largely focused on gaining knowledge. It is, however, also critical to examine how knowledge is gained, more specifically, scientific, and technological knowledge. There have been limited studies in this area on how learners and students can gain and develop their technological knowledge, as huge emphasis has been placed on the acquisition and development of scientific knowledge. According to Buckley et al., (2019), gaining knowledge in science is more visible and based on measuring performance. It is not aimed at developing a holistic learner or student. Buckley et al., (2019) further suggest that science consists of propositional or scientific knowledge whereas technology consists of technology knowledge. Technology, on the other hand, comes from the Greek *technologia*, which refers to the systematic treatment of an art (or craft). The French define *technologia* as made up of two terms: "*technologia*" refers to processes and objects, and the term "technique" refers to the individual application processes. In the late 19th century, the English definition of "technology" referred to the application of science (knowledge) to make and use objects. Nowadays, the term technology combines both the Greek and French definitions to refer to technology as the link and development of science and technology. "Technology, in other words, makes use of formal knowledge, but its application is interdisciplinary and specific to particular activities" (Herschbach, 1995, p. 33). The distinguishing facts surrounding scientific and technological knowledge, according to Herschbach (1995), could be summarised as follows: Scientific knowledge is abstract, deals with the understanding of phenomena, and deals with laws and theories to confirm understanding. Technology, on the other hand, deals with the application of the design and physical activities to produce solutions to problems in the physical world.

Another noteworthy study was conducted in Ireland involving learners from the Irish Leaving Certificate Examination. A five-year cohort study (from 2010–2014) was designed to gather data from a total sample of 1,761 learners' grades from the Irish Leaving Certificate Examination and was distributed across four schools in urban, suburban, and rural schools in regions of Ireland. This study aimed to examine the impact on overall educational performance because of engagement with technology subjects at post-primary level. According Buckley et al., (2019), technology education aims to develop technological capability, which is arguably like gaining technological knowledge. This study aimed to examine the potential impact of technological knowledge in education.

In this study, technology education was investigated within the Irish education system, as it is nationally assessed through standardised examinations (leaving certificate) created by a government body known as the State Examination Commission. At the end of post-primary education, at approximately the age of 18, learners in the Irish education system obtain the Leaving Certificate, which serves as the country's primary matriculation system for entry into third-level education. The subjects of mathematics, English, and Irish are compulsory, as they are typically required to meet university course entry requirements, and other optional subjects based on the range provided by their school. As this study focused on technology education to be included, a school had to offer three of the four technology subjects provided in the Irish post-primary national curriculum, namely, design and communication graphics, construction studies, and engineering. The fourth subject, technology, was not mandated in the inclusion criteria due to its low provision nationally.

The results of the study showed that learners who studied one or more technology subjects performed best in those subjects, which could be due to them being interested in studying the subject in school. Another reason stated by Buckley et al., (2019) relates to a recent national review of STEM education in Ireland conducted by the STEM Education Review Group (2016), which found that students' subject choices were influenced by feedback from peers, family, and teachers to secure maximum points in the Leaving Certificate. Because learners were more focused on achieving the highest points, studying technology subjects appealed to them.

One potential explanation for the marked discrepancies between pupils who choose to study technology and pupils who choose to study subjects such as mathematics, foreign languages, and the NS concerns the primary knowledge types of those subjects. Mathematics, Irish, and English are recognised as compulsory, and studying a foreign language is preferable to satisfy most university entry requirements. These subjects have, to varying degrees, a heavy focus on episteme. According to Tulley (2008), *techne* refers to the process of creating an artifact, while *episteme* involves the application of knowledge or wisdom behind the process of creation of the artifact. By the 20th century, a combination of techne and episteme gave rise to the term technology which referred to "machines, factories, industry, tools, engineering" (Tulley, 2008, p. 94). If pupils choose to study the natural sciences, more mathematics-based subjects, or more foreign languages, their learning requirements are heavily focused on acquiring propositional scientific knowledge or episteme. Pupils who choose to study the technology subjects or other subjects with more of an emphasis on techne are required to divide their attention between acquiring two different types of knowledge. Techne, as named by Aristotle, according to Ma (2018), was among the five academic virtues of phronesis (practical wisdom), sophia (philosophical wisdom), nous (self-evident truths), and episteme (scientific knowledge). Ma (2018) also suggests that Aristotle defined techne as a form of practice of theory. This was evident in teacher programmes in China where PSTs were taught the necessary practical skills before teaching in a classroom. From a performance perspective, this could be a disadvantage. By engaging with a broader range of knowledge types, learners will have less time to focus only on developing knowledge (episteme) but how to practically produce an artifact (techne) and reach an expert level of proficiency (phronesis) which is suggested by Buckley et al. (2019). A combination of phronesis and techne, that is, *phronetic techne*, is proposed by Ma

(2018), so that teachers can be tolerant of students' failures and use teaching strategies to provide multiple opportunities for students to succeed in techne.

According to Buckley et al., (2019), the differences between episteme and techne must be considered when compulsory subjects focus predominantly on one type of knowledge. When there is a possibility to sidestep the other, potentially in favour of attaining points, general educational provision is no longer general. Also, interestingly, when these learners have attained more points, they might have a scarcity in critical knowledge for work and study. Buckley et al., (2019) propose that an efficient solution to solve the above problem would be to create a balance in compulsory subjects between episteme- and techne-focused subjects. In doing so, the variance between learners who do and who do not study technology in terms of overall performance, create a more general and balanced education system and ensure that critical knowledge is made more accessible and fairer to all learners who choose to enter HE thereafter.

An implication of the results in the study conducted by Buckley et al., (2019) suggests that the change in scientific and technological knowledge affects learners' performance for studying further in HE. The study also proposed that the technology component be made compulsory in education curricula to promote the holistic development of learners in school. A learner who, therefore, performs better in technology, might have a high interest in the subject to attain a better score for entry into HE. Buckley et al., (2019) and Hsu et al., (2011) highlight the challenges regarding technological knowledge and academic performance. Academic performance is related to subject selection, and hence, learners with technological capacities might choose subjects such as maths, science, and foreign languages, but may underperform, as the focus in these subjects develop a more theory-based episteme or scientific knowledge, rather than techne or practical skills in creating an artifact.

From the above review it can be concluded that a possible inclusion of technology as a compulsory subject component in the Intermediate Phase, which forms part of the general education training system, could be advantageous to learners' holistic development. It is therefore proposed by the researcher that learners who are exposed to various knowledge types in all subjects through integration, could be equipped with the critical knowledge that is needed for the workplace and could serve as an easier transition from primary and high school into studying further in HE.

In light of the above discussion, some concluding remarks follow next.

2.8 Conclusion

The chapter provided a description of previous literature based on the works of Beane (1995; 1997; 1998; 2002; 2013) and Dewey (Wallace et al., 2007) towards the promotion of an integrated democratic curriculum. The chapter also reported on case studies around the implementation of integrated NST curricula reports in different countries in the world and currently in South Africa. A historical context of integration on three levels is also provided that is interdisciplinary, multidisciplinary, and transdisciplinary to show which integration approach would be best suited for curriculum change in promoting science and technology education. In the report in TIMSS for Grade 4 to 8 learners' performance in subjects such as mathematics and science in the world, Reddy et al., (2016) highlighted that South Africa still underperforms in subjects such as mathematics and science and that suitably trained science and technology specialists are needed to improve student achievement in both subjects in primary and high schools in South Africa. The chapter also emphasised that in the promotion of active learning of topics and concepts in an integrated science and technology curriculum must include instructional strategies such as whole class and small group discussions, cooperative learning, and CM activities. The chapter concludes with a discussion of the importance of the introduction of technology education and knowledge in the implementation of an integrated NST curriculum. Hence, PSTs might not know how to transfer what they learn as scientific knowledge (*episteme*) in NST into a practical process of creating an artefact (*techne*) and could have difficulties in transcending to phronesis (gaining practical expertise and wisdom), which is the highest form of intellectual virtue according to Aristotle.

The theoretical framework of the study is presented next.

CHAPTER 3

THEORETICAL FRAMEWORK

Introduction

The previous chapter presented the literature review of the study on NS and TECH education, with specific attention given to curriculum integration, and the relevance of an integrated NST curriculum in primary school. The current chapter provides the theoretical framework of the study. This framework is informed by studies conducted by Mavhunga (2018) and Mavhunga and van der Merwe (2017) about the development of TSPCK, as well the Beane's integrative model of democratic schools. In-service teachers' understanding of the curriculum depends on their PCK. However, most in-service teachers might not have been suitably trained as experts in PCK to teach difficult topics in NST, leading to a lack of TSPCK. This lack of TSPCK in NST gives rise to misconceptions in both subject disciplines.

The structure of this chapter is as follows. Following the introduction, the discussion shifts to the topics of pedagogical content knowledge (section 3.1), pedagogical knowledge (section 3.2); content knowledge (section 3.3), and the development of TSPCK in NST PSTs (section 3.4). Some concluding remarks are then provided to wrap up the chapter (section 3.5).

3.1 Pedagogical Content Knowledge

In seeking to define "pedagogical content knowledge", Shulman and Shulman (2004) explain that PCK is the capacity of a teacher to transform the CK he or she possesses into pedagogically powerful forms. Mavhunga (2014) further postulates that teachers must develop an awareness that teaching requires the transformation of their subject matter knowledge in general which requires five components, referred to as "content-specific components". These necessitate specific considerations to be made about Subject Matter Knowledge (SMK).

3.2 Pedagogical Knowledge

Teaching is knowing how to communicate subject matter content and how to make this content relatable to learners in a classroom. The term "pedagogy", according to Hinchliffe (2000), originated from two schools of thought, namely: (1) Isocratic (pedagogic), which focussed on training Greek aristocrats for public careers, and (2) Platonian (educative), which advocated that the pursuit of knowledge should not be hindered by the outside world. He further elaborates that *pedagogy* appears to revolve around the development of social, political, and economic needs, whereas *education* deals with the development of a holistic individual. Both pedagogy and education should be used so as to complement each other. For PSTs to teach NST in an integrated way, they must have "knowledge" of both the NST content to be taught as per the CAPS document and knowledge of how to implement suitable instructional strategies in the classroom (Bantwini, 2017). This, in a nutshell, describes the term "pedagogical knowledge" (p. 266), which according to Guerriero (2017), relates to five components of a teacher's knowledge base, including classroom management, teaching strategies, classroom assessment, the learning process, and inclusivity of individual learners in their classrooms (p. 108).

3.3 Content Knowledge

Reflecting on "content knowledge" (p. 849), Neumann, Kind and Harms (2018) revealed that an educator's beliefs and interpretation of the curriculum determines how the content is taught and learned, especially complex topics such as the particle nature of matter (Smith et al., 2017) in chemistry and the design process (Wilson-Lopez et al., 2017) in engineering, especially in primary school. It is evident from the research conducted by Rannikmäe (2016) and Bantwini (2017) that educational reform in South Africa requires that Intermediate Phase NST educators understand the CAPS curriculum and be trained in a variety of new instructional approaches to meet the different learning styles of their learners in primary schools.

3.4 Development of TSPCK in NST Pre-service Teachers

Mavhunga (2014) suggests that PCK is topic-specific, and that five components enable the transformation of topic-specific concepts to PCK, namely: (1) learner's prior knowledge, (2) curricular saliency, (3) what is difficult to teach, (4) representations including analogies, and (5) conceptual teaching strategies.

The PCK model was first introduced by Shulman and Shulman (2004) as the amalgam of content and pedagogy (Mavhunga, 2014; Mavhunga & Rollnick, 2013; Mavhunga & Van der Merwe, 2017). Other researchers (Okeke et al., 2016) refer to PCK as the knowledge of teaching to communicate subject matter content and to make this content relatable to learners in a classroom. Since then, many other models built on Shulman's model to investigate the nature of PCK. Mavhunga and Rollnick (2013) designed an assessment tool to measure teachers' TSPCK in chemical equilibrium, which comprised the following five aspects:

1) **Learner's prior knowledge** – includes any prior knowledge a learner has, including misconceptions.
2) **Curricular saliency** – encompasses the decisions a teacher makes, for instance, what to include in a teaching programme, what to leave out, and what is appropriate for a specific grade level.
3) **What is difficult to teach** – several things could make a topic difficult to present, such as learners' misconceptions and conceptual challenges. It could also include environmental concerns, such as a lack of resources and overcrowding.
4) **Representations and analogies** – include any pictures, graphs, stories, or models used to aid in understanding.
5) **Conceptual teaching strategies** – encompass all of the above categories and describe what teaching strategies a teacher employs to develop learners' understanding of the correct scientific concepts underpinned by the teacher's and students' beliefs. It all feeds into and forms the teacher's PCK. The focus of this model is the transformation of CK. Mavungha and Rollnick (2013) differentiate between the starting-specific CK of a teacher, which they coded as K. This CK then undergoes a transformation process and the resulting knowledge they termed "transformed-specific content knowledge", which is coded as K'. The space between K and K' is where the transformation process occurs. The transformation process is termed "topic specific pedagogical content knowledge" (TSPCK), which is illustrated in Figure 3.1 below.

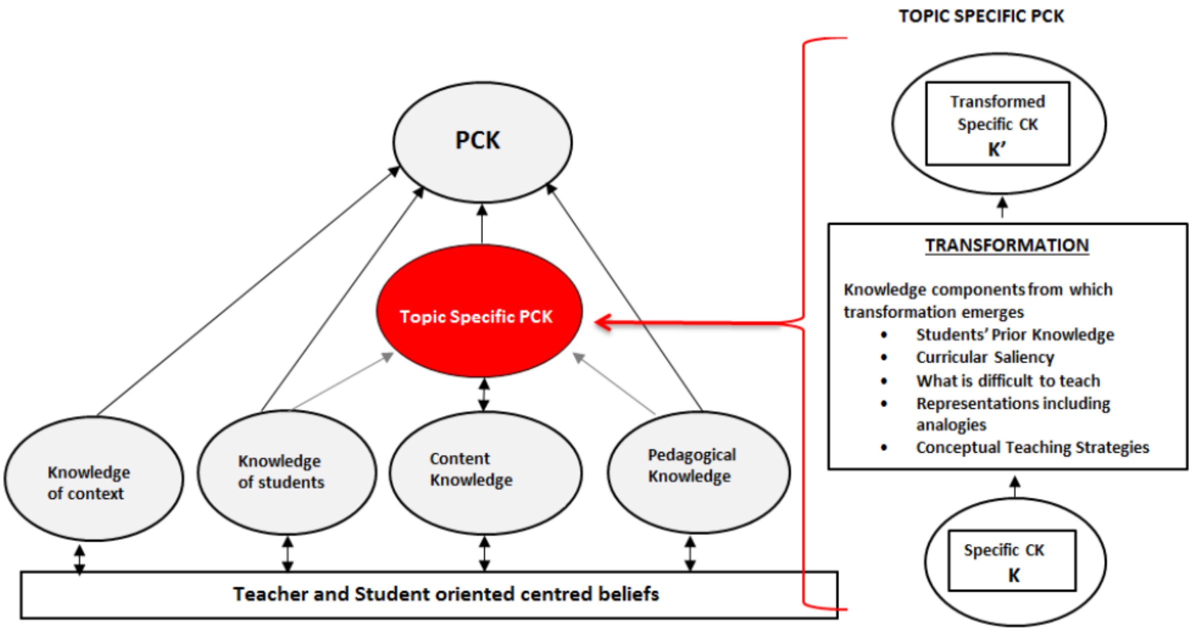


Figure 3.1: Transformation of TSPCK

(Source: Mavhunga & Rollnick, 2013, p. 115)

NS education combined with TECH could provide a holistic and integrated conceptual understanding in both subject disciplines in the future of pre-service training programmes in South Africa. According to (Pitjeng-Mosabala & Rollnick, 2018; Pitjeng, 2014), PSTs must be trained in TSPCK, especially in difficult disciplines such as chemistry (Tümay, 2016); Üce and Ceyhan (2019). I am proposing that Mavhunga's (2014) and Mavhunga and Rollnick's (2013) suggestion of the development of TSPCK could also be included in the technology discipline. If done correctly, it could lead to an understanding of how difficult topics and sub-topics could be taught successfully in an integrated NST curriculum. I believe that TSPCK could be developed in PSTs by implementing instructional strategies such as *whole class* and *small group discussions* (Arthurs & Kreager, 2017; Lehesvuori et al., 2019), *cooperative learning* (Apple & Bean, 1995; Malatji, 2016; Ogunleye, 2013), and *concept mapping activities* (Novak & Cañas, 2006; Trochim, 1989; Wandersee, 1990). Learning theories such as constructivism (Dagar & Yadav, 2016) and activity learning (Arthurs & Kreager, 2017) could also assist NST PSTs in their understanding of an integrated NST curriculum and what it entails. It is hoped that the development of an integrated NST TSPCK in topics such as Matter and Materials and Processing, when taught correctly by trained NST PSTs, could also reduce the early science and technology formation of misconceptions, and lessen the gaps in prior CK in higher grades for primary school learners in South Africa (Sadler & Sonnert, 2016).

3.5. Conclusion

It is noteworthy to mention that to date, there is insufficient research on how South African NST PSTs should receive training in teacher training programmes in HEIs so that they can develop a sound TSPCK in an integrated NST curriculum for Grades 4 to 6 in the Intermediate Phase as stipulated in CAPS (DoBE, 2011) for Grades 4 to 6. Hence, an integrated NST PST training programme should strive to produce NST PSTs who will teach primary school learners to appreciate the value and relevance of applying NST topics and concepts to their everyday lives and environments. Future NST PSTs must be trained on how to overcome previous primary school perceptions about the learning of difficult Grade 4 to 6 NST topics and concepts and; how to develop an authentic TSPCK in the teaching of abstract Grades 4 to 6 NST topics and concepts in other knowledge strands and in doing so, derive an understanding of an integrated NST curriculum for Grades 4 to 6 in the Intermediate Phase as contained in CAPS (DoBE, 2011).

In the next chapter, we will explore the research design that was carried out to collect and analyse the individual CMs to ascertain whether the Grade 6 NST PSTs gained an understanding of an integrated NST curriculum and how they represented this understanding using concept mapping.

CHAPTER 4

RESEARCH METHODOLOGY & DESIGN

Introduction

This chapter sets out to explore the development of TSPCK in Grade 6 NST PSTs in the topics and concepts pertaining to Matter and Materials in NS and Processing in TECH as stipulated in the CAPS for Grades 4 to 6 (DoBE, 2011).

The goal of this study is twofold, namely: (1) it seeks to explore the engagement of NST PSTs in a CM activity to elicit their understanding of an integrated NST curriculum, and by doing so, (2) it obtains insight into how NST PSTs' understand an integrated NST curriculum using a CM activity. Chapter 4 provides a detailed description of the research design used to explore the development of TSPCK of Grade 6 NST PSTs in the case of Matter and Materials and Processing.

The research design is guided by a qualitative exploratory case study methodology to obtain a detailed description of Grade 6 NST PSTs understanding of an integrated curriculum and how they represented their understanding using a concept mapping activity. In this study, the research design was based on the interpretivist constructivism paradigm. The aim of interpretivist research is to gain an in-depth understanding of the meaning and relevance of individuals' experiences in daily life. Grade 6 NST PSTs engaged in a concept mapping activity to derive their own understandings of an integrated NST curriculum. This resulted in the generation of various themes or patterns using the six-step process by Braun and Clarke (2006) about their understandings of an integrated NST curriculum from the concept mapping activity. Inductive analysis of qualitative data was used to obtain an in-depth, descriptive narrative (Maree, 2016) of data collection containing 40 Grade 6 NST PSTs CMs at the selected private HEI.

The chapter begins with an introduction to qualitative research and what it entails (section 4.1). Thereafter, the research design (section 4.2) that was purposefully adopted to answer the following research questions is explored:

1) **Research Question 1**:

   How do we engage NST pre-service teachers to elicit their understanding of an integrated Natural Science and Technology curriculum?

2) **Research Question 2**:

   How do NST pre-service teachers represent their understanding of an integrated Natural Science and Technology curriculum?

Thereafter, the research instruments (section 4.3), sampling (section 4.4), data collection (section 4.5), data analysis (section 4.6), limitations of the study (section 4.6), and role of the researcher (section 4.7) are discussed. The chapter ends with a brief conclusion (section 4.8).

4.1 Qualitative Research Defined

A qualitative rather than quantitative approach was undertaken in this study. A quantitative approach deals with the collection of facts and data collection is measurable and fixed. Data is analysed deductively using numerical and statistical inferences. Statistical analysis is used to compile a report on the data analysis set (Creswell, 2014; Maree, 2016). A qualitative approach, according to Creswell (2014) and Maree (2016), seeks to explore and understand how individuals ascribe meaning to a social or human problem in particular contexts using a variety of data sources (Baxter & Jack, 2010). Cohen et al., (2011) further add that a qualitative approach uses questions, procedures, individuals in a setting, and data analysis so that the researcher can inductively build on proposed theories which results in a final written report that is flexible in nature. Qualitative data analysis also deals with the classification and properties of objects, people, and phenomena (Creswell, 2014; Maree, 2016). For the purpose of this study, an inductive data analysis method was used to code data into categories and generate patterns, themes, and data during the analysis stage (Du Plooy-Cilliers et al., 2014).

A case study is when a bounded system (people and place) is explored over a period, as explained by Creswell (2014). Du Plooy-Cilliers et al., (2014) also suggest that a case study gives a detailed description and understanding of a "scenario in which a phenomenon occurs". It also explores an in-depth understanding of the experiences of the participants in a real-life context, requires multiple sources of information relevant to the context, and provides a detailed and analytical description of the case. By adopting a case study approach, the researcher could explore the phenomenon using a variety of lenses so that many aspects of the phenomenon could be revealed and understood. Inductive rather than deductive analysis and reasoning of 40 CMs was used so that I could obtain an in-depth, descriptive narrative of my teaching practice in NST as a teacher trainer and lecturer over a period at the selected private HEI. However, this inductive process took a long time as many hours were spent reading, reflecting, and comparing themes, patterns and codes analysed from the 40 CMs. Categories of the 8 qualitative Grade 6 NST PSTs' understandings of an integrated NST curriculum and how they represented their understandings using a CM activity emerged from the qualitative inductive analysis. This study set out to explore my teaching practice as an experienced NST teacher and lecturer lecturing the NST didactic module to Grade 6 PSTs at a selected private HEI in 2019. The focus of this study is on the development of TSPCK in PSTs so that they can teach topics and concepts in Matter and Materials in NS and Processing in TECH in an integrated way to primary school learners in South Africa. A review of literature by Mavhunga (2014) and Mavhunga and Rollnick (2013) suggested that PSTs lack the required integrated NST prior knowledge and PCK (specifically the "CK" aspect of PCK) in the understanding and application of NST topics and concepts to real-life contexts. According to Pitjeng (2014), PSTs need to be trained to develop TSPCK in abstract chemistry topics and concepts whereas Ankiewicz (1995) advocated that technology education is important in education and that the design process needs to be given more attention. The development of an integrated TSPCK in abstract chemistry topics and concepts in NS and the design process in TECH in future NST PSTs may result in an understanding of how difficult other NST topics and concepts in Systems and Control and Structures could be taught in primary schools as contained in CAPS for Grades 4 to 6 in the Intermediate Phase.

4.2 Research Design

According to Du Plooy-Cilliers et al. (2014), a research design is a plan of how the research is going to be conducted, who or what is involved, and where and when the study will take place. A research design is a strategic framework for action that serves as a bridge between objectives and research questions regarding the execution or implementation of the research. This research study adopted an exploratory case study approach, as it is a new approach to teaching and assessment in the integrated NST module at a third-year level. Being a teacher-trainer who observed learners' and PSTs' interaction with learning NST topics and concepts in Matter and Materials and Processing in both primary and high schools, and now, at a HE, I found it more suitable to use an exploratory case study approach.

A case study approach has a history of being used in research studies in the fields of science, social science and humanities as suggested by Hijmans and Wester (2010). The authors also stated that a case study approach was first created at the University of Chicago in the 1920s and later used in medical research in the 1930s in the United States of America. The case study approach, according to Hijmans and Wester (2010), has three characteristic features that sets it apart from experimental and survey designs: (1) it provides a more realistic study as it occurs in a natural setting. The integrity of the "boundaries of case, phenomena and context" (p .4) are valued, (2) the case study inquiry employs different phases of field inquiry and uses a variety of methods for data collection to gain an overall view of the meaning of the data in a particular setting, and finally, (3) it has a practical application that can be used by stakeholders of organisations which employs data triangulation, participatory field work, observations, and interactions with the participants in formal and informal settings, as well as brainstorming sessions, which are evaluated by experts in the field in order to derive various perspectives on the data collected in a particular context and setting (Hijmans & Wester, 2010).

4.2.1 Case study approach

In this study, an exploratory case study approach was adopted to give a detailed description and understanding of a "scenario in which a phenomenon occurs" (Du Plooy-Cilliers et al., 2014). A case study approach explores an in-depth understanding of the experiences of the participants in a real-life context, requires multiple sources of information relevant to the context, and provides a detailed and analytical description of the case (Hollweck, 2016; Yazan, 2015). According to Hollweck (2016), qualitative research uses purposive sampling where participants are chosen for a case study, have a specific purpose and criteria in mind, and represent a "phenomenon, group, incident and location". According to Yin (2014, as cited in Hollweck, 2016, p. 2), a case study is useful for beginner researchers. Yin further highlights that not only is a case study cyclic, but it also consists of six parts: "the plan, design, preparation, data collection, analysis and reporting". As a result of these six components, Yin advocates that a case study provides high- quality detailed explanations of complex phenomena but has no pre-determined outcome. Furthermore, it is also dependent on the researchers' skills and expertise. This type of research design focuses on the validity, rigour, and reliability of the case at hand (Hollweck, 2016). Yin (2014, pp. 8-9) argued that there are three conditions for an exploratory case study approach to be valid, credible, and reliable, namely:

(1) the "how" and "why" research questions that are posed.

(2) the degree of control that the researcher (myself) has over the behaviour of participants (space).

(3) the case study focuses on a current problem that is relevant to the participants' real-life context rather than on an outdated past problem.

An exploratory case study methodology followed a four-phase engagement that was adapted from Wang (2019) to elicit Grade 6 NST PSTs' understanding of an integrated NST curriculum by use of a CM activity. The study was based on the TSPCK model and studies proposed by Mavhunga and van der Merwe (2017) in the exploration of Grade 6 NST PSTs' development of an integrated TSPCK in topics and concepts pertaining to Matter and Materials and Processing of an integrated Grade 6 NST curriculum as laid out in the CAPS document for the Intermediate Phase (DoBE, 2011). After the Grade 6 NST PSTs engaged in the small group discussions and co-operative learning session, representatives of each group communicated their recall of Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing to the whole class while the researcher(myself) made observations and listened to the discussions and feedback from the Grade 6 NST PSTs without any interruptions. The feedback from the Grade 6 NST PSTs was written on the whiteboard to allow for an integrated understanding of NST topics and concepts in Matter and Materials and Processing to all Grade 6 NST PSTs in the class. The 48 Grade 6 NST PSTs participated in the concept mapping activity and worked in groups of 3 participants per group (16 small groups). Small group discussions took the form of brainstorming questions posed to the Grade 6 NST PSTs. Thereafter, the Grade 6 NST PSTs used a SAFI CM strategy using the CM template to recall their prior knowledge of NST topics and concepts of matter and Materials and Processing. Twelve participants from the small groups were purposively chosen for the focus group session to be scheduled outside lecture times. The focus group session was aimed at promoting a group discussion among the 12 Grade 6 NST PSTs to ascertain their perceptions of NST topics and concepts in Matter and Materials and Processing, understanding of an integrated NST curriculum, and challenges experienced during the concept mapping activity. Thereafter, the Grade 6 NST PSTs participated in four classroom activities, which were designed to consolidate and correct further misconceptions in the development of their TSPCK in Matter and Materials and Processing. Infographics of the whiteboard and 40 CMs were collected and presented in the data analysis Chapters 5 and 6. Thematic analysis using the six step process outlined by Braun and Clarke (2006) was applied, which resulted in 8 qualitative categories of Grade 6 NST PSTs' understandings of an integrated NST curriculum. Furthermore, there were variations in the way they represented these understandings.

To provide answers to the critical research questions asked in this study, the case study methodology was conducted in two phases, namely:

Phase one explored Research Question 1:

How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?

The CM strategy was implemented during a 2-hour lecture session in the second semester of 2019 with a class of 48 Grade 6 NST PSTs. A CM template was used as an instrument to collect data on their understanding of what an integrated Grade 6 NST curriculum entails. According to Wang (2019), a practical application of a concept mapping activity should entail the following three phases:

1) The preparation phase,
2) The interactive phase,
3) The feedback and evaluation phase.

The three-phase strategy by Wang was tweaked to serve the purpose of the study. Various sources such as college textbooks, the CAPS document, and other sources were used to explore my understanding of an integrated NST curriculum pertaining to NST topics and concepts in Matter and Materials in NS and Processing in TECH. In addition, the first phase aimed to record experiences or classroom challenges of the Grade 6 NST PSTs understanding of an integrated NST curriculum.

Phase two sought to explore Research Question 2:

How do NST pre-service teachers represent their understanding of an integrated NST curriculum?

We explored the qualitatively different ways in which the 40 NST PSTs conceptualised the integration by looking at the following questions:

(iv) What was foregrounded in terms of what is being integrated?

(v) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and OTHER?

(vi) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

The above information was presented in a table and used to collect the data from the PSTs CMs, as illustrated below. Table 4.1 indicates the NS and TECH topics and concepts placed in categories 1 to 8, captured from the Grade 6 NST PSTs concept maps from CAPS and "OTHER" sources to show their understanding of an integrated NST curriculum. Table 4.1. below contains the information captured to illustrate Grade 6 NST PSTs' understanding of an integrated NST Curriculum.

Table 4.1. Rubric used to elicit NST PSTs understanding of an integrated Science and Technology curriculum

Category 1	Integrated NS and TECH	NS Strand - CAPS	NS Strand - OTHER	TECH Strand - CAPS	TECH Strand - OTHER	Linking NS to TECH
PST CM Response	What is being integrated?	Topics/concepts w.r.t. CAPS	Topic/concepts w.r.t. OTHER	Topics/concepts w.r.t. CAPS	Topics/concepts w.r.t. OTHER	How are the two being linked?

The above rubric was used to show how the two knowledge strands (NS and TECH) were integrated and what link was used to integrate the two strands. The rubric assisted me producing another rubric that was used to summarise the findings from the data analysis and graphical representation of the eight categories of Grade 6 NST PSTs understanding of an integrated curriculum.

4.3 Research Instruments

Data was collected from visual sources, such as photographs of the whiteboard during the whole class and small group discussions, co-operative learning sessions, and photographs of the 40 CMs (see Appendix 3 and 4). A rubric as mentioned in Table 4.1. and appendix 5 was also used to analyse the NST topics and concepts contained in the 40 CMs to show how the Grade 6 NST PSTs integrated their understanding of the two knowledge strands of NS and

TECH and the links that were made between the two knowledge strands. CMs are visual representations of a learners' cognitive structure that is made up of pre-existing and new concepts and propositions. These concepts and propositions are arranged hierarchically from basic to more complex. Using linking words and crosslinks indicates an understanding of the relationships between two or more concepts, which results in the meaningful learning of a topic or focus question (Novak, 2008).

A type of CM that is widely used is student-generated CMs in which students rearrange and link concepts with phrases (Ruiz-Primo, 1996). Student-generated maps require that students have a prior understanding of the prepositions needed to generate their own concepts or to use given concepts to generate many different CMs (Cañas & Novak, 2008). A scoring method is then quantitatively used to assess the students' conceptual understanding using scoring schemes as suggested by Rice (1998). However, according to Schau et al., (2001), there are four limitations to student generated CMs. Firstly, students can become easily frustrated and may experience difficulties in drawing CMs, as it takes a long time, and may therefore decide not to draw CMs at all. Secondly, there is no widely accepted standard scoring rubric that can be used to score the student generated CMs. Thirdly, the scoring is difficult using a computer, and fourthly, a students' level of communication skills will pre-determine the assessment of the CM that is produced. An approach that is rarely explored is the fill-in CM method (Schau et al., 2001) which requires that students "select-and-fill-in" or SAFI. The findings put forward by Schau (2001) are that SAFI CMs overcome many of the four above-mentioned limitations as many students adopt a positive attitude and complete the CMs at a faster pace; the students' responses can be assessed as correct or incorrect without the use of a scoring rubric; the correct and incorrect responses can be calculated by using a computer; and finally, SAFI CMs also caters for students with low communication skills to also complete the CMs. In my study, a SAFI was used in which Grade 6 NST PSTs used a CM template and completed Grade 4 to 6 NST topics and concepts in Matter and Materials in NS and Processing in TECH.

4.4 Sampling

The sample size included 48 students – both male and female – from various cultural and socio-economic backgrounds, residing in KZN. Heterogenous or maximum variation sampling was used to generate themes which resulted in data saturation of a rich description of Grade 6 NST PSTs' understandings of an integrated curriculum (from a diverse range of participants). The Grade 6 NST PSTs also indicated that they found some Grade 4 to 6 NST topics and concepts confusing, especially regarding Processing in TECH. It was at this point that I explained to the Grade 6 NST PSTs the importance of undertaking research to determine how to improve Grade 6 NST PSTs' understanding of an integrated NST curriculum and that more research needs to be done in the area of the teaching and learning of abstract NST topics and concepts in an integrated way in primary schools in South Africa. This dialogic discussion between myself as the lecturer and the Grade 6 NST PSTs using a whole class discussion during the lecture provided an excellent entry point for me to introduce my study. I explained that I would be carrying out a research project to explore Grade 6 NST PSTs' understanding of teaching the topics of Matter and Materials in NS and Processing in TECH in an integrated way. The purpose of my study was explained to them as my attempt to further promote the development of TSPCK in the teaching of NST topics and concepts in Matter and Material and Processing in an integrated way. TSPCK is a specialised form of knowledge (Mavhunga, 2014; Mavhunga, 2018; Mavhunga & Van der Merwe, 2017; 2020; Mavhungha & Rollnick, 2013) that incorporates a teacher's understanding of the content and concepts contained in a specific topic which can be successfully taught to learners with the use of suitable teaching strategies.

4.5 Data Collection

4.5.1 Validity

According to Creswell (2014), for qualitative validity, the researcher uses certain procedures to check for the accuracy of data, while qualitative reliability suggests that the approach adopted by the researcher is consistent across different researchers and projects. *Validity* is a kind of truth. In this study, triangulation was used to gather information from different sources to validate whether TSPCK was developed in Grade 6 NST PSTs through an understanding of an integrated curriculum. If the sources of data or perspectives from participants come together, then a claim could be made that the study has validity.

Validity also ensures accuracy because it considers the researcher, participant, or reader to ensure trustworthiness, authenticity, and credibility (Creswell & Miller, 2000, cited in Creswell, 2014).

In this study:

Data were also collected through the whole class discussion and small group discussions, co-operative learning, and concept mapping activities. The Grade 6 NST individual CMs were analysed to determine how they derived and represented their understanding of an integrated NST curriculum in the topics and concepts pertaining to Matter and Materials and Processing using a CM activity.

The data from the CMs were read repeatedly to gain a better understanding of the participants' responses and identify key topics, concepts, and possible gaps in their Grade 6 CK of Matter and Materials and Processing. The key Grade 4 to 6 NST topics and concepts were ordered and categorised, then organised and sorted into categories with codes to reveal various themes and understandings of an integrated NST curriculum. My supervisor who is an expert in the field of science and technology education checked the data through a verification and auditing process as suggested by Nowell et al., (2017). The audit trail undertaken by my supervisor provided feedback for an in-depth thematic analysis. The verification and auditing of the data analysis over a period of months resulted in the validation of the findings and presentation of the eight categories of the Grade 6 NST PSTs understanding of an integrated NST curriculum in Chapters 5 and 6.

4.5.2 Reliability

Reliability, according to Maree (2016), occurs when an instrument used to measure the data in a research study is consistent and can be repeated with different participants at different times and the results obtained will be the same. In this study, reliability was enhanced in the following manner: The data and findings were discussed with my supervisor to ensure that my interpretation of the findings was not different from the ideas of others in the field. This is in line with the belief that credibility can be ascertained if other participants understand and interpret the findings of a study in the same way as the researcher.

For this study, *credibility* was ensured by using triangulation to gather information from different sources to gain a deeper understanding of Grade 6 NST pre-service teachers' TSPCK in the teaching of Matter and Materials in an integrated NST curriculum. In other words, credibility would be increased when Grade 6 NST PSTs believe the findings of the study to be true, as the study aims to consider the participants' views (Creswell, 2014).

Credibility involved multiple sources of data collection methods used in this study which included the photographs on the whiteboard, photographs of the 40 CMs, and a rubric to determine how the Grade 4 to 6 NST topics were integrated and how links were made between the two knowledge strands of NS and TECH. The data collected from the multiple sources were continuously checked so as to produce emerging themes and various Grade 6 NST PSTs' understandings of an integrated NST curriculum. This ensured the *trustworthiness* of the study.

4.6 Data Analysis

The Grade 6 NST PSTs understandings of an integrated NST curriculum was explored using Table 4.2 below of the summarised Grade 6 Term 2 NST topics and concepts adapted from CAPS (DoBE, 2011, pp. 52-56).

Table 4.2: Summary of Grade 6 NST topics and concepts adapted from CAPS (DoBE, 2011, pp. 52-56)

	Topic	Contents & Concepts
1	Solids, liquids and gases	Arrangement of particles
2	Mixtures	Mixtures of materials
3	Solutions as special mixtures	Solutions
		Soluble substances
		Saturated solutions
4	Dissolving	What is dissolving?
		Rates of dissolving
5	Mixtures and water resources	Water pollution
		Importance of wetlands
6	Processes to purify water	Clean water

Thematic analysis was conducted using Braun and Clarke's (2006) six step process in which Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing as contained in CAPS, were analysed. The six steps involved:

(vii) The initial familiarisation of the Grade 4 to 6 NST topics and concepts that were written in the CMs.

(viii) Coding was used to identify NST topics and concepts pertaining to Matter and Materials and Processing in Grade 6 Term 2

(ix) The NST topics and concepts in Matter and Materials and Processing were then organised according to the themes, sub-themes, and codes.

(x) Themes were checked against the sub-themes and codes to gain a deeper meaning of the 40 CMs.

(xi) Ongoing revision of the themes, sub-themes and codes generated defined themes and names for the data set.

(xii) A final report on the eight categorical data analysis was compiled and presented by the use of graphical representations and narratives in relation to the themes, research questions, and literature present in the study.

According to Seale and Silverman (1997), a variety of methods must be employed to ensure rigour and validity in a qualitative research study. In this case study to determine Grade 6 NST PSTs' understanding of an integrated NST curriculum, Chapter 5 presented a detailed account of events that took place during the teaching and learning phase in semester 1. The presentation and analysis of the Grade 6 NST PSTs understanding of an integrated NST curriculum was carried out in two phases:

Phase one explicated Research Question 1 which set out to explore: "How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?"

Grade 6 NST pre-service teachers' TSPCK in Matter and Materials and Processing, as well as the misconceptions and gaps in prior knowledge of an integrated Grade 4 to 6 NST curriculum was further explored using a three-phase practical concept mapping activity which was tweaked to meet the purpose of this study (Wang, 2019). The teaching and learning events occurred in four parts:

(i) Eliciting prior knowledge of Term 2 Grade 6 NST topics on Matter and Materials and Processing through peer interaction in groups of three.
(ii) Whole class feedback on Activity 1.
(iii) The process of construction of students' understanding of an integrated NST curriculum as derived from concept mapping, and
(iv) Feedback on the construction of students' understanding of an integrated NST curriculum as derived from concept mapping.

As the Grade 6 NST PSTs worked in groups, I walked amongst the groups listening to and observing what each group was saying and doing. The following three observations were made:

- The need for clarification regarding instruction – some groups required clarification and further explanation of the new Grade 6 NST concepts that were required for the activity.
- The promotion of peer interaction and learning – some groups assisted others with their interpretation of Grade 6 NST topics of Matter and Materials and Processing concepts.
- The choice of referencing – most students did not refer to the CAPS for Grades 4 to 6 of the Intermediate Phase (DoBE, 2011) document, but preferred using the textbook (Bezuidenhout et al., 2013) and other online resources such as YouTube videoclips and science websites. Instructional strategies involved a constructivist principle and student-centred approach of facilitation and mediation using whole class and small group discussions, co-operative learning, and a concept mapping activity. Five understandings of integration of Grade 6 NST topics and concepts (61%) and three understandings of Grade 4 to 6 NST topics and concepts (39%) from the eight categories collectively emerged from the analysis of the 40 (out 48) PSTs who submitted their CMs. It is significant to note that five groupings (60%): Categories 1 to 5 identified Matter and Materials and Processing as the main topics to be discussed in Grade 6 Term 2 NST. The rest of the three groupings (40%): Categories 6 to 8 identified Grade 4 to 6 Term 2 Matter and Materials and Processing under the knowledge strands of NST. However, there were variations in how the different PSTs within these three groups talked about the other components.

Phase two expounded Research Question 2 intended to explore: "How do NST pre-service teachers represent their understanding of an integrated NST curriculum?"

During Phase two, a SAFI approach was taken in which the Grade 6 NST PSTs where the Grade 6 NST PST, 40 CMs were collected and the Grade 4 to 6 topics and concepts pertaining to Matter and Materials and Processing were analysed. The qualitatively different ways in which the NST PSTs conceptualised the integration was explored by looking at the following:

(i) What was foregrounded in terms of what is being integrated?
(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?
(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

The Grade 6 NST PSTs' individual CMs were analysed to determine how the Grade 6 NST derived and represented their understanding of an integrated NST curriculum in the teaching of topics and concepts pertaining to Matter and Materials and Processing. Chapter 6 provided a graphical representation of the Grade 4 to 6 NST topics and concepts contained in the 40 individual CMs of the Grade 6 NST PSTs. Thematic coding of the individual CMs assisted in maintaining rigour on how the Grade 6 NST service teachers derived and represented their understanding of an integrated NST curriculum. Eight categories of the CMs were further analysed and themes of Grade 6 NST PSTs' understanding of topics and concepts regarding Matter and Materials in NS and Processing in TECH were generated. These themes were reviewed and critically analysed with my supervisor before graphs were used to represent the data of the Grade 6 NST PSTs' understanding of an integrated NST curriculum. The data in each graph was further scrutinised and critiqued by my supervisor before a detailed discussion and report of the analysis was ensued. It must be reiterated that the thematic data analysis was time consuming as we had to go back and forth with analysis of the themes, sub themes and codes until we were satisfied with the categories of the 8 qualitative understandings of an integrated NST curriculum. The above information was presented in table format, and used to collect the data from the PSTs CMs, as illustrated in Table 4.1. which indicated the NS and TECH topics and concepts placed in Categories 1 to 8, captured from the Grade 6 NST PSTs CMs from CAPS and "OTHER" sources to show their understanding of an integrated NST curriculum.

4.7 Time Constraints in the Study

This section acknowledges the limitations that were encountered in this study with regards to how Grade 6 NST PSTs derived their understanding of an integrated NST curriculum and how they represented their understanding thereof. Due to time constraints of the duration of NST lectures from 1 October 2019 to 1 November 2019, data collection was limited to Grade 6 NST PSTs at the selected private HEI. It would have been an enriching experience to have conducted my research in various HEIs in order to gain multiple perspectives from other Grade 6 NSTs groups to address the two research questions posed in my study. Another limiting factor that did not allow me to gain a deeper insight into individual NST PSTs and their challenges and suggestions with regards to the CM activity was due to the Teaching Experience from August and September 2019. Furthermore, the Grade 6 NST PSTs were absent towards the end of the data collection phase after the CMs were collected, as they had many formative assessments to submit on those days. As a result of this absence, semi-structured interviews and focus group sessions could not be planned. Practical activities were restricted, as there was a lack of laboratory apparatus and resources to properly conduct them. Observations of Grade 6 NST PSTs in the lecture rooms were used to describe their peer interactions and discussions during the practical activities. If such a study is to be conducted in the future, audio-recordings of the researcher's engagement with the NST PSTs during the whole class and small group discussions as well as the co-operative learning sessions could be used to reflect on success and challenges of the interactive sessions as well as how the NST PSTs peer interaction in follow up sessions could be improved. NST PSTs could also be given an opportunity (after participation of the SAFI CM activity) to draw their own CMs in another session without any guidance form the researcher. By allowing the NST PSTs to draw their own CMs this would provide evidence to the researcher as to whether the NST PSTs reached an understanding of an integrated NST curriculum and how they represented this understanding independently. Semi-structured interviews and focus group sessions of small groups of NST PSTs would enhance the findings of the effectiveness of implementing instructional strategies and whether NST PSTs experienced challenges in drawing CMs on their own.

4.8 Role of the Researcher

However, Orb et al., (2001) state that the role of a qualitative researcher in research is exploratory and descriptive in relation to their participants in a particular setting. Therefore, the qualitative researcher who chooses to become a participant in the study needs to clarify the purpose and intention of the study as they are dealing with human behaviour which may cause ethical dilemmas during data collection. Also, since qualitative research entails observation and the use of interviews, the researcher cannot be subjective and needs to listen to the participants' responses or make observations by limiting interactions and to avoid any influence over the data production. Creswell (2014) and Maree (2016) also agree that qualitative researchers find it difficult to find a balance between their relationships and interactions with the participants and maintaining an objective stance as the role of a qualitative researcher. However, Orb et al. (2001) states that participant interaction with the researcher "is crucial" (p. 94) in the data collection process and that the researcher should be clear on the research questions and research design methodology in which are ethically sound during the data collection stage.

The Grade 6 NST PSTs were also informed that the study would be implemented during their lectures, except for the focus group interview. They were further made aware that participation in the study was completely voluntary and that the research study would not interrupt the teaching and learning process during the NST lectures. This would ensure that there was no bias and influence of my role as a researcher during my interactions with the Grade 6 NST PSTs and the outcome could not be pre-determined. I engaged the Grade 6 NST PSTs further and assured them that should they decide to participate in the study, their individual contributions would be invaluable, as their participation could also assist in the training of future Grade 6 NST PSTs in the understanding of an integrated NST curriculum and could also promote the development of TSPCK in the difficult topics and concepts of Matter and Materials in NS and Processing in TECH as contained in the CAPS document. My interaction with the Grade 6 NST PSTs was that of facilitation and mediation as a lecturer during the CM activity. I identified Grade 6 NST pre-service teachers' TSPCK in Matter and Materials, and the misconceptions and gaps in prior knowledge in an integrated Grade 6 NST curriculum by using the whole-class discussion strategy. I investigated Grade 6 NST PSTs' misconceptions and gaps in prior knowledge of Matter and Materials in NS and Processing in TECH by using small-group discussions. Grade 6 NST PSTs' perceptions of an integrated NST curriculum were also identified. How they might have been taught Matter and Materials in NS and Processing in TECH in primary school, was also investigated by carefully listening to the Grade 6 NSTs feedback after the whole class and small group discussions and co-operative learning brainstorming sessions. The 48 Grade 6 NST PSTs then completed templates of the CM as collaborative small group discussions and co-operative learning peer interaction was facilitated.

A number of ethical considerations were adhered to in this study. Participants were assured of anonymity before requesting information from them during all the phases of the data collection process. Only the researcher knew the participants' identities, keeping with the University's required ethical standards for research. Thus, anonymity and confidentiality were safeguarded throughout the study. Furthermore, the purpose of the research and what it entailed was explained to all the participants before they agreed to participate and signed the consent forms. Participation was completely voluntary, and participants were given permission to withdraw from the study at any time without any repercussions. In addition, permission to conduct the research study on site was granted by the national Academic Team of the private HEI and ethical clearance was granted by the Research committee of UKZN.

4.9 Conclusion

This chapter presented the research design and that were employed in this study. The study used qualitative research, in particular, a case study design. In addition to describing the type of research and research methods that were used, reasons for using purposive sampling were provided, followed by a description of the processes of data collection and analysis. After reflecting on the ethical considerations of the study, and measures taken to ensure validity, reliability, and credibility, the limitations of the study were acknowledged. A brief summary followed next to wrap up the chapter which presents the various stages of engagement which led to the elicitation of Grade 6 NST PSTs' understanding of an integrated NST curriculum. Feedback is provided on significant observations that were made during the process.

The next chapter provides a description and discussion of the four-phase process of eliciting Grade 6 NST PSTs' understanding of an integrated NST curriculum.

CHAPTER 5

PROCESS OF ELICITING GRADE 6 NST PRE-SERVICE TEACHERS' UNDERSTANDING OF AN INTEGRATED NST CURRICULUM

Introduction

In the quest to explore how to develop Grade 6 NST PSTs' understanding of an integrated NST curriculum, this chapter presents the various stages of engagement which led to the elicitation of Grade 6 NST PSTs' understanding of an integrated NST curriculum. Feedback is provided on significant observations that were made during the process.

The application of concept mapping to elicit Grade 6 NST PSTs' understanding of an integrated NST curriculum was implemented during 2-hour lecture sessions over 5 weeks (from 1 October 2019 to 1 November 2019), and was divided into the following four parts, namely:

Part A: Activity 1

Date: 4 October 2019

Duration: 10 minutes

Activity: Eliciting prior knowledge of Term 2 Grade 6 NST topics on Matter and Materials and Processing through peer interaction in groups of three.

Part B: **Activity 2**

Date: 4, 7 and 8 October 2019

Duration: 30 minutes

Activity: Whole class feedback on Activity 1.

Part C: Activity 3

Date: 18 October 2019

Duration: 50 minutes

Activity: The process of construction of students' understanding of an integrated NST curriculum as derived from concept mapping.

Part D: Activity 4

Date: 24, 25 and 31 October 2019

Duration: 30 minutes

Activity: Feedback on the construction of students' understanding of an integrated NST curriculum as derived from concept mapping.

The CM strategy was implemented during a 2-hour lecture session in the second semester of 2019 with a class of 48 Grade 6 NST PSTs. A CM template was used as an instrument to collect data on their understanding of what an integrated Grade 6 NST curriculum entails. According to Wang (2019), a practical application of a concept mapping activity should entail the following three phases:

1) The preparation phase,
2) The interactive phase,
3) The feedback and evaluation phase.

The *first phase* requires the teacher to plan and prepare by setting clear objectives for the activity. A suitable structure of the CM must be prepared by the teacher before the activity containing the topic and concepts under the theme of the learning unit. The topics, concepts, and themes must be aligned to the prescribed textbook. The *second phase* is where the teacher explicitly explains the objectives and the intended purpose and meaning of the activity. In the *last phase*, students engage in a peer review process where students mark each group's CM according to a rubric or rating scale provided by the teacher. Due to the fact that this is a research project, the above phases had to be tweaked slightly so that they serve the purpose of this study. Lectures in the NST module began in the second semester on 1 October 2019 and were completed on 1 November 2019. Grade 6 NST PSTs returned to the second semester from teaching experience in August and September 2019. The first lecture began with a brainstorming session and whole class discussion. Although the Grade 6 NST PSTs recalled and consolidated their prior knowledge and understanding of the NS theme of Life and Living with ease, most of the students' responses indicated that they found it challenging to teach certain topics and concepts in the other themes found in the Grade 4 to 6 NST CAPS document in an integrated way. The next hour of the lecture – the discussion about the challenges of teaching Grade 6 NST topics and concepts in general in the classroom – continued as I introduced the Grade 6 NST topics and concepts of Matter and Materials and Processing. The Grade 6 NST PSTs articulated that they did not clearly understand the topics and concepts in Matter and Materials from their prior knowledge gained in primary school. The Grade 6 NST PSTs also indicated that they found some Grade 4 to 6 NST topics and concepts confusing, especially regarding Processing in TECH. It was at this point that I explained to the Grade 6 NST PSTs the importance of undertaking research to determine how to improve Grade 6 NST PSTs' understanding of an integrated NST curriculum and that more research needs to be done in the area of the teaching and learning of abstract NST topics and concepts in an integrated way in primary schools in South Africa. This dialogic discussion between myself as the lecturer and the Grade 6 NST PSTs using a whole class discussion during the lecture provided an excellent entry point for me to introduce my study.

I explained that I would be carrying out a research project to explore Grade 6 NST PSTs' understanding of teaching the topics of Matter and Materials in NS and Processing in TECH in an integrated way. The purpose of my study was explained to them as my attempt to further promote the development of TSPCK in the teaching of Matter and Material and Processing in an integrated way. TSPCK is a specialised form of knowledge (Mavhunga, 2014; Mavhunga, 2018; Mavhunga & Rollnick, 2013; Mavhunga & Van der Merwe, 2017, 2020) that incorporates a teacher's understanding of the content and concepts contained in a specific topic which can be successfully taught to learners with the use of suitable teaching strategies.

The Grade 6 NST PSTs were also informed that the study would be implemented during their lectures, except for the focus group interview. They were further made aware that participation in the study was completely voluntary. Engaging the Grade 6 NST PSTs further, I assured them that should they decide to participate in the study, their individual contributions would be invaluable, as their participation could also assist in the training of future Grade 6 NST PSTs in the understanding of an integrated NST curriculum and could also promote the development of TSPCK in the difficult topics and concepts of Matter and Materials in NS and Processing in TECH as contained in the CAPS document. By doing so, future Grade 6 NST PSTs could become specialist NST in-service teachers who would have gained an understanding of the meaning of an integrated NST curriculum and how to use instructional strategies to promote the teaching and learning of difficult and abstract topics and concepts in Matter and Materials in NS and Processing in TECH for the Intermediate Phase as stipulated by the DoBE (2011).

Future Grade 6 NST PSTs could further apply an integrated TSPCK not only in the topics of Matter and Materials in NS and Processing in TECH but in other NST topics as stipulated in the CAPS document for Grades 4 to 6 in the Intermediate phase (DoBE, 2011). Furthermore, this study could assist future Grade 6 NST PSTs to use their understanding of an integrated NST curriculum and developed integrated TSPCK in research and in the teaching and learning of complex concepts in other Grade 6 NST knowledge strands such as Life and Living and Processing; Energy and Change; Systems and Control; and Planet Earth and beyond (DoBE 2011, pp. 14–15).

5.1 Part A: Activity 1

Activity 1 was focused on eliciting prior knowledge of Term 2 Grade 6 NST topics of matter and Materials and Processing.

To kick start this session, the following focus question was posed to the whole group – written on the whiteboard – and used as an entry point (ice breaker) for our discussion:

- *Can you recall your prior knowledge of Grade 4 and 5 concepts of Matter and Materials and Processing?*

Guided by a social constructivist approach (Adom et al., 2016; Dagar & Yadav, 2016) that promotes active learning through peer interaction in a social setting (Arthurs & Kreager, 2017; Yeboah et al., 2019), the Grade 6 topics and concepts of Matter and Materials and Processing according to CAPS for Grades 4 to 6 in the Intermediate Phase (DoBE, 2011, pp. 52–56) were introduced to the Grade 6 NST PSTs. The purpose of focussing on the above knowledge strands is in accordance with Wang's (2019) three phases of instructional strategy using concept mapping to enable the Grade 6 NST pre-service students to represent a deeper understanding of integrated Grade 6 NST abstract topics and concepts in a concrete way, so that the Grade 6 NST PSTs could freely communicate; find a deeper meaning of concepts related to the topics within the NST knowledge strands of Matter and Materials and Processing; and develop an understanding of instructional strategies, such as active learning, whole class discussion, small group discussions, and co-operative learning (Arthurs & Kreager, 2017; Malatji, 2016; Maphosa & Ndebele, 2014; Ogunleye, 2013; Yeboah et al., 2019). By creating a more student-centred approach and a learning environment conducive to each student's learning style, such as visual, audio, audio-visual, and kinaesthetic (Brough, 2012; Lehesvuori et al., 2018), the Grade 6 NST PSTs would also feel at ease to express their past experiences and challenges in their present understanding of abstract and complex concepts in topics such as Matter and Materials and Processing. The Grade 6 NST PSTs could apply their developed TSPCK in the topics of Matter and Materials in NS and Processing in TECH to problematisation and contextualisation, in order to find practical solutions to real life problems in South Africa.

Grade 6 NST PSTs' prior knowledge was explored using questioning prompts (both enabling and extended)[1]. This was meant to ascertain how much the students already knew about the Grade 6 topics. Through the use of "what", "how", and "why" open-ended and divergent questions with a wait and response time (Ogunleye, 2013)[2] of 2 minutes after each question, students were allowed to think about the question and then respond with concepts related to the Grade 4 and 5 NST topics of Matter and Materials and Processing. The NST concepts recalled by the group of students relating to Grades 4 to 6 Matter and Materials and Processing were written on the whiteboard, as illustrated in Figure 5.1 below:

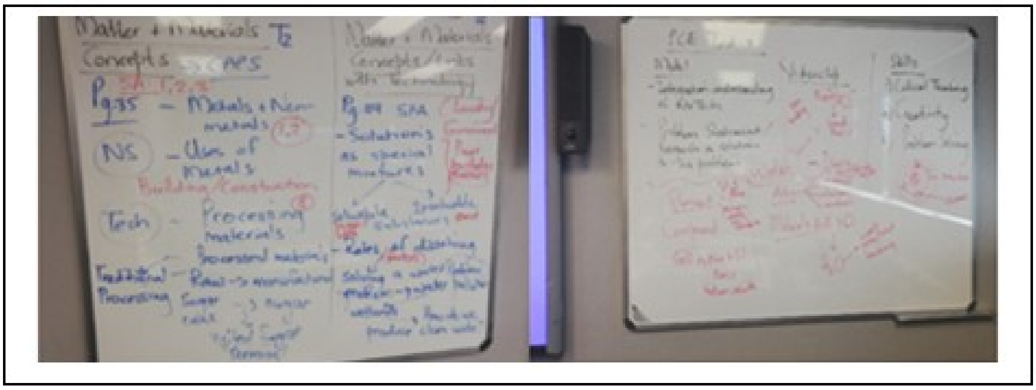


Figure 5.1: Eliciting Prior Knowledge of Grade 4 and 5 Concepts in Matter and Materials and Processing

Figure 5.1 above was generated from the question: "*Can you recall your prior knowledge of Grade 4 and 5 concepts of Matter and Materials and Processing?*" As can be seen in Figure

[1] Enabling prompts are used in developing mathematical thinking by providing support to learners who struggle with challenging tasks whereas extending prompts are given to learners who have completed all tasks with ease and allows for these learners to apply their thinking to other tasks (Sullivan et al., 2014).
[2] Examples include: What is your understanding of the topics of Matter and Materials and Processing? How will you teach Matter and Materials and Processing in an integrated way? Why is the teaching of an integrated Grade 6 NST curriculum important for Science, Technology and Society? (DoBE, 2011, p. 11).

5.1, Matter and Materials concepts were written on the left-hand side and the Matter and Materials concepts' link with TECH on the right-hand side of the whiteboard. The students' recall of NST topics and concepts was written in blue ink. The red ink indicates my feedback to the Grade 6 NST PSTs.

With regards to Grade 6 NST PSTs' recall of Grades 4 to 5 NST topics and concepts and topics relating to Matter and Materials and Processing, the following ideas were presented as illustrated in Table 5.1 below.

Table 5.1: Recall of Prior Knowledge of Grade 4 and 5 NST Concepts

Grade 4	**Grade 5**	**Grade 6**	**Other**
NST strand	**NST strand**	**NST strand**	
Matter and Materials and Structures (Term 2)	Matter and Materials and Processing (Term 2)	Matter and Materials and Processing (Term 2)	Matter and Materials Concepts/Links with Technology
	Metals and non-metals Uses of Metals. Processing and processed materials		Excursion to the South African Sugar Mill Association (SASA) in Semester 1 on 25 July 2019. Grade 6 NST PSTs recalled how they watched a videoclip about sugarcane being converted to raw sugar. The raw sugar was placed onto conveyor belt machines that transported the raw sugar to different parts of the terminal. The raw sugar was stored in silos and tested for impurities in the chemical laboratory before being distributed to

			manufacturers and exported to other countries in the form of various processed sugar products.
	Traditional processing	Solutions – made up of soluble and insoluble substances.	Matter and Material concepts could be linked to TECH concepts such as separation of solutions.
	Processing of raw and manufactured materials	Rates of dissolving factors affecting the rates of dissolving	Rates of dissolving could be used to solve a water problem such as water pollution which could also affect the environment like wetland areas
			How do we produce clean water?

Table 5.2: NST Content Knowledge and Concepts Covered in Grades 4 to 6

Grade 4		Grade 5		Grade 6	
Strands		**Strands**		**Strands**	
NS	**TECH**	**NS**	**TECH**	**NS**	**TECH**
Matter & Materials	**Structures**	**Matter & Materials**	**Processing**	**Matter & Materials**	**Processing**
Materials around us	Strengthening materials	Metals and non-metals	Processing materials	Solids, liquids, and gases	Processes to purify water
Solid materials	Strong frame structures	Uses of metals	Processed materials	Mixtures	
				Solutions as special mixtures	
				Dissolving	
				Mixtures and water resources	

In Table 5.2 above, the content knowledge comprising of Grades 4 to 6 NST topics and concepts in Matter and Materials in NS and Structures and Processing in TECH are highlighted. If we compare the topics covered in Grades 4 to 5 and what the Grade 6 NST PSTs foregrounded, it is encouraging to see that they could recall all the concepts in Grade 5 relating to Matter and Materials and Processing. However, they had difficulties in recalling Grade 4 NST concepts relating to Matter and Materials and Structures. It was interesting to note that the Grade 6 NST PSTs also mentioned the excursion to the Sugar Mill when recalling Grade 5 concepts relating to Matter and Materials and Processing. With regards to Grade 6 NST concepts pertaining to Matter and Materials and Processing, they were only able to highlight three topics, namely, *solutions, dissolving,* and *processes to purify water*.

Seeing that the Grade 6 NST PSTs experienced difficulties in recalling much of the work covered in Grades 4 and 5, I added the following to the whiteboard:

- The three specific aims indicated in CAPS for the Intermediate Phase (Grades 4 to 6) (DoBE, 2011) include:

- **Specific aim one**: "*Learners should be able to complete investigations, analyse problems and use practical processes and skills in designing and evaluating solutions*" (p. 10). The teacher must provide multiple opportunities for learners to engage in various forms of practical work to gain specific integrated NST process skills that could be applied to learners' real-life contexts.

- **Specific aim two**: "*Learners should have a grasp of scientific, technological and environmental knowledge and be able to apply it in new contexts*" (p. 11). This was meant to highlight the relevance and application of metals, non-metals, and their uses to science and technological advancements to address the needs of society.

- **Specific aim three**: "*Learners should understand the practical uses of Natural Sciences and Technology in society and the environment and have values that make them caring and creative citizens*" (p. 11). This was meant for students to enable them to understand the application of NST to their everyday lives.

- Points that needed to be revisited:
  - Revise prior knowledge of Matter and Materials in Chemistry.
  - Explore new concepts in topics such as the Environment to better understand the links between Matter and Materials and Technology relating to solutions, dissolving, and water pollution. In addition, I listed examples of soluble and insoluble substances such as sugar, salt, and sand, respectively.
  - Investigate the factors that affect the rate of dissolving by carrying out an investigation.

5.2 Part B: Activity 2

Activity 2 was focused on providing feedback on Activity 1.

The initial aim of this session was to discuss the feedback on shared ideas, where prior knowledge was to be "deconstructed and reconstructed into new schemes of knowledge" (Hattie & Timperley, 2007; Mapplebeck & Dunlop, 2019). However, this session proved to be more difficult than anticipated. Even though I used prompting and open-ended questioning techniques to elicit the Grade 6 NST PSTs' prior knowledge, students were hesitant to share their ideas with the rest of the class. Only half of the class actively engaged in the whole class discussion. Seeing that almost half of the Grade 6 NST PSTs did not engage fully in this activity, I opted to revise the specific aims of NST as contained in the NST CAPS for Grades 4 to 6 in the Intermediate Phase (DoBE, 2011) document and linked metals and non-metals in NS to processed materials in TECH that could be used in the construction of buildings and structures.

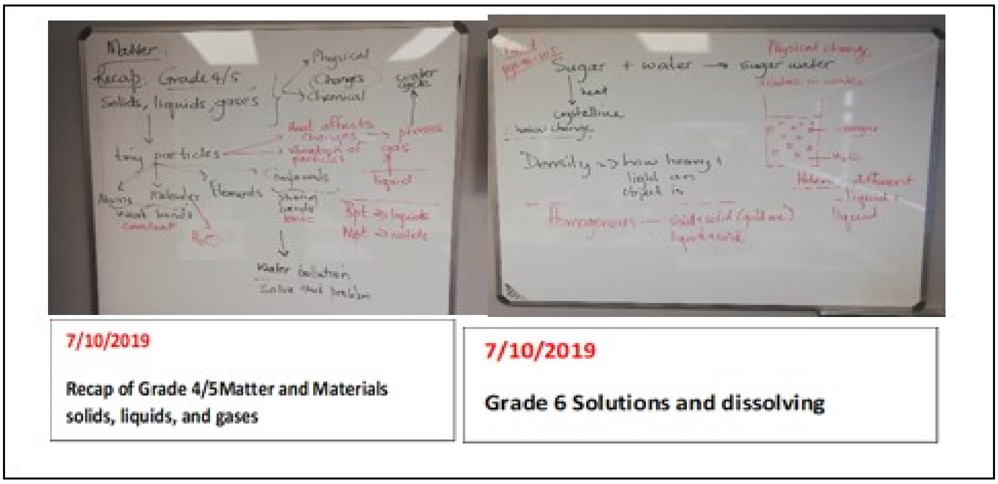


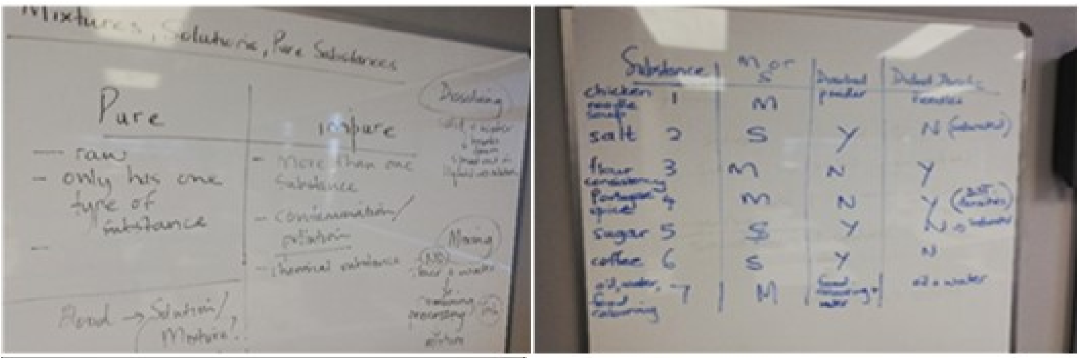
Figure 5.2: Elicitation of Prior Knowledge in Topics and Concepts of Grades 4 and 5 Matter and Materials in NS

In our revision of prior knowledge of Matter and Materials in Chemistry as can be seen in Figure 5.2, the following topics and concepts were highlighted:

- States and phases of matter and the particle nature of matter
- Physical and chemical changes of solids, liquids, and gases
- Boiling and melting points of liquids and solids

- Water cycle and how it is related to phase change of particles of water.
- Water pollution and how this problem could be solved.
- Dissolution process of sugar and water
- The formation of crystalline structures and solutions
- Composition of homogenous and heterogenous mixtures
- The role of density in dissolving particles and substances

The revision of the above Grade 4 to 5 work formed the basis upon which I could introduce the Grade 6 NST topics and concepts of dissolving and mixtures (homogenous and heterogenous).



8/10/2019

Grade 6 Pure and Impure substances

8/10/2019

Grade 6 Practical investigation using household substances

Figure 5.3: Introduction of Grade 6 NST Concepts of Solutions and Consolidation of the Topics and Concepts of Dissolving by Carrying out a Practical Investigation

As can be seen from the above images (Figure 5.3), the following points were highlighted:

- Pure substances are raw and contain one type of substance.
- Impure substances are contaminated by more than one chemical substance.
- There is a difference between dissolving salt and water and mixing flour and water.
- Is blood a solution or mixture?
- Practical investigation from textbook to show the degree of solubility of different states of substances when dissolved in cold water.

- Saturated solutions and different densities are reasons why substances do not dissolve in water.

The elicitation of Grades 4 and 5 NST prior knowledge of topics and concepts by the Grade 6 NST PSTs set the platform for the introduction of more complex Grade 6 NST concepts such as “pure” and “impure substances” and consolidation of the concept of “solubility”. Grade 4 and 5 elicitation of prior knowledge of topics and concepts in the Particle Nature of Matter and its phases when heat is added or taken away as well as the properties of Matter were used as an introduction to Grade 6 concepts relating to the concepts of “substances” and “solubility”. According to a number of researchers (Akgün, 2009; Sadler & Sonnert, 2016; Tümay, 2016; Üce & Ceyhan, 2019; Zoller, 1990), chemistry is often perceived negatively by first-year college students who may have developed prior misconceptions from primary and high school. Zoller (1990) reckons that prior misconceptions range from the learning of the structure and properties of the atom from the Bohr Atomic Model to the chemical reactivity of single and double bonds within molecules formed earlier in their primary school years. Akgün (2009) also suggests that science PSTs may experience challenges in this area due to the foundation of conceptual understanding not being properly laid down in primary school science, which may have led to misconceptions about the conservation of mass, density, and volume of particles making up substances, and their ability to dissolve to form solutions. According to Mudadigwa and Msimanga (2019), students also find the topics and concepts of the chemistry of aqueous solutions and the dissolution process confusing, and may regard the solute as an active component whereas the solvent plays a passive role.

The topic and concept of dissolving (Naah & Sanger, 2013) was developed in the Grade 6 NST PSTs by them engaging in a practical chemistry investigation (Köller et al., 2015; Okorie & Ugwuanyi, 2020) using kitchen household substances. The Grade 6 NST PSTs were divided randomly across the class and engaged in this activity in small groups of three individuals seated together. Each group was given a polystyrene cup containing cold water, a plastic teaspoon, and a different unknown kitchen household substance placed in an unlabelled plastic packet. Each Grade 6 NST PST in the small group had a turn in stirring the substance into the water with the plastic teaspoon to see if it dissolved or not. Each group also discussed the appearance, texture, and state of the unknown kitchen household substance, and used touch, smell, and taste to identify the substance. At the end of the investigation, a Grade 6 NST PST from each group communicated the results and provided a possible name for the unknown kitchen household substance in the practical investigation to the rest of the class. The Grade 6 NST PSTs' feedback was written into the table on the whiteboard. After completion of the feedback session, a whole class discussion was held to clarify the Grade 6 NST topics and concepts that they had trouble in understanding and explaining in relation to Grade 6 Term 2 mixtures and solutions. Also, the reasons why some substances dissolve and do not dissolve in water were also discussed.

Figure 5.4: Whole Class and Small Group Discussions of Grade 6 NST Separation Methods and Revision of Grade 6 NST Topics and Concepts Relating to Solutions and Mixtures

As can be seen from the above images (Figure 5.4), the following points were highlighted:

- A solution is formed when a solute dissolve in a solvent.
- Homogenous mixtures can be separated by evaporation, distillation, and using a separating funnel.
- Heterogenous mixtures can be separated by magnetism and filtration.
- Summary to revise and consolidate understanding of pure substance, mixture, solution, mechanical mixture, and dissolving.

The individual responses when asked to define the following terms: "substance", "mixture", "solution", "mechanical mixture", and "dissolving" included the use of key words pertaining to each of these concepts (DoBE, 2011). This showed that Grade 6 NST PSTs were able to identify the components/words that made up that specific topic or concept. I also observed that there were more individual responses in providing key words to the definitions of "mixture", solution", "mechanical mixture", and "dissolving". The observation made during this practical chemistry investigation was that all students in the small groups of three were fully engaged in interactive peer discussions during the practical activity. By carrying out this observation during the practical investigation, the more passive Grade 6 NST PSTs became more actively involved and it was apparent that their curiosity and interest in NST was reignited from the social interaction with their peers.

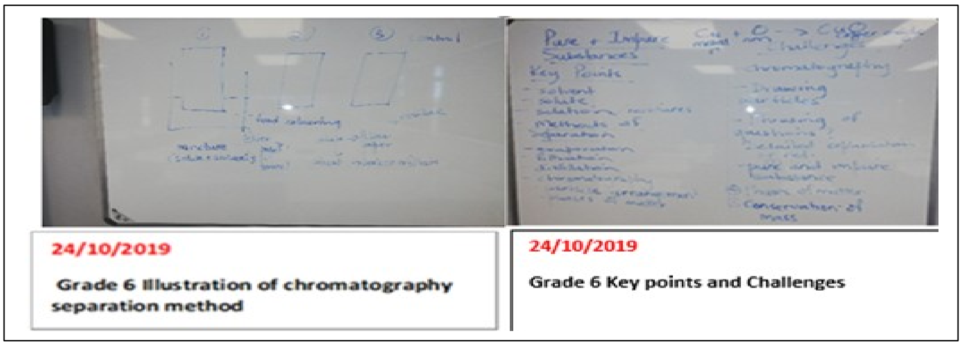


Figure 5.5: Revision of Chromatography Separation Method and Revision of Grade 6 Key Topics and Concepts in Matter and Materials

As can be seen from the above images (Figure 5.5), the following points were highlighted:

- Chromatography can be used to separate a mixture of two soluble substances, like food colouring in water, using paper towel or tissue paper using a control.
- The paper towel dotted with food colouring is placed in a glass of water, dissolves with the water, and travels a distance up the paper. The food colouring is left to dry, is separated from its different colour pigments, and compared to the control.
- Key points regarding the composition of a solution containing a solute and solvent. A solution can be separated by filtration using chemical apparatus such as a glass beaker, glass filter funnel, and filter paper. The substance left behind on the filter paper is called the "residue", while the solvent that passes through the filter funnel is called the "filtrate".
- Key points regarding separation methods included evaporation, filtration, distillation, and chromatography, which relates to particle arrangement and phases of matter.
- Challenges that the Grade 6 NST PSTs faced was: in their understanding of the separation method of chromatography; drawing of particles and using graphical representations of atoms, molecules, elements and compounds; uncertainty in providing single words or statements or detailed explanations; the complex scientific language that was used in most textbooks; differences between pure and impure substances and

the three states of matter; and finally, conservation of mass of particles of matter and its meaning in chemistry.

This activity focused on the active listening (Arthurs & Kreager, 2017; Maphosa & Ndebele, 2014; Yeboah et al., 2019) of the Grade 6 NST PSTs' challenges with the learning of the new Grade 6 NST topics and concepts as well as highlighting of key points relating to the methods of separation of solutions, such as filtration and chromatography. An increased number of Grade 6 NST PSTs in the class (during oral interaction of feedback) indicated that they had some idea of the process of filtration but did not fully understand the separation method of chromatography as they were not taught this type of separation method in primary school.

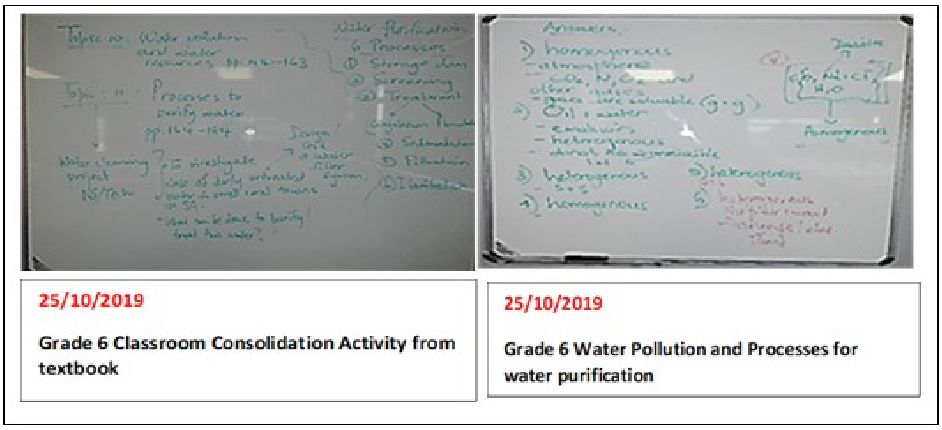


Figure 5.6: Exploration of Grade 6 NST Topics and Concepts in Processes to Purify Water and Consolidation Activity of Prior Knowledge of Grade 6 NST Topics and Concepts in Solutions and Mixtures

As can be seen from the above images (Figure 5.6), the following points were highlighted:

- Concepts that need to be explored in Grade 6 NST include water pollution and water resources; processes to purify water; and designing a water filter system to address the water crisis in rural areas in South Africa.
- The six steps used in water purification, such as the storage of water in dams, namely: screening, treatment by coagulation and flocculation, sedimentation, filtration, and disinfection.
- The classroom consolidation activity was taken from the textbook and used to correct some of the students' misconceptions as explained below:

- The atmosphere is made up of air. Grade 6 NST PSTs were referred to the CAPS approved NST textbook entitled *Grade Six Solutions for All* by Bezuidenhout et al. (2013), which contained brief explanations of the atmosphere that is made up of air and many gases, such as 70% nitrogen, and 30% comprising of oxygen, carbon-dioxide, and other gases. The Grade 6 NST textbook did not explain in detail the chemistry aspect of the particle nature of the atoms and molecules in the gases.

- Oil and water do not mix due to the oil not dissolving in the water. I used the concept of "density" to explain that liquids that are light will float in denser liquids like water.

- Heterogenous mixtures are made up of solids and liquids only. I used the example of the solidified sulphur paste on a wooden matchstick to explain that there are other examples with two solids that are heterogenous as well.

- Salt mixes with water and the salt disappears in the water. I explained to the Grade 6 NST PSTs the chemical symbols of the elements that make up salt and water, namely, sodium, chlorine, hydrogen, and oxygen. When salt and water are mixed, the salt breaks up into tiny particles and because there are tiny spaces in the water, the salt particles fill these spaces and becomes a solution. By stirring the salt in the water, it breaks down the salt grains faster. The salt does not disappear and when you taste the solution, it will be salty. Also, the salt is the solute dissolves in the spaces of the solvent to form a solution. When you add more salt into the salt solution and it does not dissolve, it will settle at the bottom of the container. We say that the salt solution has reached its "saturation point" (Chang, 1994).

- Extension of Grade 6 NST PSTs' application of present TSPCK in the topics of Matter and Materials in NS and Processing in TECH was further developed by posing to them challenging questions (Mapplebeck & Dunlop, 2019; Prud'homme et al., 2017). The Grade 6 NST PSTs were asked to explain the Grade 6 NST topics and concepts covered in high school chemistry by using chemistry symbols and formulae regarding the composition of the gases of the atmosphere. They were also asked to use another word that applies to oil and water or less dense liquids not mixing (only pertaining to liquids of different densities). The textbook entitled *Grade Six Solutions for All* by Bezuidenhout et al. (2013) did not contain detailed explanations. The Grade 6 NST PSTs resorted to using online resources to research the question (Mathai, 2014;

Moulton, 1997; Ramnarain & Padayachee, 2015), and after a few minutes, they provided me with the term “immiscible”, which I wrote on the whiteboard. Heterogenous and homogenous mixtures and their components, for example, when sulphur on a wooden matchstick head is burned, it gives off a blue flame while the wood will burn with an orange flame (Siyavula & Volunteers, 2015a). In the last question, I probed the Grade 6 NST PSTs’ prior high school chemistry knowledge and their ability to use chemical symbols and formulae to describe what happens when salt dissolves in water.

This activity focussed on students engaging in a Grade 6 NST consolidation activity related to the revision of their understanding of homogenous and heterogenous mixtures and the chemical process of dissolving salt in water (DoBE, 2011). The dissolution process of salt in water was illustrated on the whiteboard as an increased number of the Grade 6 NST PSTs indicated that they did not have a chemistry background and found the process and concept of dissolution difficult to visualise. Furthermore, their individual responses of reaching an understanding of this Grade 6 NST consolidation activity enabled the further addition of Grade 6 NST topics of Water Pollution and the Water Purification Process. In this way, it was hoped that the Grade 6 NST PSTs would apply the relevant Grade 6 NST topics and concepts, and knowledge gained in the application of Specific Aim three in which intermediate phase learners solve problems facing “Science, Technology, and Society” as stated in CAPS for Grades 4 to 6 in the Intermediate Phase (DoBE, 2011 p. 11), specifically with regards to the water and sanitation problem in rural communities in South Africa.

Figure 5.7: Exploration of the Chemistry of the Water Molecule, Design Process Steps (IDMEC) and Summary of all Grade 6 NST Topics and Concepts Covered in the TNST Module

As can be seen from the above images (Figure 5.7), the following points were highlighted:

- Teaching the chemistry of the water molecule by drawing and stating the shape (angular). Also, illustrating the symbols of the two hydrogen and one oxygen atom, polar bonds, and attractive forces between the atoms.
- Comparing the water molecule and carbon dioxide molecule which are covalent in nature to the salt crystal (sodium chloride) which is ionic in nature. Also, explaining that bonds are weaker in covalent molecules and stronger in ionic compounds (Siyavula & Volunteers, 2015b).
- Discussion of the steps of the design process (Department of Basic Education., 2012), namely, investigate – Design – Make – Evaluate – Communicate (IDMEC), to design a low cost-effective water filter system (Mahajan et al., 2018) to address the water and sanitation problem in the rural communities of South Africa. Also, Singh et al., (2015) described various types of low-cost effective water filter designs that were used in India, such as the cheap portable water filter that was designed by a group of students; and the emergency home-made filter which appears to use low-cost materials and is easily accessible to rural communities when compared to the other suggested water treatment systems by the author. In my study, Grade 6 NST PSTs had to build a model of a low cost-effective home-made filter system and could have used any one of these two water filter designs. However, not many students opted for the low cost water filter project as outlined in the textbook. Bezuidenhout et al. (2013) described the various steps in designing, making, evaluating, and communication of the home-made water filter systems which could have assisted the Grade 6 NST PSTs in the construction of the water filter system models. The following steps were outlined in the textbook: (1) a local problem statement needed to be researched; (2) the design brief must contain specifications and constraints; and (3) the water filter project was a group activity and was to be carried out over two to three weeks. Finally, the Grade 6 NST PSTs had to evaluate their water filter models by using impure muddy water so that it could be filtered through the various layers of the water filter system to obtain clear water. The water filter system should also be cost effective, easily accessible, and should use recyclable materials that would be accessible to rural communities who experience water and sanitation problems in South Africa. The two diagrams below (Figures 5.8

and 5.9) provide a description of the three low cost-effective water filter systems that are used in India.

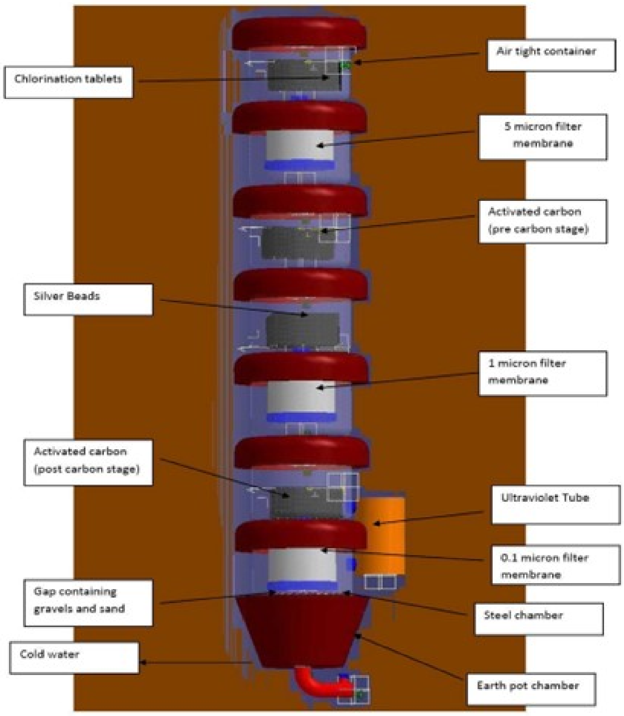


Figure 5.8: Portable Cheap Water Filter

(Source: Singh, Gupta & Singh, 2015 p. 7)

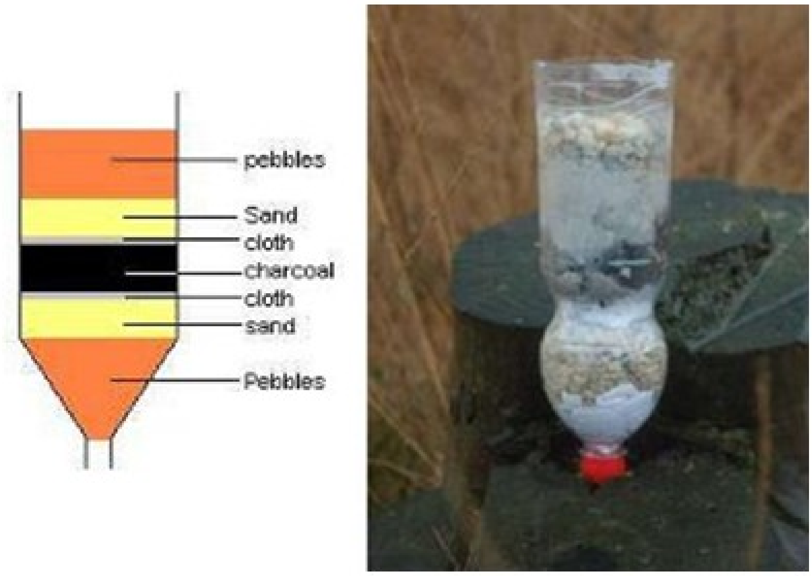


Figure 5.9: Emergency Homemade Water Filter

(Source: Singh, Gupta & Singh, 2015, p. 8)

- The lesson ended with a summary of all the topics and concepts covered in Grade 6 NST relating to Matter and Materials in NS and Processing in TECH an integrated way.

The purpose of this activity was three-fold:

- To highlight the chemistry of the water molecule and salt crystals – It is important to understand the difference in state, appearance, structure, bonds, and forces that act within molecules and crystals which give rise to its properties and change of state when heated.

- To introduce the design process steps (IDMEC) and how this process can be applied to designing and constructing a water filter system to address the problem of water and sanitation in rural communities in KZN in South Africa. Figure 5.10 below represents an illustration of the delay in the improvement of water and sanitation in rural communities of KZN from 2012–2013. It is concerning that it would take 29–37 years to address the water problems and 23–28 years to rectify the backlog in sanitation in the blue and brown coloured KZN mapped regions (Figure 5.10), which is also due to a lack of funding, according to Sutherland et al. (2014, p. 480).

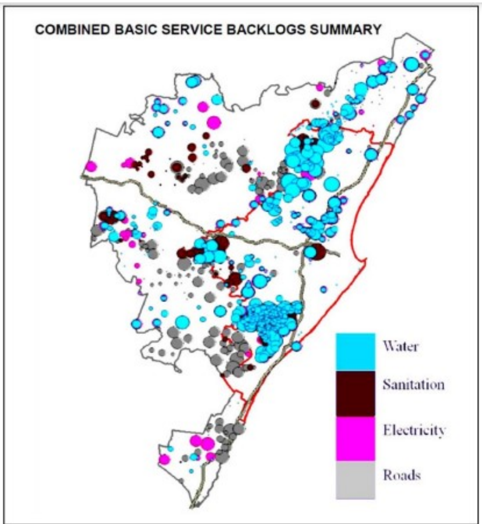


FIGURE 6
Combined service backlogs in the eThekwini Municipality

Source: eThekwini Municipality (2012a), *Spatial Development Framework Report 2012–2013*, eThekwini Municipality, Durban, page 92.

Figure 5.10: Illustration of Combined Service Backlogs Including Water and Sanitation in the eThekwini Municipality in KZN

(Source: Sutherland et al., 2014, p. 480)

- To consolidate all the Grade 6 NST topics and concepts taught from the beginning of this NST didactic module and to develop the Grade 6 NST PSTs' present TSPCK in the topics of Matter and Materials in NS and Processing in TECH for Grades 4 to 5 as well. The activity suggests that Grade 6 NST PSTs, possibly due to not being taught Chemistry and the steps used in the design process of a homemade water filter system during the teaching of primary school NST, may have also experienced difficulties in recalling and consolidating their understanding of Grade 4 to 5 NST topics and concepts in Matter and Materials and Processing when this NST didactic module was introduced in HE studies.

5.3 Part C: The Activity 3

Activity 3 focused on the process of construction of Grade 6 NST PSTs' understanding of an integrated NST curriculum as derived from concept mapping.

In preparation for this session, I first explored my own understanding of the links between concepts of Grade 6 topics of Matter and Materials in NS and Processing in TECH. These topic links were further investigated by studying the NST CAPS for the Intermediate Phase (Grades 4 to 6) (DoBE, 2011), the prescribed Grade 6 NST textbook entitled *Solutions for All* by Bezuidenhout et al., (2013), my college Chemistry textbook (Chang, 1994), and a review of research articles relating to the topic of Water Processing and Water Purification (Clements & Haarhoff, 2004; Committee, 1980; Kucera, 2019; Mahajan et al., 2018; Masindi & Duncker, 2016; Singh et al., 2015; Singh & Gupta, 2016; Zinn et al., 2018) (see Figure 5.11 below). Figure 5.11 below illustrates what was foregrounded in my engagement with the students.

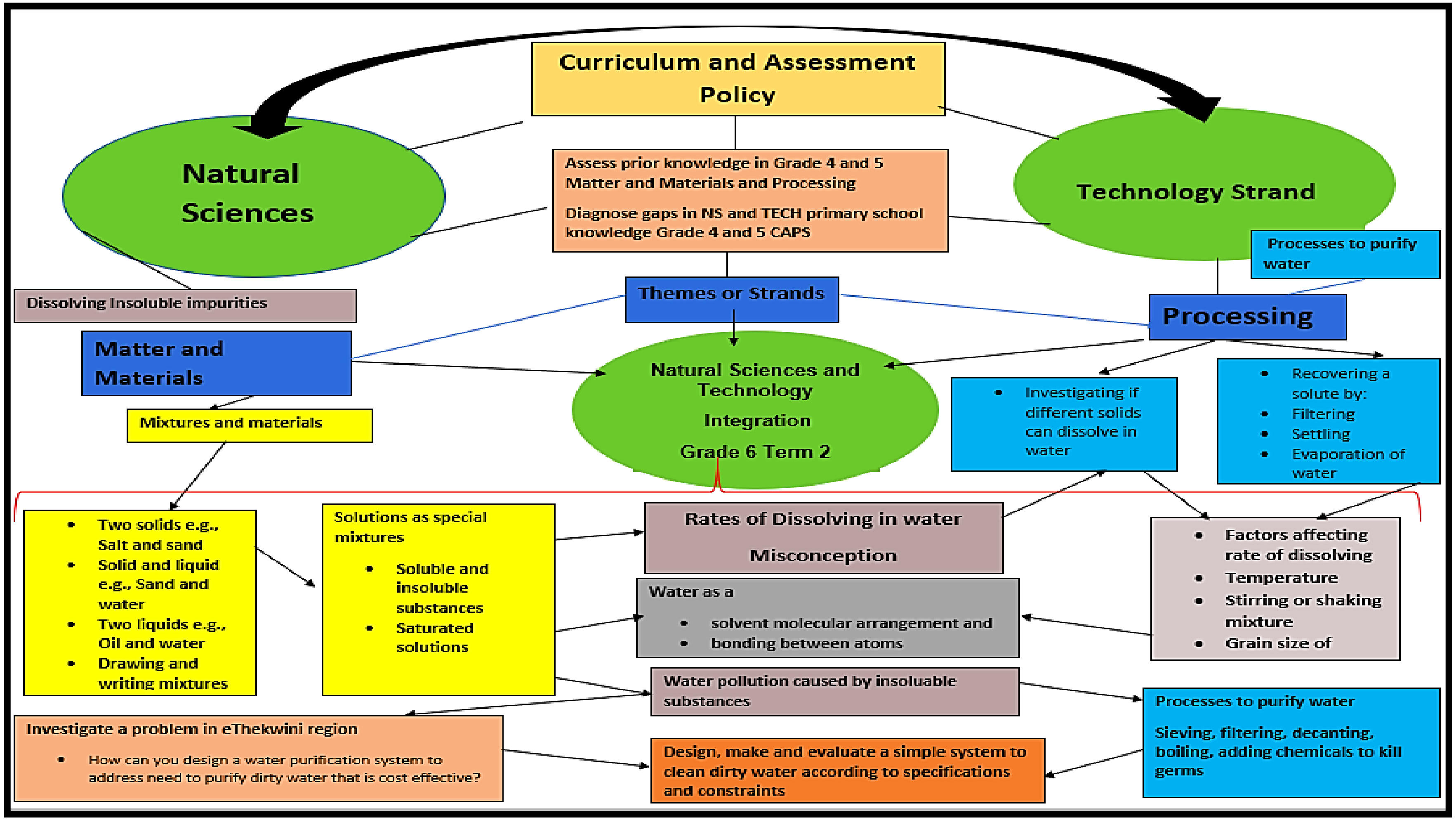


Figure 5.11: Concept Map Illustrating My Understanding of a Grade 6 NST Integrated Curriculum According to the CAPS for Grades 4 to 6 for the Intermediate Phase (DoBE, 2011)

The intention with the construction of the above CM was two-fold: Firstly, to derive personal meaning in the process of constructing my own understanding of an integrated NST curriculum through a CM, I needed to identify for myself the Grade 6 NST topics and concepts relating to Matter and Materials and Processing and how these could be taught in an integrated way under the above-mentioned knowledge strands of NST. Secondly, it was a way in which to challenge my own teaching practice; as well as a way to facilitate change in the Grade 6 NST PSTs' understanding of an integrated NST curriculum; and to assist them in the use of a concept mapping activity to bring about an improvement in the teaching and learning of abstract Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing in an integrated way. I wanted to focus more on an interactive student-centred pedagogy that involved active participation, co-operative learning, and divergent thinking. Thus, the following CM template as presented in Figure 5.12 was used for this session.

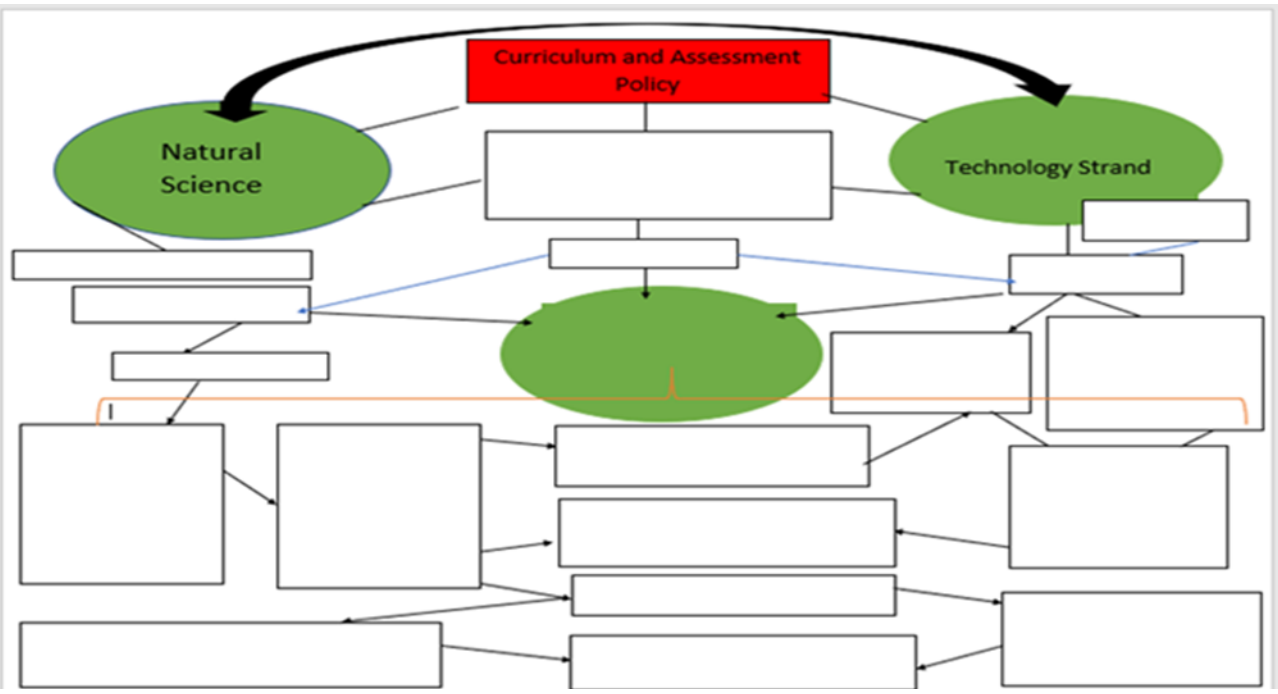


Figure 5.12: Grade 6 NST Concept Map Template

The whole group of 48 Grade 6 NST PSTs were divided into sixteen groups of three. Each student in the class was provided with the above CM template. In this context, the CM was aimed to determine the Grade 6 NST PSTs':

- Prior knowledge,
- Misconceptions in the topics of Matter and Materials and Processing

- Understanding of an integrated Grade 6 NST curriculum.

The small group discussions were thirty minutes in duration and the Grade 6 NST PSTs referred to the CAPS for Grades 4 to 6 for the Intermediate Phase (DoBE, 2011) as well as other online resources in populating their concept maps. As the Grade 6 NST PSTs worked in groups, I walked amongst the groups listening to and observing what each group was saying and doing. The following three observations were made:

- The need for clarification regarding instruction – some groups required clarification and further explanation of the new Grade 6 NST concepts that were required for the activity.
- The promotion of peer interaction and learning – some groups assisted others with their interpretation of Grade 6 NST topics of Matter and Materials and Processing concepts.
- The choice of referencing – most students did not refer to the CAPS for Grades 4 to 6 of the Intermediate Phase (DoBE, 2011) document, but preferred using the textbook (Bezuidenhout et al., 2013) and other online resources such as YouTube videoclips and science websites to research and consolidate their understanding of the difficult Grade 6 NST topics and concepts of Matter and Materials and Processing. This was evident from the Grade 6 NST PSTs' interaction with their cell phones and laptops which they accessed on their desks.

The observations in Activity 3 suggest that the Grade 6 NST PSTs still relied on the teacher using direct instruction to explain what was required in the activity. Small Group discussions promoted active participation and knowledge construction by the sharing of ideas and peer interaction in the social setting of the classroom, and finally, Grade 6 NST PSTs preferred interacting with their technological devices (cell phones and laptops) to research the Grade 6 NST topics and concepts in Matter and Materials and Processing and were not textbook orientated.

5.4 Part D: Activity 4

Activity 4 was focused on providing feedback on the construction of Grade 6 NST PSTs' understanding of an integrated NST curriculum as derived from concept mapping.

It was intriguing to see how the Grade 6 NST PSTs worked in small groups using co-operative learning to discuss and share their prior knowledge and experiences of Grade 4 and 5 topics and concepts in Matter and Materials and Processing with their peers. The following observations were made during the feedback, which were related to:

- The differences in recalling prior knowledge in NST – most students (40) found it easier to recall Grade 4 and 5 topics and concepts NS than in TECH. One of the reasons being that many of the Grade 6 NST PSTs had been taught by primary school teachers who focussed more on a teacher-centred approach in the teaching and learning of Grade 4 to 6 NST topics and concepts, particularly in the knowledge strands of Matter and Materials in NS and Processing in TECH. In addition, the Grade 6 NST PSTs also commented that they could not: recall being taught TECH topics and concepts relating to Processing; that the design process steps (IDMEC) seemed vague and confusing, and that they did not fully understand the application of the topics and concepts of Matter and Materials Processing in an integrated NST curriculum to problematisation and contextualisation with regards to the problem of water and sanitation in rural communities in South Africa.
- The newness of concept mapping – with the idea of concept mapping being a fairly new activity, it was difficult to recall Grade 4 and 5 prior TECH topics and concepts, particularly in Processing. In addition, they could not list and explain all the new Grade 6 NST topics and concepts for this Teaching Natural Science and Technology (TNST) didactic module. In the past, the Grade 6 NST PSTs may only have gained experience in mind mapping activities, and thus, not concept mapping.

Furthermore, it was observed that out of the 48 Grade 6 NST PSTs, only 40 were fully engaged in the small group discussions. Although spread out in the class, 8 individual students in the small group discussions remained passive throughout the session. I was particularly interested to see if the CM activity would be completed by the entire class at the end of the second session. As anyone would have guessed, only 40 out of 48 CMs were completed and submitted at the end of the session. It is interesting to note that the eight NST PSTs who remained passive during the small group discussions did not submit their CMs at the end of the sessions. There may have been many personal or environmental factors that could have hindered the submission of the eight CMs. One possible reason could possibly have been a result of the eight PSTs not feeling confident in the recall of Grade 4 to 6 NST prior knowledge due to negative primary school experiences. Another reason for the eight PSTs not completing the CMs could possibly have been due to wanting further guidance and explanation by the lecturer regarding unfamiliar Grade 4 to 6 NST topics and concepts. An interview would have assisted in confirming the above reasons that may have caused the eight PSTs to not submit their CMs. However, if additional time were also given to them in another lecture, the eight PSTs could have possibly completed and submitted their CMs.

Activity 4 suggested that initially the Grade 6 NST PSTs could not recall Grade 4 and 5 prior knowledge of NST topics and concepts relating to Grade 6 NST in Matter and Materials and Processing due to undiagnosed misconceptions that developed in primary school. Since the Grade 6 NST PSTs were taught mind mapping in the past, they experienced challenges in embracing concept mapping as an instructional tool in the teaching and learning of new Grade 6 NST topic and concepts in an integrated way. This was possibly due to them being taught NST separately by either NS or TECH primary school teachers who focused on teaching topics and concepts of NST that were familiar and interesting to them only. In the past, the consequence of primary school NST in-service teachers that taught fewer Grade 4 to 6 NST topics and concepts in isolation, may have resulted in primary school learners who developed undiagnosed misconceptions. Primary school learners in the Intermediate Phase who developed NST undiagnosed misconceptions in primary school, may have also developed negative attitudes and beliefs about learning NST topics and concepts further in high school, which deterred them from studying in the science and engineering fields in HE.

5.5 Conclusion

This chapter explored the implementation of a four-stage process of eliciting Grade 6 NST PSTs' understanding of an integrated NST curriculum. The focus of this chapter was on the elicitation of the four stages of engagement which were involved in the exploration of Grade 6 NST PSTs' understanding of an integrated NST curriculum (DoBE, 2011).

These four stages of engagement are summarised as follows:

Part A: Activity 1

Part A which dealt with the extraction of prior knowledge with the aid of peer interaction in groups of three. With regards to the elicitation of Grade 6 NST prior knowledge, the Grade 6 NST PSTs experienced difficulties in recalling NST topics and concepts relating to Matter and

Materials and Processing in Grade 6. An excursion to the South African Sugar Association Terminal proved to be an enriching experience for the Grade 6 NST PSTs as they recalled their experiences of the videoclip, talks, and tour inside the silos and laboratory.

Part B: Activity 2

The findings of the feedback session (Part B) proved to be demanding as Grade 6 NST PSTs experienced challenges in communicating their understanding of an integrated NST curriculum. Some of the challenges involved their understanding and explanation of certain chemistry topics and concepts related to Grade 6 NST Matter and Materials and Processing such as mixtures, solutions, and why some substances dissolve and do not dissolve in water.

Part C: Activity 3

The observations that were made in Part C using the concept mapping activity were also perplexing. The Grade 6 NST PSTs preferred direct instruction as the instructional teaching method to clear up prior misconceptions and to provide detailed explanations of difficult Grade 6 NST topics and concepts. Another noteworthy observation during this stage was that the Grade 6 NST PSTs preferred interacting with their technological devices to research NST topics and concepts relating to Matter and Materials and Processing than referring to their prescribed textbook and the CAPS document.

Part D: Activity 4

The findings of Part D included feedback concerning the concept mapping activity. The engagement of the Grade 6 NST PSTs with the concept mapping activity was captivating to watch, particularly as they began sharing their ideas and prior knowledge of Grade 4 and 5 NST topics and concepts more freely with each other. However, the Grade 6 NST PSTs also indicated that since they had engaged in mind mapping activities in the past, the concept mapping activity was new to them. The concept mapping activity could also prove to be challenging for them when they are required to derive their own CMs in the future.

The exploration of Grade 6 NST PSTs' understanding of an integrated NST curriculum is presented in the next chapter.

CHAPTER 6

PRESENTATION OF THE RESULTS OF THE CONCEPT MAPS

Introduction

This chapter presents the results of ***how Grade 6 NST PSTs represented their understanding of an integrated Grade 6 NST curriculum through the use of CMs)***. According to Cañas and Novak (2008), the structure of a concept map net reveals the development of meaningful knowledge construction. A divergent CM structure is indicative of prior knowledge recall combined with new knowledge of concepts. This type of CM contains varying levels of concepts, ranging from the most important concepts ranked higher than the least important concepts ranked at the bottom of the CM. Concepts that are connected to each other by an unlimited number of linking phrases illustrate the relationship between the concepts and are called 'propositions. The propositional nature and use of unlimited linking phrases make CMs unique from other types of maps, such as mind maps. Jonassen et al., (1997, cited in Kinchin, Hay &Adams, 2000, p. 54) highlight that "higher-order thinking skills, particularly problem-solving, rely on well-organized, domain-specific knowledge". In this regard, they argue that concept mapping aids the development and representation of such knowledge.

As pointed out in Chapter 4, a "select-and-fill-in" (SAFI) qualitative approach to concept mapping was used. A qualitative approach had to be employed because of the nature of the topic explored, namely: Grade 6 NST PSTs' understanding of an integrated NST curriculum. The qualitatively different ways in which the NST PSTs conceptualised the integration was explored by looking at the following:

(vii) What was foregrounded in terms of what is being integrated?

(viii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?

(ix) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

The above information was presented in table format and used to collect the data from the PSTs CMs, as illustrated in Table 6.1 below. Table 6.1 below indicates the NS and TECH topics and concepts placed in categories 1 to 8, captured from the Grade 6 NST PSTs CMs from CAPS and "OTHER" sources to show their understanding of an integrated NST curriculum.

Table 6.1: Information Captured to Illustrate NST PSTs' Understanding of an Integrated NST Curriculum

Category 1	**Integrated NS and TECH**	**NS Strand - CAPS**	**NS Strand - "OTHER"**	**TECH Strand - CAPS**	**TECH Strand - "OTHER"**	**Linking NS to TECH**
PST CM Response	What is being integrated?	Topics/concepts w.r.t. CAPS	Topic/concepts w.r.t. "OTHER"	Topics/concepts w.r.t. CAPS	Topics/concepts w.r.t. "OTHER"	How are the two being linked?

The following five understandings of integration of Grade 6 NST topics and concepts (61%) and three understandings of Grade 4 to 6 NST topics and concepts (39%) from the eight categories collectively emerged from the analysis of the 40 (out 48) PSTs who submitted their CMs:

Category 1: **Matter and Materials (NS) and Processing (TECH)**

Understanding of integration 1: Integration of two processes: Scientific and design processes **(22,5%)**

Category 2: **Matter and Materials (NS) and Processing (TECH)**

Understanding of integration 2: Integration of the NST (topics of Dissolving, Mixtures and Water resources) as well as the TECH topic of Processes to Purify Water and the concept of clean water **(7,5%).**

Category 3: **Matter and Materials (NS) and Processing (TECH)**

Understanding of integration 2: Integration of the NST (topics of Solids, Liquids and Gases; Mixtures and Water Resources; concepts of the arrangement of particles); as well as the TECH topic of Processes to Purify Water and concept of clean water supply **(10%).**

Category 4:	**Matter and Materials (NS) and Water Pollution (TECH)**
Understanding of integration 2:	Integration of NST (topics of Mixtures and Solutions as special mixtures; concepts of soluble substances, saturated solutions, and water pollution with a particular focus on the topic of Separation; as well as the TECH topic of processes to purify water **(10%).**
Category 5:	**Arrangement of Particles (NS) and Processing (TECH)**
Understanding of integration 2:	Integration of NST (concepts of arrangement of particles, mixtures of materials, solutions; and the TECH topic of Processing, with a particular focus on the concept of crystallisation **(10%).**
Category 6:	**Raw Materials (NS) and Man-made or Manufactured Materials (TECH)**
Understanding of integration 2:	Integration of NST Grade 5 topics and concepts **(17,5%)**
Category 7:	**Raw Materials (NS) and Man-made or Manufactured Materials (TECH)**
Understanding of integration 2:	Integration of NST Grade 5 topics and concepts **(12,5%)**
Category 8:	**Various Topics (NS) and Various Topics (TECH)**
Understanding of integration 2:	Integration of NST (different NS and TECH topics and concepts from Grades 4 to 6). **(10%)**

It is significant to note that five groupings **(60%):** Categories 1 to 5 identified Matter and Materials and Processing as the main topics to be discussed in Grade 6 Term 2 NST. The rest of the three groupings **(40%)**: Categories 6 to 8 identified Grade 4 to 6 Term 2 Matter and Materials and Processing under the knowledge strands of NST. However, there were variations in how the different PSTs within these three groups talked about the other components.

The following section provides a detailed descriptive analysis of the eight categories from the graphical representations of the Grade 6 NST pre-service teachers' CMs based on the three criteria noted above – points (i) to (iii). To repeat, only 40 out of 48 CMs were collected at the end of the concept mapping activity, as was explained in Chapter 5.

6.1. Analysis of Category 1

Matter and Materials (NS) and Processing (TECH)

Understanding of the integration of the two processes: Integration of NS: Scientific process, and TECH: Design process **(22,5%)**

(i) What was foregrounded in terms of what is being integrated?

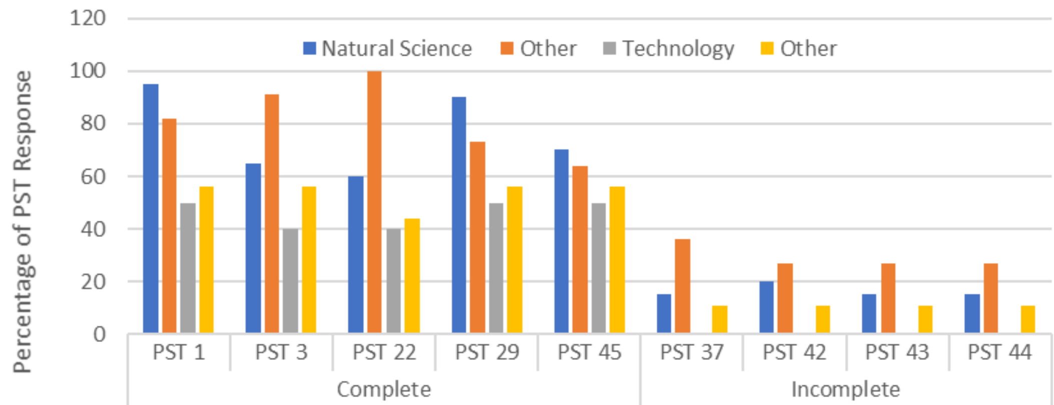
The understanding of the nine (22,5%) PSTs that fell under Category 1 of an integrated Grade 6 NST curriculum ***foregrounded the integration of two major processes: The NS scientific and the TECH design processes***. These were cast against the background of the 3 specific aims covered in CAPS (DoBE, 2011 pp. 10–11), namely.

- Specific aim one was mentioned as "doing Science and Technology". According to CAPS, learners should be able to "complete investigations, analyse problems and use practical processes and skills in designing and evaluating solutions" (p. 10).
- Specific aim two was stated as "understanding and connecting ideas". "Learners should have a grasp of scientific, technological, and environmental knowledge and be able to apply it in new contexts" (p. 11).
- Specific aim three included "Science, Society and Technology". "Learners should understand the practical uses of Natural Sciences and Technology in society and the environment and have values that make them caring and creative citizens" (p. 11). The integration of the two processes included the science process under the knowledge strand of NS and the design process under the knowledge strand of Processing.

The science process as contained in the CAPS for the Intermediate Phase (Grades 4 to 6) is a major process to be carried out in NS through: "planning and conducting investigations, evaluating and communicating findings", as well as the use of rational thought processes (DoBE, 2011, p. 9). The design process, on the other hand, is a major process in Technology and is used to find solutions to problems in society by: "identifying the need, planning, and designing, making (constructing), evaluating and improving products and communication of the process" (DoBE, 2011, p. 9). By foregrounding the scientific and design processes implied that this group of PSTs are aware that both the scientific and design processes are important in developing an understanding of an integrated Grade 6 NST curriculum.

(ii) Which Natural Sciences and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?

The analysis of Category 1's NST topics and concepts is presented in Figure 6.1 below i.t.o. of CAPS and "OTHER". The presentation of the analysis will begin with the NST topics and concepts i.t.o. CAPS, followed by the NST topics and concepts i.t.o. "OTHER". This structure will be followed throughout the presentation of all eight categories.



	PST 1	PST 3	PST 22	PST 29	PST 45	PST 37	PST 42	PST 43	PST 44
Natural Science	95	65	60	90	70	15	20	15	15
Other	82	91	100	73	64	36	27	27	27
Technology	50	40	40	50	50	0	0	0	0
Other	56	56	44	56	56	11	11	11	11

Figure 6.1: PSTs' Response to NST Topics, Content, and Concepts in Category 1

- *Which Natural Sciences and Technology topics and concepts are foregrounded i.t.o. CAPS?*

It is important to highlight at this stage that there are five Grade 6 topics and nine Grade 6 content and concepts under the knowledge strand of NS: There is only one Grade 6 topic that pertains to the knowledge strand of TECH, namely: Processes to Purify Water. The Grade 6 content and concepts relating to the topic of Processes to Purify Water includes only one section on clean water. The Table 6.2 below provides an outline the Grade 6 NST topics and concepts of an integrated curriculum for Grades 4 to 6 as stipulated in the CAPS (DoBE, 2011).

Table 6.2: Topics, Content, and Concepts of an Integrated Grade 6 NST Curriculum as Contained in CAPS (2011)

	Topic	Contents & Concepts
1	Solids, liquids and gases	Arrangement of particles
2	Mixtures	Mixtures of materials
3	Solutions as special mixtures	Solutions
		Soluble substances
		Saturated solutions
4	Dissolving	What is dissolving?
		Rates of dissolving
5	Mixtures and water resources	Water pollution
		Importance of wetlands
6	Processes to purify water	Clean water

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.1 above shows that PSTs 1 and 29 covered 95% and 90%, respectively, of the Grade 6 NS topics and concepts covered in CAPS. This observation implies that PSTs 1 and 29 recalled a higher percentage of topics and concepts in Matter and Materials in NS and Processing in TECH in primary school. The higher percentage suggests that PSTs 1 and 29 may have possibly gained good Grade 6 NST prior knowledge. The good recall of Grade 6 NST prior knowledge may have also been as a result of being taught these topics and concepts by a specialist NST teacher. PST 1 and 29 were followed by PSTs 45, 3 and 22, who covered 70%; 65% and 60%, respectively, of the work. PSTs 42, 37, 43 and 44 did not complete their CMs; as a result, their CMs showed a low level of familiarity with the topics and concepts covered in CAPS. The data shows that they could only recall between the range of 20% and 15%. It was interesting to note that none of the Grade 6 NST PSTs in Category 1 mentioned the Grade 6 NS topic, content, and concept relating to the importance of wetlands under the knowledge strand of Matter and Materials.

W.r.t. the TECH topics and concepts, five PSTs completed their CMs. PSTs 1, 29 and 45 covered 50% of Grade 6 TECH topics and concepts. They were followed by PSTs 3 and 22 who both covered 40% of Grade 6 TECH topics and concepts. It is interesting to note that PSTs 37, 42, 43 and 44 did not complete their CMs and covered 0% of Grade 6 TECH topics and concepts. All of the above nine Grade 6 NST PSTs in Category 1 used the theme of the water molecule and linked the water molecule to solutions and mixtures under Processing. Two key aspects under the topic of Processing in TECH were mentioned: properties of matter and the separation of different types of mixtures, for example, heterogenous and homogenous mixtures using different separation methods, such as filtration, decanting, evaporation, and distillation.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. OTHER?*

In terms of the "OTHER" NS topics and concepts that were mentioned by the PSTs in Category 1, it should be pointed out that PSTs 3 and 22 had high percentages of 91% and 100%, respectively, of "OTHER" NS topics and concepts in comparison to the Grade 6 NS topics and concepts as mentioned in CAPS which were 65% and 60%, respectively. This possibly means that PSTs 3 and 22 could easily recall "OTHER" NS topics and concepts possibly in Grades 4 and 5. However, they recalled a lower percentage of CAPS Grade 6 NS topics and concepts, suggesting that the foundational Grade 6 NS prior knowledge may not have been properly laid in primary school. It is important to note that the "OTHER" NS topics and concepts in Matter and Materials recalled were Grade 4 NS prior knowledge of the three states of matter and the arrangement of particles. However, PST 3 was the only one who included a graphical representation of how particles are arranged in homogenous mixtures, heterogenous mixtures, elements, and compounds of pure substances, suspensions, and immiscible. This finding is significant as this suggests that PST 3 was possibly taught how to draw and represent particles in different states of matter in primary school which is aligned to Grade 6 NST CAPS. PST 3 also mentioned that bonds between the substances affect their ability to mix and separate. PST 22, on the other hand, mentioned that the combination between the substances affect their stability to mix and separate. This finding suggests that PSTs 3 and 22 recalled prior Grade 10 chemistry knowledge due to possibly having chosen physical science in Grades 10 to 12 in high school as part of their subject selection. This was evident in the way in which PSTs 3 and 22 were able to explain the reason mixtures mix and separate was due to the stability of the bonds between elements and compounds which is part of the Grade 10 physical science curriculum.

In terms of the "OTHER" TECH topics and concepts, it is interesting to note that PSTs 1, 3, 29 and 45 obtained a higher percentage of 56% for the recall of prior knowledge in "OTHER" TECH topics and content which included Grade 4 and 5 topics and concepts of mixing of different substances, physical changes, distillation and creation of structures, systems and processes which could be used to improve the daily lives of people by finding solutions to problems especially in rural communities in South Africa.. It is important to highlight that the PSTs recalled prior knowledge of the "OTHER" TECH topics and concepts in an attempt to link the processes to purify water to the problem identification of water and sanitation in rural communities in South Africa.

(iii) *How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?*

It must be pointed out that all nine Grade 6 NST PSTs were also able to link the problem of water pollution to mixtures and arrangement of particles under the topic of Matter and Materials to different ways of separating clean water from contaminated water under the topic of Processing in TECH using filtration and evaporation as methods to purify water.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, it was observed that five out of the nine ***used problem identification***. The focus was water and the chemical formula for water (H_2O). The problem highlighted was linked to the provision of clean water in rural contexts. The concept of water and sanitation was contextualised and problematised within the local context of rural communities in South Africa.

Figure 6.2 below graphically illustrates PST 3's CM that attempts to explain the NST topics, content and concepts in Category 1. Arrows are added with short explanations for clarification.

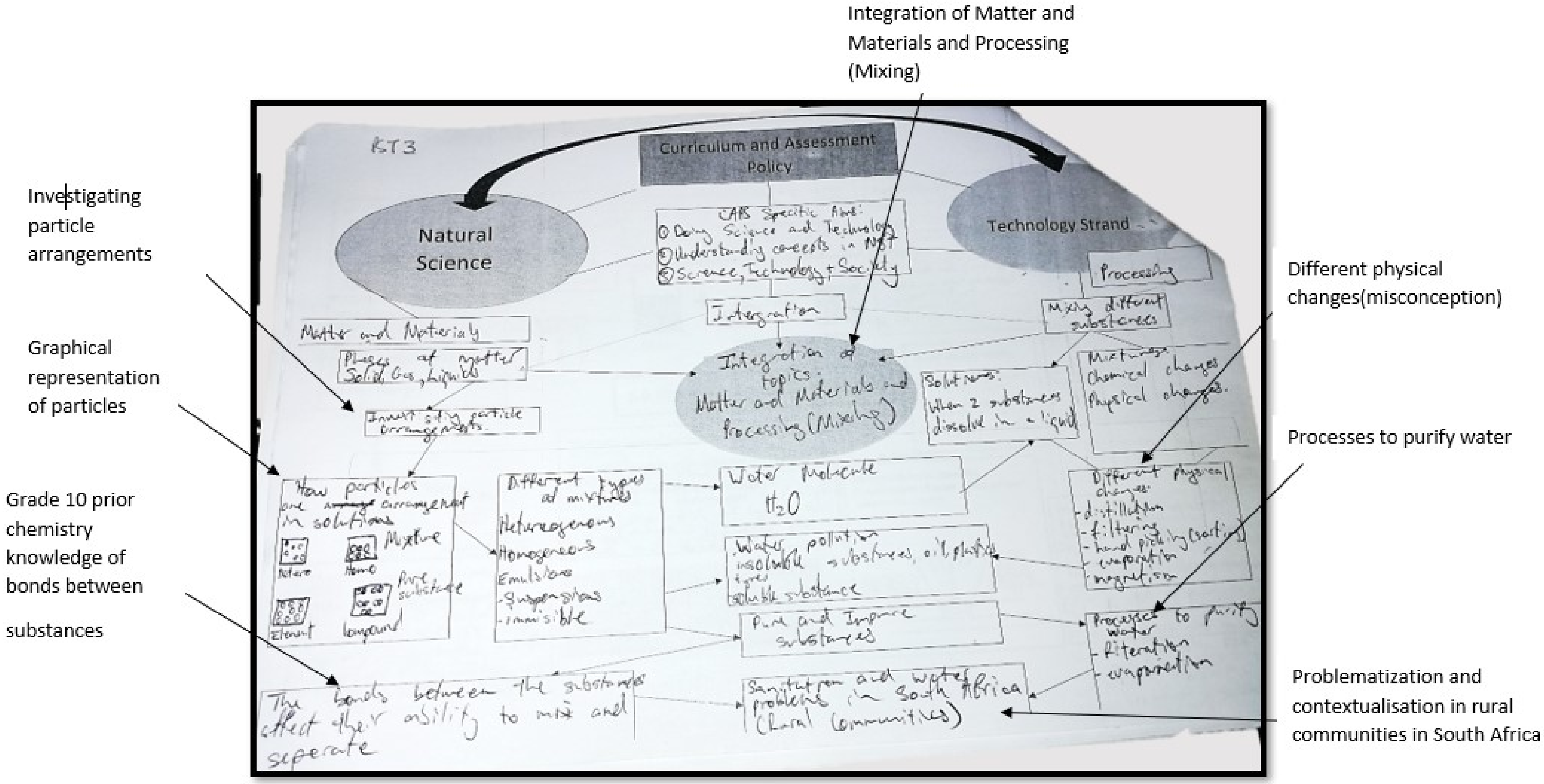


Figure 6.2: Example of PST 3's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 1

Furthermore, the problem of water pollution was linked to the content of mixtures and arrangement of particles under the topic of Matter and Materials and the different ways of separating clean water from contaminated water under the topic of Processing in TECH. The Grade 6 NST PSTs linked the concept of mixtures to water pollution caused by *soluble substances* as observed in their environments, such as soaps, acids, and fertilisers, and *insoluble substances* such as oil, plastic, and tyres.

The Grade 6 NST PSTs in Category 1 possibly had prior CK in the science and design processes and linked these processes to their understanding of an integrated Grade 6 NST curriculum.

6.2. Analysis of Category 2

Matter and Materials (NS) and Processing (TECH)

Understanding of integration: Integration of the NST (Topics of Dissolving, Mixtures and Water Resources as well as the Tech topic of Processes to Purify Water and the concept of clean water **(7,5%).**

(i) What was foregrounded in terms of what is being integrated?

The implications i.t.o what is being foregrounded is dissolving and processes to purify water which is aligned to the Grade 6 NS topics and concepts in CAPS. It is noteworthy that the PSTs in Category 2 had prior knowledge of the Grade 6 NS topic of Dissolving and the concepts related to processes to purify water. There was no written specific focus in the central block of the CMs which indicated that although the PSTs in Category 2 mentioned Grade 6 NST topics and concepts, they may not have possibly gained prior understanding of an integrated Grade 6 NST curriculum in primary school.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?*

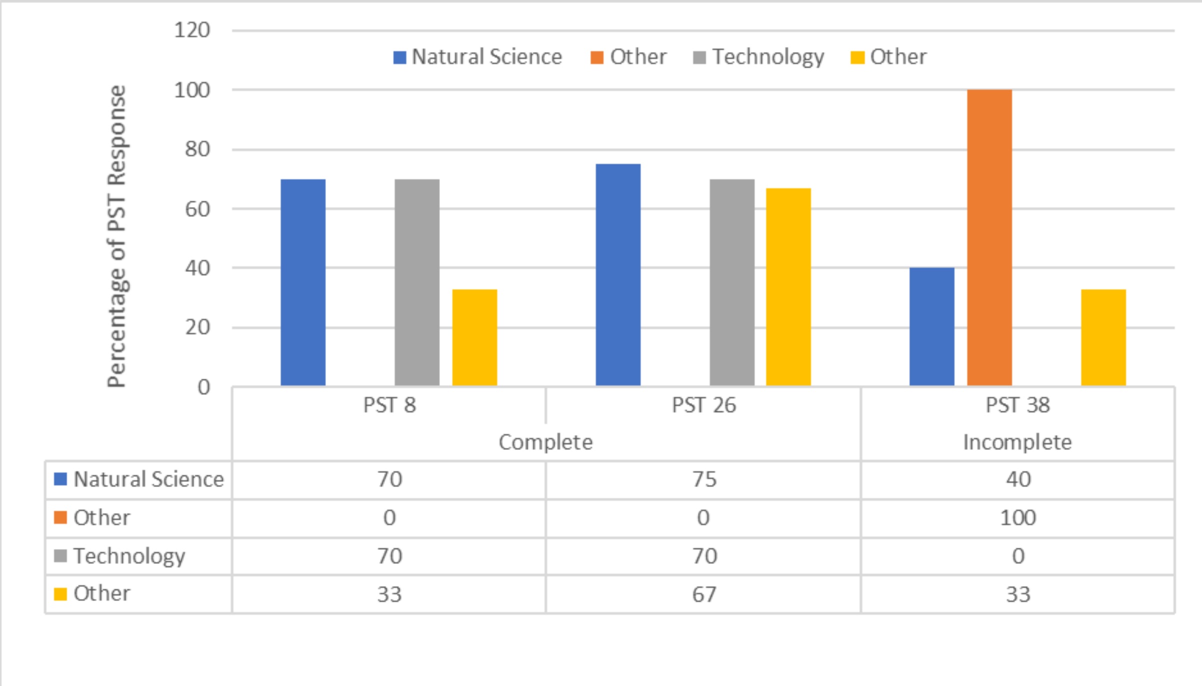


Figure 6.3: PSTs' Response to NST Topics, Content, and Concepts in Category 2

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS?*

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.3 above shows that PSTs 26 and 38 covered 75% and 70% of the topics and concepts covered in CAPS. PSTs 8 and 26 completed their CMs. Their CMs showed a high level of familiarity with the topics and concepts covered in CAPS. On the other hand, PST 38's CM was incompletely filled in in the lower region and only covered 40% Grade 6 NS and 0% of Grade 6 TECH topics and concepts covered in CAPS.

W.r.t. the TECH topics and concepts, all three PSTs used the theme of dissolving. However, only PSTs 8 and 26 linked processes to purify polluted water to provide a clean supply of water to humans and nature. PSTs 8 and 26 also emphasised that municipal water must be cleaned before use.

Two key aspects under the topic of Processing in TECH were mentioned, namely: (1) the three factors affecting the rate of dissolving, which included the temperature of the mixture, stirring or shaking the mixture, and the grain size of the solute by investigation, measuring, and drawing of the graph, and (2) the importance of providing a clean supply of water to humans and nature. It is noteworthy to mention that all three Grade 6 NST PSTs were unable to link the problem of water pollution to mixtures and a clean water supply under the topic of Matter and Materials to different ways of separating clean water from contaminated water under the topic of Processing in TECH. PST 26 was the only one who mentioned separation methods such as sieving, filtering, boiling, and adding chemicals to kill germs.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of the "OTHER" NS topics and concepts that were mentioned by the PSTs in Category 2, it is important to highlight that PST 38 mentioned the highest percentage of "OTHER" NS topics and concepts in comparison to PSTs 8 and 26 who obtained 0%, respectively. This implies that PSTs 8 and 26 displayed no prior knowledge of "OTHER" NS topics and concepts in Matter and Materials. A further noteworthy point is that PST 38 was the only one who recalled compound "OTHER" NS topics and concepts in Matter and Materials. This finding is significant in that PSTs 8 and 26 may have gained prior Grade 10 chemistry knowledge in high school as compounds appear in the Grade 10 physical science curriculum.

In terms of the "OTHER" TECH topics and concepts, it must be pointed out that PST 26 obtained the highest percentage in comparison to PSTs 8 and 38. PST 26 was the only one who mentioned that the rate of dissolving can be carried out by investigation, measuring, and drawing graphs of time taken to dissolve a solute in hot or cold water, or when stirring, or shaking, or not stirring or shaking. This finding suggests that PST 26 recalled prior knowledge of process skills that could be used during experimentation.

- *How is the knowledge of the two strands being integrated – what link is used to integrate the two?*

PSTs 8 and 26 used the term 'integration' as a link between mixtures and processes to purify water. However, there was no particular focus at the central point of their concept maps. PST 38 used the topic of Solutions to link mixtures to processing, but lacked a central focus which should detail an integrated understanding of topics, content, and concepts of Grade 6 Matter and Materials in NS and Grade 6 Processing in TECH. To provide some clarification, although the NS topics and concepts mentioned in Category 2 are similar to the topics and concepts relating to Grade 6 mixtures and solutions in Category 1, the focus in both categories differ.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that all three PSTs ***did not use problem identification***. There was no particular focus, although dissolving and processes to purify water were foregrounded. The problem highlighted was linked to the integration of both NST that come together to form one subject. The concept of water and sanitation was not contextualised and problematised within the local context of rural communities in South Africa, as was observed in the Grade 6 NST PSTs' concept maps in Category 1.

Figure 6.4 below graphically illustrates PST 26's CM that attempts to explain the NST topics, content and concepts related to dissolving and the factors affecting dissolving in Category 2. Arrows are added with short explanations for clarification.

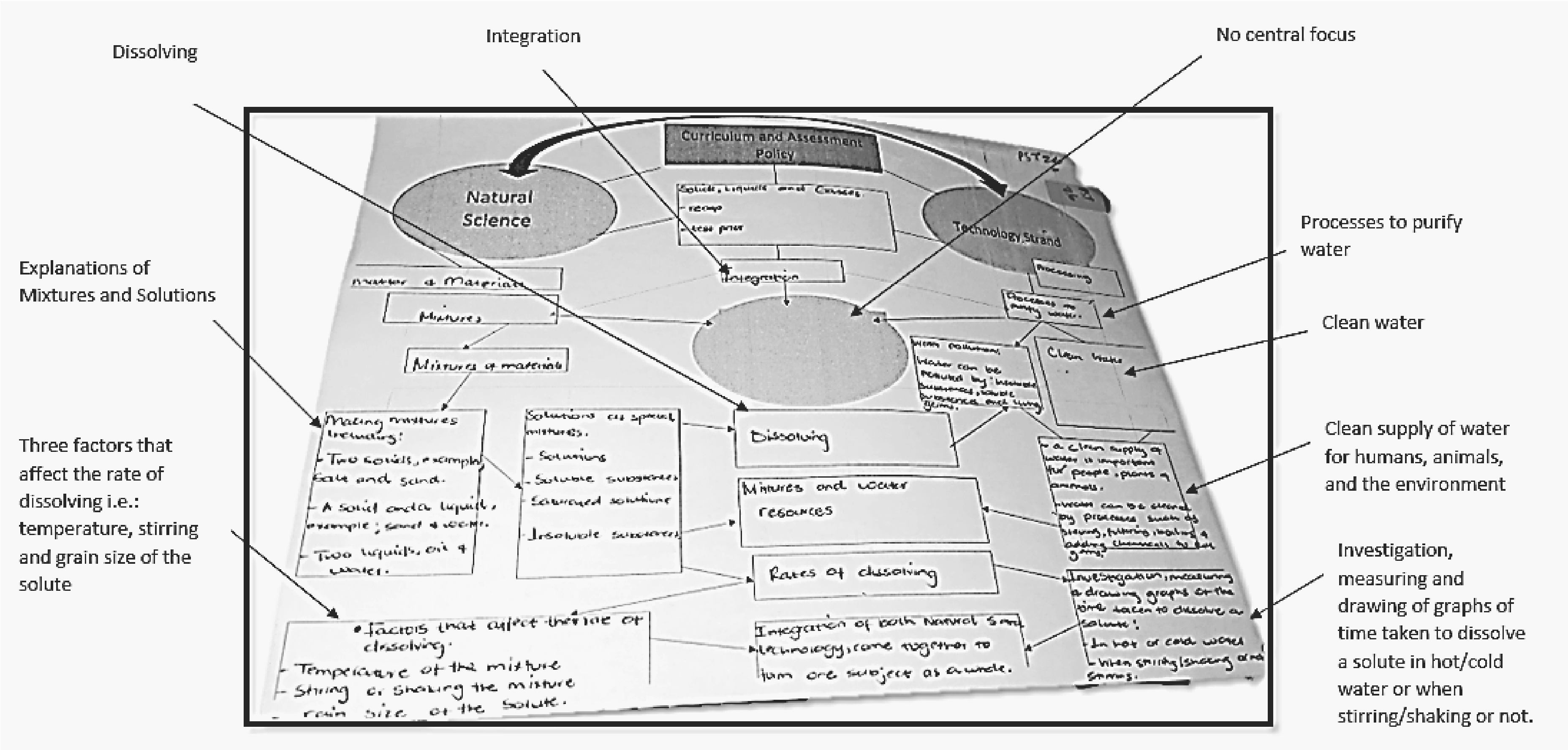


Figure 6.4: Example of PST 26's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 2

The three PSTs in Category 2 may have gained a generalised understanding of Grade 6 topics and concepts under the knowledge strands of NST. There is no evidence demonstrating the application of the acquired understanding of the knowledge strands by the Grade 6 NST CK of the PSTs in Category 2 to the identification of the water and sanitation problem in rural communities in South Africa. This implies that the PSTs in Category 2 could not make a connection between how dissolving in NS could be used in the processes to purify water in TECH to address the water and sanitation problem in rural communities in South Africa. The analysis of Category 3 is presented next.

6.3. Analysis of Category 3

Matter and Materials (NS) and Processing (TECH)

Understanding of integration 2: Integration of the NST (topics of Solids, Liquids and Gases; Mixtures and Water resources; concepts of the arrangement of particles, as well as the TECH topic of Processes to Purify Water, and concept of clean water supply **(10%).**

(i) What was foregrounded in terms of what is being integrated?

It is an integration of the Grade 6 Term 2 NS topics of Solids, Liquids and Gases; Mixtures and Water Resources, as well as concepts of the arrangement of particles; and Technology topic of Processes to Purify Water, and concept of clean water supply.

(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?

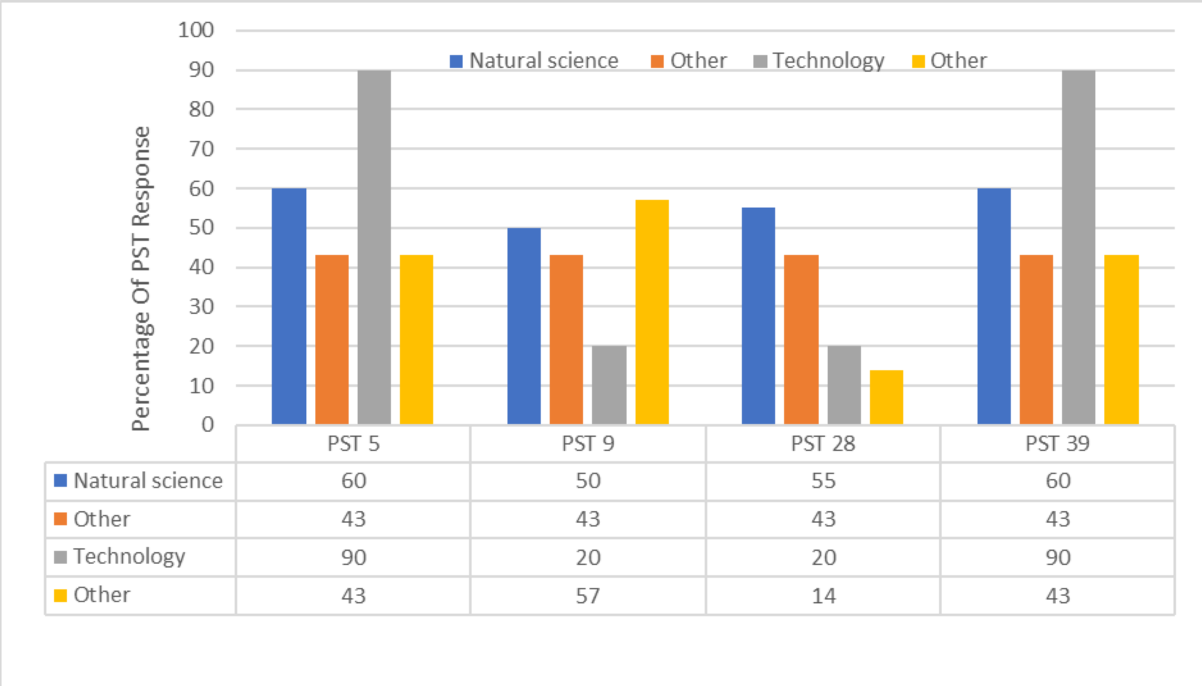


Figure 6.5: PSTs' Response to NST Topics, Content and Concepts in Category 3

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS?*

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.5 above shows that PSTs 5 and 39 covered 60% of the NS topics and concepts covered in CAPS. They were followed by PSTs 9 and 28 who covered 50% and 55%, respectively, of the Grade 6 Term 2 topics and concepts. It is interesting to note that PSTs 5, 9, 28 and 39 completed their CMs. In comparison, not all PSTs in Categories 1 and 2 completed their CMs. As a result, the PSTs' CMs in Category 3 showed a familiarity with the recall of Grade 6 topics and concepts in Term 2 as a central focus of their CMs, unlike the central focus of Categories 1 and 2. The data shows that they could recall between the range of 60% and 50%.

On further analysis of the CMs in Category 3, PST 9 was the only one in Category 3 who did not mention the factors affecting dissolving, whereas PST 28 only provided a vague description of topics, content, and concepts of mixtures and solutions as special mixtures under the NS knowledge strand. It can be deduced that PSTs 5, 9, 28 and 39 attempted to focus on Grade 6 Term 2 NS topics, content, and concepts as contained in the CAPS (DoBE, 2011). However, the finding suggests that not all PSTs in Category 3 could recall their Grade 6 prior knowledge, even though all four PSTs had completed their CMS and mentioned similar Grade 6 topics and concepts pertaining to mixtures, mixtures of materials, making of mixtures, solutions as special mixtures, dissolving and the factors affecting the rate of dissolving, such as temperature of the mixture, stirring, and shaking the mixture, as well as grain size of the solute, as mentioned in CAPS. It is interesting to note that only PSTs 5 and 39 linked the rates of dissolving to investigation, measuring, and drawing of graphs of time taken to dissolve a solute in hot and cold water versus the time taken for stirring, or shaking, or not stirring or shaking.

W.r.t. the TECH topics and concepts PSTs 1 and 39 covered 90% of Grade 6 TECH topics and concepts contained in CAPS. They were followed by PSTs 9 and 28 who covered 20% of Grade 6 TECH topics and concepts in CAPS. The Grade 6 NST PSTs in Category 3, like Category 2, used the theme of Dissolving and Processes to Purify Water linked to water pollution and a clean water supply under Processing. Two key aspects under the topic of Processing in TECH were mentioned as follows: Water Pollution where water can be polluted by insoluble and soluble substances and living germs, and the importance of a clean water supply for humans and nature.

The above observation is significant as it suggests that PSTs 5, 8, 26 and 39 may have acquired prior primary school CK of Grade 6 Term 2 NST topics and concepts of dissolving and processes to purify water through engagement in practical experiments. The evidence also points to the development of NS process skills in PSTs 5 and 39 who mentioned investigation, measuring, and drawing of graphs to determine if a solute dissolved in hot or cold water, or when stirred, shaken, or not over a period of time.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of the "OTHER" NS topics and concepts that were mentioned by the PSTs in Category 3, it is interesting to note that all four PSTs mentioned 43% of "OTHER" NS topics and concepts, which was lower than the percentages of the Grade 6 NS topics and concepts in CAPS. Furthermore, the "OTHER" NS topics and concepts that were mentioned in Category 3 did not appear in the Grade 6 NS topics and concepts in CAPS. The "OTHER" NS topics and concepts included the three factors affecting dissolving, how mixtures and dissolving affect clean water supply, and the integration of NST in the designing, making, and evaluation of a simple system to purify water. However, PST 9 was the only one who recalled prior Grade 4 NS topics and concepts of solids, liquids and gases, and arrangement of particles in Matter and Materials, specifically. It is interesting to note that PST 9 attempted problem identification by mentioning that integration of NST can be used in designing, making, and evaluating a simple system to purify water.

In terms of the "OTHER" TECH topics and concepts, PST 9 obtained the highest percentage (57%), which was higher than the Grade 6 TECH topics and concepts mentioned from CAPS. PST 9 also attempted problem identification of water pollution which appears in Grade 6 NS topics and concepts under mixtures and water resources. It is important to note that PST 9 highlighted the TECH topics and concepts of Grade 6 processes to purify water by investigating clean water; how to best purify water; designing, making, and evaluating a simple system to purify water; and the design process under Processing in TECH.

(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

It is important to note that all four Grade 6 NST PSTs were unable to link the problem of water pollution to different ways of separating clean water from contaminated water under the topic of Processing in TECH using filtration and evaporation as methods to purify water. However, only PSTs 5 and 39 mentioned separation methods, such as sieving, filtering, settling, decanting, boiling, and adding chemicals to kill germs.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that ***none of the PSTs in Category 3 used problem identification***. Although none of the four Grade 6 NST PSTs in Category 3 identified the problem of water and sanitation in rural communities in South Africa, it was interesting to note that under Processing in TECH, only PST 9 had prior knowledge of how dirty water could be cleaned. PST 9 mentioned that in order to clean water, designing, making and evaluation of a simple system could purify water caused by the problem of water pollution. This finding suggests that PST 9 identified that water pollution is a problem and could have further explored the idea of using a simple water filter system to solve the water and sanitation problem in rural communities in South Africa. According to the CAPS for the Intermediate Phase (Grades 4 to 6) (DoBE, 2011), the Grade 6 topic of Processes to purify water (p. 55) relates to Processing in TECH where learners are required to apply the design process to make a simple water filter system that could be used in households, for example, in rural communities.

It is promising to note that PST 9 appeared to have an overall idea of Grade 6 topics and concepts under the topic of Processing in TECH. PST 9's completed CM is presented in Figure 6.6 below.

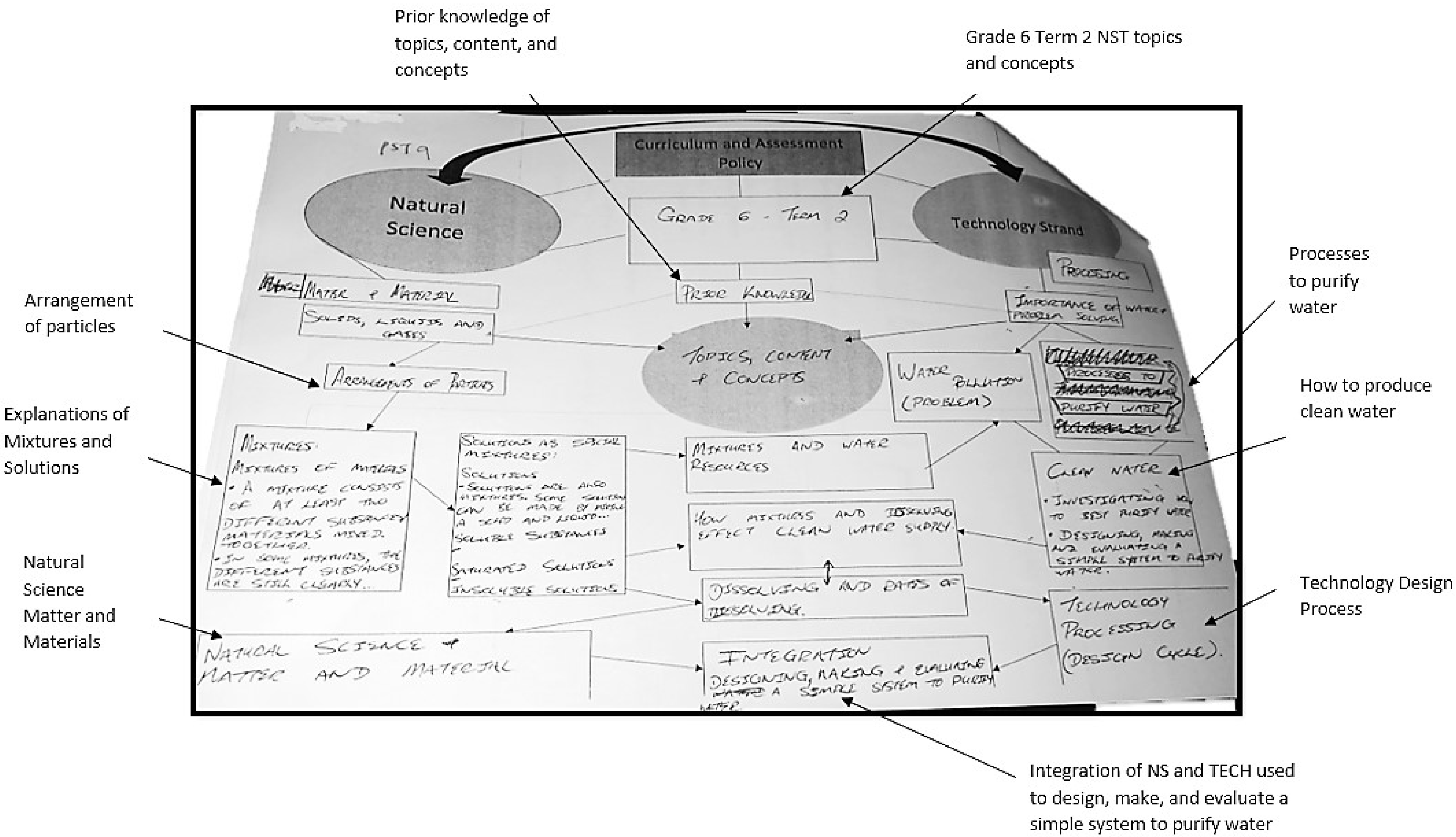


Figure 6.6: Example of PST 9's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 3

However, research and detailed explanations of an integrated Grade 6 NST Term 2 topics, concepts, science experimentation, as well as use of the steps in the design process, need to be explored further by PSTs in Category 3. In addition, the Grade 6 NST PSTs' integrated CK needs to be developed further in the Grade 6 TECH topics and concepts related to processing and methods of separation of the purification of dirty water to clean water using science experiments and the design process. By doing so, the Grade 6 NST PSTs' acquired integrated NST CK of the topics and concepts under Matter and Materials and Processing can be applied to problematisation and contextualisation of water and sanitation in rural communities in South Africa. The analysis of category 4 is presented next.

6.4. Analysis of Category 4

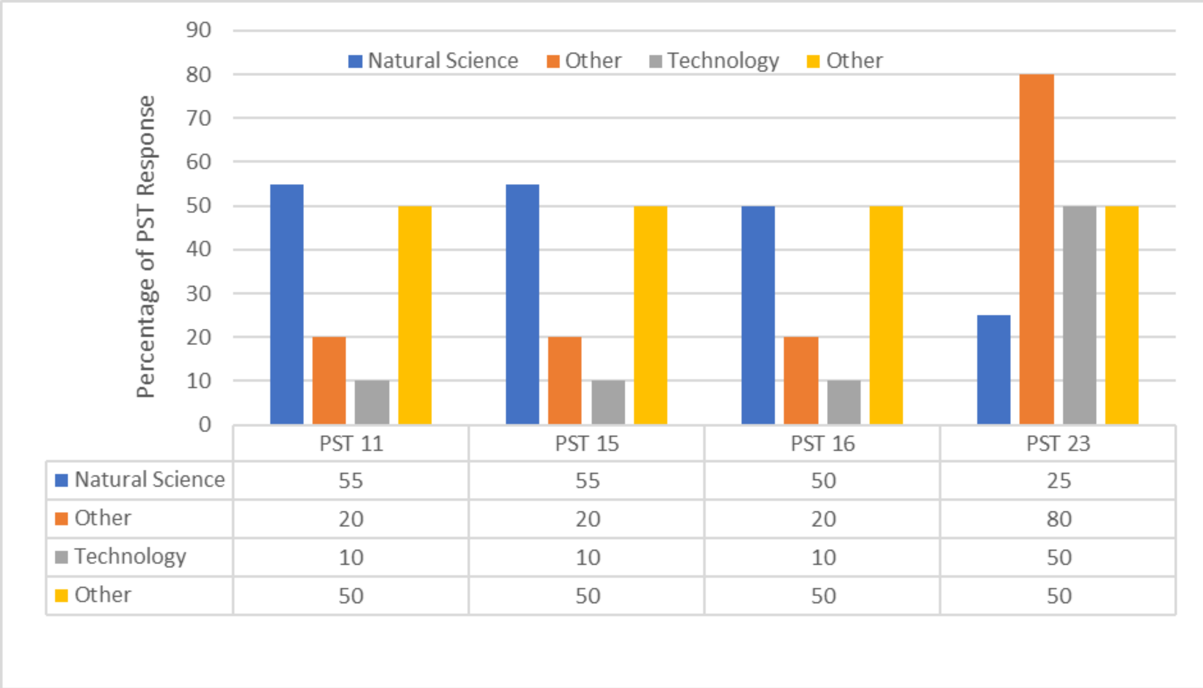
Matter and Materials (NS) and Water Pollution (TECH)

Understanding of integration 2: Integration of NST (Topics of Mixtures and Solutions as special mixtures; concepts of soluble substances, saturated solutions, and water pollution with a particular focus on the topic of separation; as well as the TECH topic of processes to purify water **(10%).**

(i) What was foregrounded in terms of what is being integrated?

It is an integration of Grade 6 NS Grade 6 topics of Mixtures and Solutions as special mixtures, concepts of soluble substances, saturated solutions, and water pollution with a particular focus on the topic of separation. Also, includes the integration of the TECH topic of processes to purify water (10%).

(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?



	PST 11	PST 15	PST 16	PST 23
Natural Science	55	55	50	25
Other	20	20	20	80
Technology	10	10	10	50
Other	50	50	50	50

Figure 6.7: PSTs' Response to NST Topics, Content and Concepts in Category 4

- *Which Natural Science and Technology topics and concepts are foregrounded? i.t.o. CAPS?*

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.7 above shows that PSTs 11 and 15 covered 55% of the Grade 6 NS topics and concepts covered in CAPS. They were followed by PSTs 16 and 23 who covered 50% and 25% of the Grade 6 Term 2 topics and concepts. PSTs 11, 15, 16 and 23 did not complete their CMs; as a result, their CMs showed a low level of familiarity with the topics and concepts covered in CAPS. The data shows that they could only recall between the range of 50% and 25%.

W.r.t. the TECH topics and concepts, PSTs 11, 15, 16 and 23 covered 11% of Grade 6 TECH topics and concepts from CAPS. The PSTs in Category 4 also stated that Processing under the TECH knowledge strand can be subdivided into processes for purifying water, and mixtures, and water resources, which led to the separation of solutions. PST 23 is the only one that mentioned water pollution under Processing, as well as filtration, heat, evaporation, sieving, and decanting. Additionally, PST 23 also stated under Processing that water can be processed from dirty to clean.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of the "OTHER" NS topics and concepts mentioned in Category 4, PST 23 obtained the highest percentage (80%), while PSTs 11, 15 and 16 covered 20% of the "OTHER" NS topics and concepts pertaining to Grade 10 physical science, such as: mixtures made from different matter or phases of the same matter; emulsions that cannot mix and separate easily; and that homogenous and heterogenous solutions are dependent on bonds, density, and reactivity. The finding suggests that PST 9 may have taken physical science and recalled Grade 10 chemistry knowledge pertaining to the science topics and concepts of chemical bonds, density, and reactivity.

In terms of the "OTHER" TECH topics and concepts, all four PSTs obtained the same percentage of 50%. PST 23 was the only one who did not mention separating solutions, but rather recalled prior knowledge of clean water made up of pollutants and included heating and evaporation as methods to clean water. Two key aspects under the topic of Processing in TECH were mentioned as follows: (1) processing, which was linked to process for purifying water, mixtures, and water resources, and (2) separating solutions.

(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

In Category 4, PSTs 11, 15 and 16 used the rates of dissolving as a Grade 6 topic as a link to the topics, content, and concepts relating to Matter and Materials and Processing. PST 23 did not mention dissolving. Instead, PST 23 mentioned that an emulsion does not mix and cannot be separated easily. PST 11 crossed the three bottom blocks of the CM, while PSTs 15, 16 and 23 also had incompletely filled blocks in this level of their CMs. It is interesting to note that, unlike in Category 1 where the Grade 6 NST PSTs were able to identify the problem of water and sanitation in rural communities in South Africa, this is not the case in Category 4. All four Grade 6 NST PSTs in Category 4 were unable to problematise the topics, content, and concepts related to water and sanitation in rural communities in South Africa.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that none of the PSTs in this group used problem identification. The focus was on separation, and the separation of mixtures and solutions were foregrounded in the four Grade 6 NST PSTs concept maps. Separation of mixtures is also mentioned under mixtures of materials, while separation of solutions appears under "Solutions as special mixtures" in the CAPS document for Grades Four to 6 (DoBE, 2011 pp. 52–53). PST 23's CM is illustrated in Figure 6.8 below.

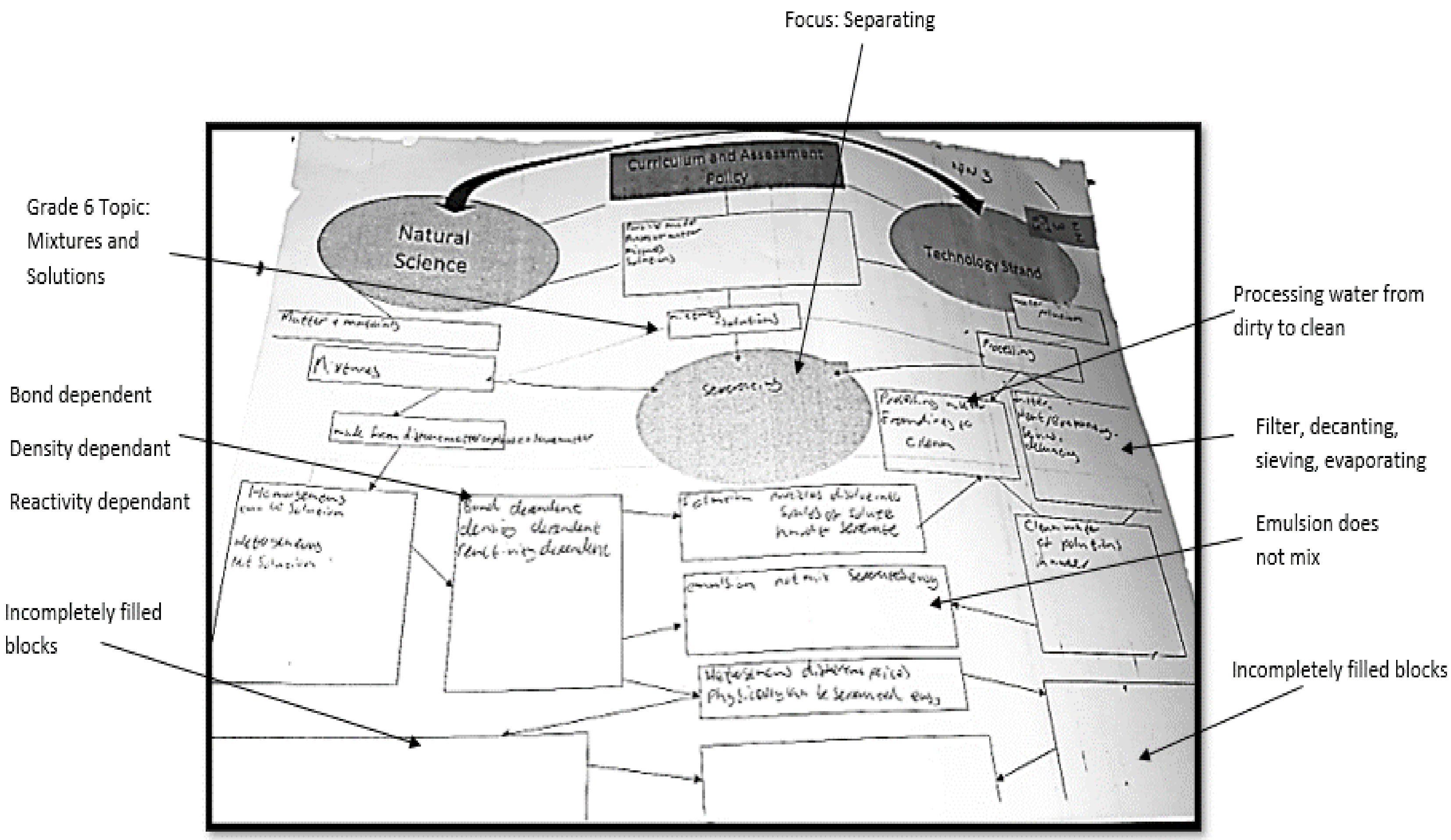


Figure 6.8: Example of PST 23's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 4

PST 23 is the only one that mentioned water pollution under Processing and filtration, heat, evaporation, sieving, and decanting. PST 23 also stated under Processing that water can be processed from dirty to clean. It is significant to note that all four Grade 6 NST PSTs in Category 4 did not mention the following topics, content, and concepts in the lower region of their CMs: dissolving and the rates of dissolving under Matter and Materials; processes to purify water, such as filtration and evaporation under Processing; and processes to purify water to address the water and sanitation problem in rural communities in South Africa under the link between Matter and Materials and Processing. The analysis of Category 5 is presented next.

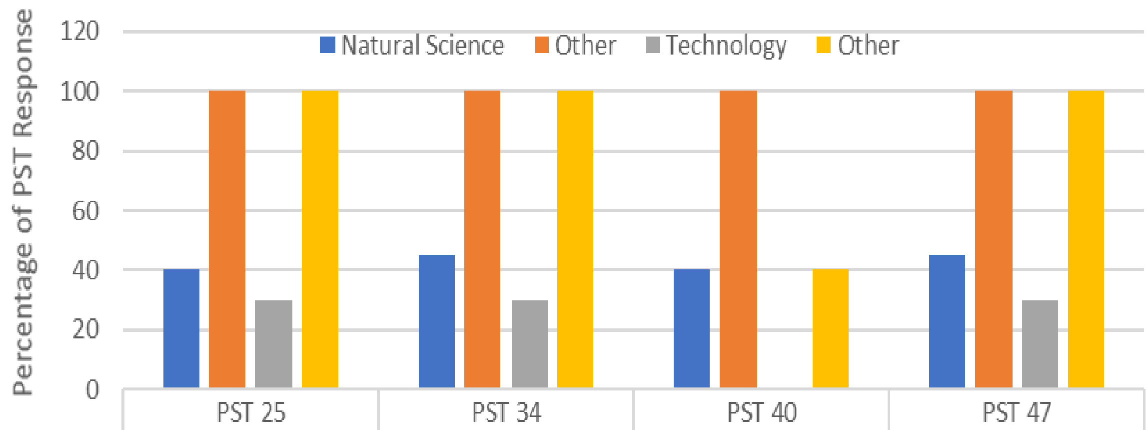
6.5. Analysis of Category 5

Arrangement of Particles (NS) and Processing (TECH)

Understanding of integration: Integration of NS concepts of arrangement of particles, mixtures of materials, solutions; and the TECH topic of Processing, with a particular focus on the concept of crystallisation **(10%).**

(i) What was foregrounded in terms of what is being integrated?

It is an integration of NS Grade 6 Term 2 concepts of arrangement of particles, mixtures of materials, solutions: and the TECH topic of processing, with a particular focus on the concept of crystallisation.



	PST 25	PST 34	PST 40	PST 47
Natural Science	40	45	40	45
Other	100	100	100	100
Technology	30	30	0	30
Other	100	100	40	100

Figure 6.9: PSTs' Response to NST Topics, Content and Concepts in Category 5

- *Which Natural Science and Technology topics and concepts are foregrounded?*

  i.t.o. CAPS?

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.9 above shows that PSTs 34 and 47 covered 45% of the Grade 6 NS topics and concepts contained in CAPS. They were followed by PSTs 25 and 40 who covered 40% of the Grade 6 NS topics and concepts in CAPS. Although PSTs 25, 34, 40 and 47 completed their CMs, their CMs showed a moderate level of familiarity with the Grade 6 NS topics and concepts covered in CAPS. The data shows that all PSTs in Category 5 could only recall between the range of 45% and 40%.

W.r.t. the TECH topics and concepts, three Grade 6 NST PSTs, namely, 25, 34 and 47 covered 30% of the Grade 6 TECH topics and concepts, whereas PST 40 covered 0% of the Grade 6 TECH topics and concepts from CAPS. It is important to point out that PSTs 25, 34 and 47 had possibly gained prior chemistry knowledge and provided a chemical equation of the reactants, that is, sodium chloride and water in symbol form ($NaCl$ and H_2O) under process. It also appears that PSTs 25, 34 and 47 in Category 5 had prior knowledge of Grade 6 topics and concepts of solutions from the evidence of the chemical equation containing a solution of salt water. According to CAPS (2011, p. 53), solutions are made by mixing a solid and liquid together, such as salt and water. After mixing the salt (solute) and water (solvent), the solid is invisible in the liquid. The salt (solute) upon evaporation (when the water is heated) appears in the form of salt crystals when water is removed. The process of where a solute can be recovered by heating the solvent (evaporation) is crystallisation, according to CAPS (2011).

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of "OTHER" NS topics and concepts, all four PSTs in Category 5 mentioned 100% of the "OTHER" NS topics and concepts regarding crystallisation. This finding indicates that the PSTs in Category 5 may have gained prior CK in crystallisation in Grade 6 Matter and Materials in Term 2. They also mentioned that soluble solids dissolve and are pure, while insoluble solids do not dissolve and are impure. Both soluble and insoluble solids are linked to crystallisation and table salt dissolved in water ($NaCl + H_2O$). This finding suggests that three PSTs gained chemistry knowledge on the separation of a mixture of salt water by filtration and evaporation. This was evident in their use of chemistry concepts, such as chemical formulae, settling, and crystallisation, which is contained in the Grade 10 physical science curriculum.

In terms of the "OTHER" TECH topics and concepts, PSTs 25, 40 and 47 obtained 100%, which was relatively higher in comparison to the Grade 6 TECH topics and concepts contained in CAPS. PSTs 25, 40 and 47 mentioned emulsion, separating mixtures, hand sorting, $NaCl + H_2O$, and evaporation. It is also interesting to note that these topics and concepts are not aligned to Grade 6 processes to purify water in CAPS (2011, p. 55). The "OTHER" TECH topics and concepts are aligned to the Grade 6 NS topics and concepts in CAPS (2011, pp. 52–53). Furthermore, it is important to highlight that PST 40 covered 40% of the "OTHER" TECH topics and concepts when compared to 0% of Grade 6 TECH topics and concepts as contained in CAPS.

Two key aspects under the topic of Processing in TECH were mentioned: (1) separation of mixtures and emulsions by physical means, such as sieving, hand sorting, and filtration, and (2) separation of mixtures by dissolving $NaCl + H_2O$.

(ii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

It has to be noted that all four Grade 6 NST PSTs in Category 5 did not apply their integrated understanding to problem identification of water and sanitation in rural communities in South Africa. Interestingly, the PSTs in Category 5 also <u>*used the term 'integration' to link the topics*</u>

and concepts under Matter and Materials in NS to topics and concepts of processing separation of mixtures in TECH. All four of the PSTs focussed on the Grade 6 concept of crystallisation and solutions under Matter and Materials in the NS knowledge strand. PST 25 is the only one that links mixtures of materials to the three specific aims, pure and impure substances to settling and emulsions, as mentioned in the CAPS for the Intermediate Phase (Grades 4 to 6) (DoBE, 2011). It could be inferred that PST 25 was referring to the settling of the heavier particles of a mixture. Thus, the lighter liquid could be decanted or poured into another container. Unlike Category 4 in which the PSTs displayed prior knowledge in Grade 6 Term 2 topics and concepts of mixtures and materials and the process of dissolving under Matter and Materials in NS, the PSTs in Category 5 focussed more on the arrangement of particles, pure and impure solids (soluble and insoluble), and water pollution under Matter and Materials.

It is important to point out that the PSTs in Category 5 recalled the arrangement of particles, which appears in Grade 4 Term 2 Matter and Materials (DoBE, 2011, p. 20) under the topic of Materials around us in CAPS. It can be concluded that the Grade 6 topics and concepts of mixtures of materials, solutions, and water pollution under Matter and Materials in NS were linked to the Grade 6 concept of crystallisation and separation of mixtures under Processing in TECH. This finding suggests that this group of PSTs in Category 5, unlike Categories 1, 2, 3 and 4, were the only group to mention the Grade 6 topic of crystallisation, which indicated that they had prior knowledge of crystallisation, possibly having carried out experiments using different combinations of soluble and insoluble substances.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that all four PSTs linked water pollution under NS to filtration and evaporation as separation methods under TECH to purify water. It is interesting to note that PSTs 34, 40 and 47 focused on filtration as a suitable separation method to purify water. However, none of the four PSTs in Category 5 mentioned how filtration could be used in finding a solution to the problem of water and sanitation in rural communities in South Africa. An illustration of PST 34's completed CM is presented in Figure 6.10 below.

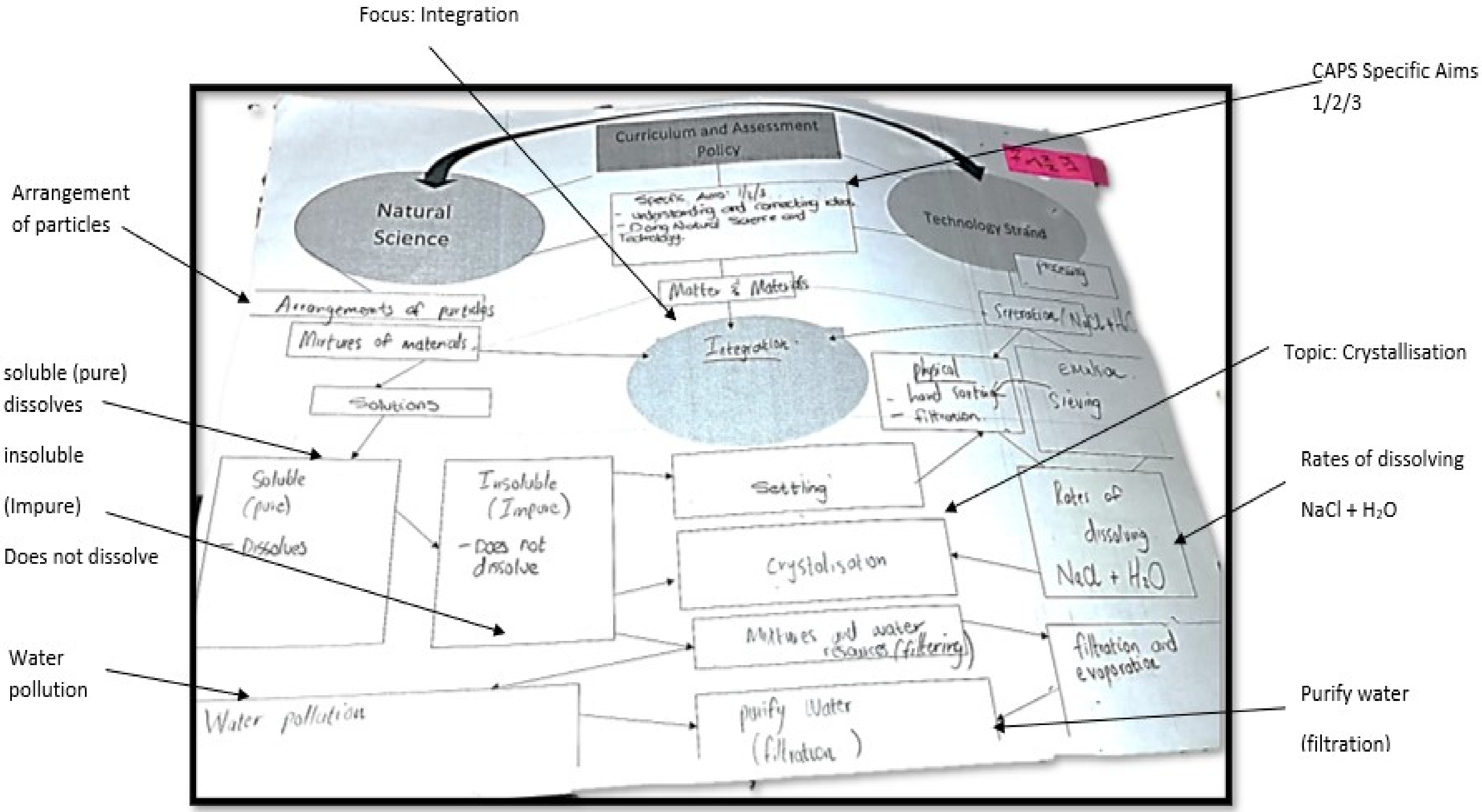


Figure 6.10: Example of PST 34's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 5

Three Grade 6 NST PSTs, namely, 25, 34 and 47, provided a chemical equation of the sodium chloride and water ($NaCl + H_2O$) and rates of dissolving under Processing. This implies that Grade 6 NST PSTs in Category 5 need to explore other examples of solutes and solvents, for example, how sugar dissolves in water and is recovered through evaporation and crystallisation. The PSTs in Category 5 could also explore the use of the chemical formula for sugar/glucose ($C_6H_{12}O_6$) as sugar/glucose, which is mentioned in another knowledge strand – Life and Living – under the topic of Photosynthesis (DoBE, 2011 p. 47) in Grade 6 Term 1.

The finding also implies that Grade 6 PSTs need to be taught chemistry concepts, such as chemical formulae and chemical equations, and how the processes of dissolving, filtration, and evaporation could be used to understand the process of crystallisation of mixtures caused by water pollution. This integrated understanding of the topics and concepts in Grade 6 Matter and Materials and Processing in Category 5 would result in a deepened understanding of water pollution and its effects on water and sanitation in rural communities in South Africa. Also, how filtration and evaporation of mixtures of soluble substances can be purified through a process of crystallisation. The analysis of Category 6 follows next.

6.6. Analysis of Category 6

Raw Materials (NS) and Man-made or Manufactured Materials (TECH)

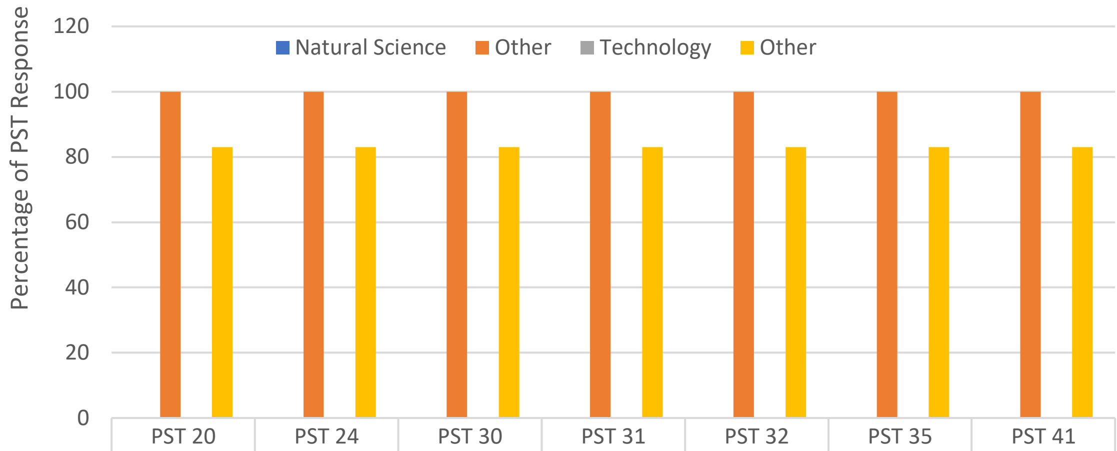
Understanding of integration 2: Integration of NS & TECH (Grade 5 topics and concepts

(17,5%)

(i) What was foregrounded in terms of what is being integrated?

It is an integration of NST Grade 5 topics and concepts. The focus was on the integration of NST Grade 5 topics and concepts in Term 2 (CAPS, pp. 35–36). **All the CMs in Category 6 were completely filled.**

(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?



	PST 20	PST 24	PST 30	PST 31	PST 32	PST 35	PST 41
Natural Science							
Other	100	100	100	100	100	100	100
Technology							
Other	83	83	83	83	83	83	83

Figure 6.11: PST Response to NST Topics, Content and Concepts in Category 6

It is important to highlight that the seven Grade 6 NST PSTs in Category 6, unlike the PSTs in Categories 1, 2, 3, 4 and 5 who focussed on Grade 6 topics and concepts of Matter and Materials and Processing, did not focus on any Grade 6 Term 2 NST topics and concepts. The PSTs in Category 5 focussed on Grade 5 NST (other) topics and concepts. It is to be further noted that the central idea on the seven PSTs' CMs was the integration of NST, which was further linked to Grade 4 states of matter and particle change under Matter and Material in NS (p. 20) and man-made or manufactured materials under Processing in TECH (p. 21).

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS?*

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.11 above shows that all seven Grade 6 NST PSTs in Category 6 covered 100% of the "OTHER" NS topics ad concepts, completed their CMs, and filled in similar topics, content, and concepts relating to the topic of Grade 4 and 5 Matter and Materials under NS. However, they did not mention any CAPS aligned Grade 6 NS concepts pertaining to Matter and Materials (0%). The seven Grade 6 NST PSTs focused on Grade 4 concepts, such as "states of matter, particle change which was a process of changing particles in order to create or synthesize matter and materials, elements and compounds and understanding Natural Science and Technology where mankind can make a difference in the world".

W.r.t. the TECH topics, it is important to emphasise that all seven Grade 6 PSTs in Category 6 mentioned 83% of the "OTHER" TECH topics and concepts pertaining to Grade 5 Term 2 TECH topics and concepts of metals and non-metals under Processing. They did not mention any Grade 6 TECH topics and concepts as contained in CAPS, but instead, mentioned Grade 5 topics of the uses of metals, processing, and processed materials. However, PST 36 linked states of matter under raw materials to nature and mankind's influence under man-made materials. According to PST 36, mankind's influence on the environment could be impacted by mining of metals and non-metals.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of the "OTHER" NS topics and concepts, all seven PSTs completed (100%) the "OTHER" Grade 4 and 5 Term 2 NS topics and concepts pertaining to states of matter and particle change. This suggests that they did not recall prior knowledge in any Grade 6 NS topics and concepts in Matter and Materials. Furthermore, the PSTs CMs showed a low level of familiarity with the Grade 6 NS Term 2 topics and concepts in Matter and Materials, as stipulated in CAPS. This finding highlights the problem related to NST instruction that exists in primary schools today. In addition, this finding suggests that PSTs in Category 6 may not have received proper NS instruction of the Grade 6 Term 2 topics and concepts pertaining to Matter and Materials in primary school.

In terms of "OTHER" TECH topics, all PSTs mentioned a high percentage (83%) Grade 5 NS topics pertaining to metals and non-metals, which is contained under Metals and Non-metals in the Grade 5 Term 2 CAPS (2011, pp. 35–36). Man-made or manufactured material appears under Structures in Grade 4 Term 2 (p. 21). Elements and compounds do not appear in the Grade 4 to 6 NST curriculum, which implies that the PSTs recalled prior chemistry knowledge from the Senior or FET phases. Moreover, two key aspects under the topic of Processing in TECH were mentioned: (10 man-made or manufactured materials, and (2) mankind's influence on matter and materials.

(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

Evidently, the seven Grade 6 NST PSTs in Category 6 related Grade 5 Term 2 metals, non-metals, elements, and compounds to physical and chemical changes by use of Technology. According to CAPS (pp. 35–36), metals and non-metals have different physical and chemical properties which distinguish them from each other. The PSTs in Category 6 may possibly hold a misconception that metals and non-metals are states of matter that go through physical and chemical changes. However, this is not the case, as metals and non-metals have properties which can be investigated through practical work and demonstrations according to CAPS. In the lower region of the PSTs' CMs under Processing in TECH in Category 6, the seven PSTs mention that the "Design Process, is used to research and investigate, make discoveries and to find solutions". It is significant to note that only PST 20 did not mention that the design process could be used to make discoveries and find solutions.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that ***none of the seven PSTs used problem identification.*** The focus was metals and non-metals, and the scientific and design processes were foregrounded. However, there was no evidence of concepts that linked to the problem identification of water and sanitation in rural communities in South Africa. PST 24's completed CM is illustrated in Figure 6.12 below.

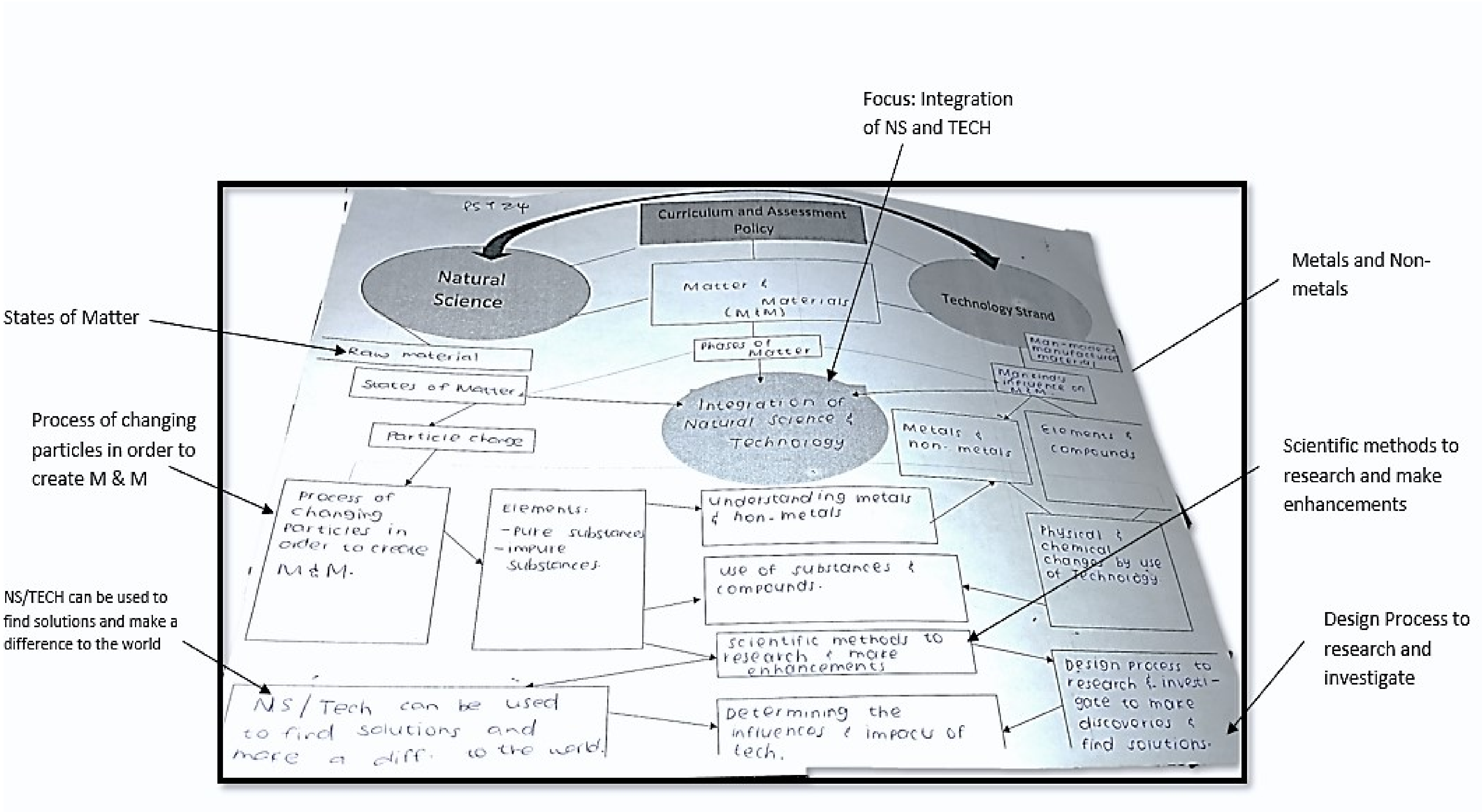


Figure 6.12: Example of PST 24's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 6

It is noteworthy that the seven PSTs in Category 6 completed their CMs and appeared to have a good prior knowledge of Grade 4 and 5 Term 2 NST topics and concepts. The seven PSTs in Category 6 also linked the scientific process with the design process, and stated that the two processes could be used to research and investigate the influences and impacts of technology. In addition, all seven PSTs mentioned that an understanding of NST could possibly assist mankind to find solutions to better the world around us. However, the evidence in Category 6 also implies that the PSTs had a good recall of Grade 4 and 5 Term 2 NST topics and concepts. However, Grade 6 instruction in the teaching of Grade 6 Term 2 topics and concepts need to be taught by specialist NST teachers who have an integrated understanding of a Grade 6 NST curriculum, as well as specialised CK in the teaching of the science and design processes and Grade 6 topics and concepts pertaining to Matter and Materials and Processing in both knowledge strands of NST as contained in CAPS. The analysis of Category 7 is presented next.

6.7. Analysis of Category 7

Raw Materials (NS) and Man-made or Manufactured Materials (TECH)

Understanding of integration 2: Integration of NST Grade 5 topics and concepts (12,5%)

(i) What was foregrounded in terms of what is being integrated?

It is the integration of NST Grade 5 topics and concepts, which included metals and non-metals, and elements and compounds under Raw Materials (NS) and Man-made or Manufactured Materials (TECH). There was a particular focus on the integration of NST topics, content, and concepts in Grades 4 and 5 Term 2. **The CMs in Category 7 were incompletely filled.**

(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?

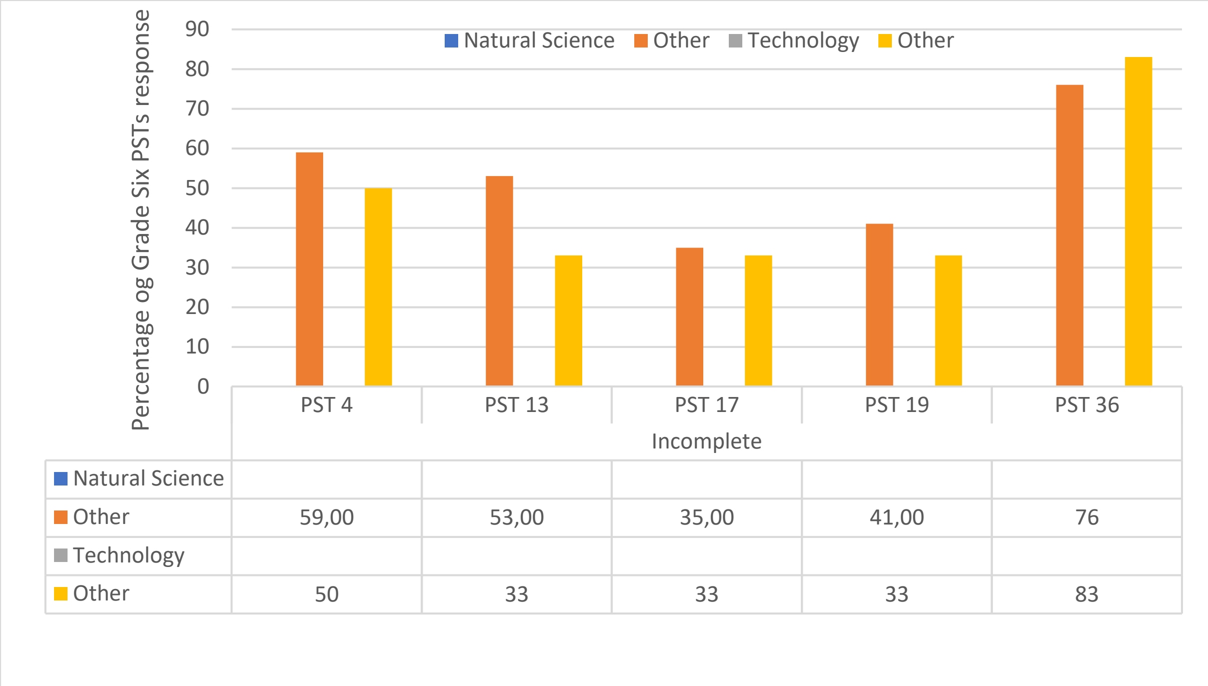


Figure 6.13: PSTs' Response to NST Topics, Content and Concepts in Category 7

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS?*

The topics, content, and concepts covered in Category 7 in the knowledge strands of Matter and Materials and Processing are aligned to the CAPS document for Grade 4 (DoBE, 2011 pp. 20–21) and Grade 5 Term 2 topics and concepts in the NST knowledge strands, according to the DoBE (2011, pp. 35–38). Similarly, the data corresponds with the CMs in Category 6, as the PSTs in that category could also not recall any of the Grade 6 topics and concepts under both NST knowledge strands. However, unlike Category 6 in which the PSTs completed all levels of their CMs under NST, the PSTs in Category 7 did not complete all levels of their CMs. This suggests that the PSTs in Category 7 could not recall prior knowledge in all Grade 4 and 5 (there was also no mention of Grade 6) Term 2 topics and concepts pertaining to Matter and Materials and Processing.

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.13 above shows that PSTs 4, 13, 17, 19 and 36 covered 0% of the Grade 6 Term 2 NS topics and concepts as contained in CAPS. Only PST 36 completed the CM, whereas PSTs 4, 13, 17 and 36 did not complete their CMs. However, it must be pointed out that the PSTs CMs in Category 7 also showed a low level of familiarity with the Grade 6 topics and concepts covered in CAPS.

W.r.t. the TECH topics and concepts, all five PSTs mentioned 0% of Grade 6 TECH topics and concepts. This finding suggests that the PSTs in Category 7 could not recall any prior knowledge of TECH topics and concepts pertaining to Grade 6 processing.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of "OTHER" NS topics and concepts, PST 36 obtained the highest percentage of 76% of "OTHER" NS topics and concepts. PSTs 4, 13, 19 and 17 mentioned 59%, 53%, 41% and 35% of "OTHER" NS topics and concepts, respectively. The finding reveals that the PSTs in Category 7 recalled more of the Grade 4 NS "OTHER" topics and concepts of states of matter and particle change as well as Grade 5 metals and non-metals. It is important to note that there was no Grade 6 NS topics and concepts from CAPS. The focus of the PSTs in Category 7 appeared to be on Grade 5 topics and concept's relating to metals, non-metals, uses of substances, and the scientific process that can be used to research and investigate the impacts of technology on the environment. It is further noted that there was no recall of Grade 6 NS topics and concepts for Term 2 Matter and Materials. This finding highlights another problem that exists in the teaching and learning of Grade 6 NST in primary schools. This challenge in recalling Grade 6 NS topics and concepts could possibly be due to the PSTs in Category 6 and 7 not having received a good foundational Grade 6 NS CK and not gaining an understanding of specific topics and concepts in Matter and Materials in primary school.

In terms of "OTHER" TECH topics, PST 36 once again covered the highest percentage of 83% of "OTHER" TECH topics and concepts in comparison to 0% of Grade 6 TECH topics and concepts in CAPS. PST 4 mentioned 50% of "OTHER" TECH topics and concepts followed by PSTs 13, 17 and 19 who each mentioned 33%, respectively.

The "OTHER" TECH topics and concepts included Grade 4 TECH topics and concepts of man-made and manufactured materials under Structures, and Grade 5 metals and non-metals and mining in Category 7. Elements and compounds and physical and chemical change were also mentioned from high school chemistry under Processing which was not aligned to the Grade 4 to 6 NST curriculum for primary school. It is important to highlight that PST 4 mentioned the water purification by a water purifier machine, while PST 36 stated that the design process could be used to research, investigate, make discoveries, and find solutions on the impacts of technology on the environment. This finding suggests that PST 4 and 36 recalled prior knowledge of the design process and its application, either from gaining technology instruction that focussed on application of the design process, or by engaging in technology activities that required the use of the design process in primary or high school Technology.

It is noteworthy that only PST 36 mentioned two key aspects under the topic of Processing in TECH, namely: Metals and non-metals, elements, and compounds and mining.

(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

The link made between NST knowledge strands is similar to Category 6 Grade 6 PSTs CMs. However, all four of the five PSTs in Category 7 did not fill in the blocks in certain parts of their CMs. This finding suggests that there may also appear to be gaps in their prior knowledge of Grade 4 to 6 NST topics and concepts. These gaps in prior knowledge may have formed in primary school during their years in the Intermediate Phase. Furthermore, none of the PSTs in this category showed problematisation and contextualisation to water and sanitation in rural communities in South Africa. This may be as a result of not being taught in primary school, the relevance and application of their NST conceptual understanding of specific topics and concepts, to problems facing their communities or society as a whole.

W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that ***all five PSTs did not use problem identification***. The focus was on Grade 5 metals and non-metals, and Grade 10 elements and compounds were foregrounded in Figure 6.14 below.

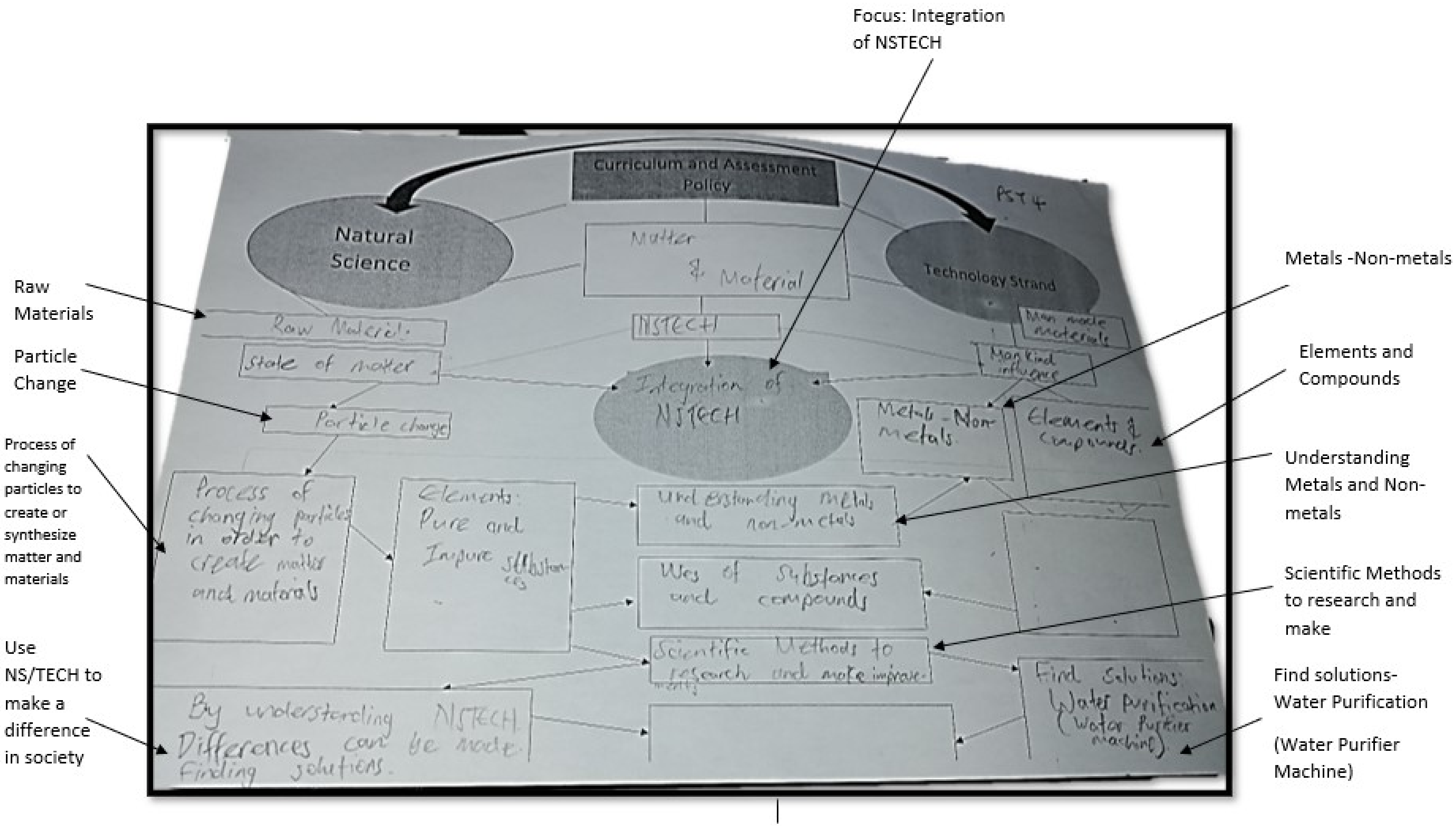


Figure 6.14 Example of PST 4 Completed CM Highlighting the NST Topics, Content, and Concepts in Category 7

The data in Category 7 implies that all five PSTs in Category 7 recalled their prior knowledge of topics and concepts relating to an integrated Grade 4 and 5 Term 2 NST curriculum. This finding suggests that PSTs in Category 7 did not gain a good understanding of specific topics and concepts relating to Matter and Materials and Processing of an integrated Grade 6 NST curriculum in primary school. The analysis of Category 8 is presented next.

6.8. Analysis of Category 8

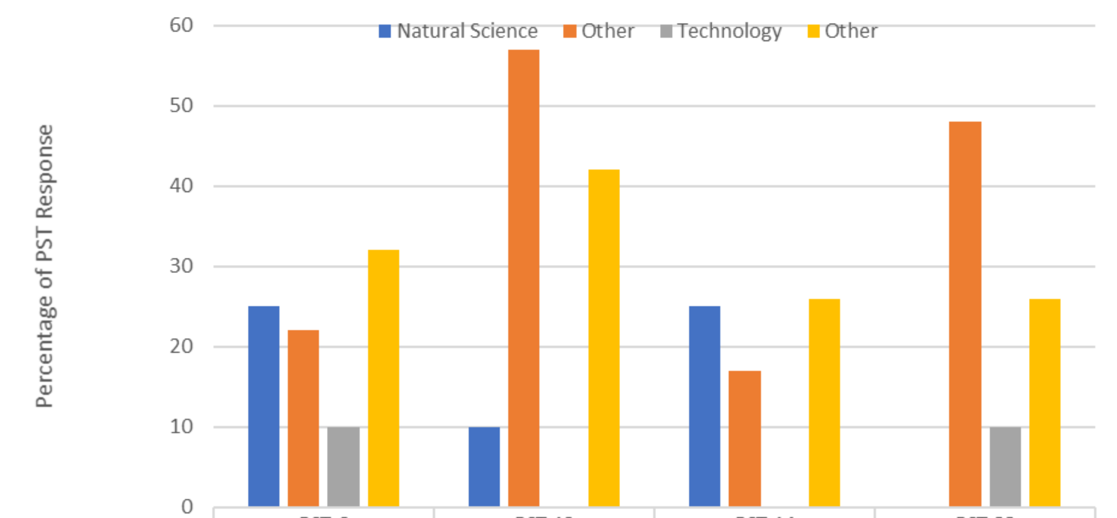
Various Topics (NS) and Various Topics (TECH)

Understanding of integration 2: Integration of NST (different NST topics and concepts from Grades 4 to 6) **(10%)**

(i) What was foregrounded in terms of what is being integrated?

It is an integration of different NST topics and concepts from Grades 4 to 6. In Category 8, different Grade 4 to 6 topics in NST knowledge strands were mentioned by the four PSTs with a particular focus on "content integration".

(ii) Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?



	PST 6	PST 12	PST 14	PST 33
Natural Science	25	10	25	0
Other	22	57	17	48
Technology	10	0	0	10
Other	32	42	26	26

Figure 6.15: PSTs' Response to NST Topics, Content and Concepts in Category 8

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. CAPS?*

W.r.t. the NS topics and concepts covered in relation to the CAPS, Figure 6.15 above shows that PSTs 6 and 14 also covered 25% of the topics and concepts as contained in CAPS. These were followed by PSTs 12 and 33 who covered 10% and 0%, respectively, of the topic and concepts covered in CAPS. All four PSTs completed their CMs; as a result, their CMs showed a low level of familiarity with the Grade 6 topics and concepts covered in CAPS. The data shows that they could only recall between the range of 25% and 0%.

PSTs 6 and 14 mentioned Grade 6 topics, content, and concepts, while PSTs 12 and 33 focused on the integration of Grade 4 to 6 topics, content, and concepts. PST 6 linked topics, content, and concepts relating to Matter under NS and Materials under TECH. Under Matter and Materials, PST 6 linked the states of matter to phases of matter and included metals and non-metals as elements. These topics, content, and concepts are further linked to mixtures of materials and solutions, for example, salt water. PST 14 did mention chemistry concepts and a few Grade 6 topics, content, and concepts under Matter and Materials. However, PST 14 did not provide an explanation for these topics, content, and concepts. PST 33's CM is similar to PST 14. Under Matter and Materials, PST 33 mentioned life and living, energy and change, and linked this to Planet Earth and Beyond and the Solar System and Systems for looking into space. It is significant to note that PST 33 mentioned Grade 4 to 6 integrated topics, content, and concepts linked to Electrical circuits and Systems and control.

W.r.t the NS topics and concepts, PSTs 6 and 14 covered 25% of Grade 6 NS topics and concepts form CAPS. They were followed by PSTs 12 and 33 who covered 10% and 0%, respectively, from CAPS. The CMs of PSTs 6 and 14 in Category 8 contained similar topics and concepts in comparison to the CMs in Categories 6 and 7. However, PST 12 and 33 in Category 8 are unlike the other categories in that these CMs contained a variety of NS topics and concepts related to the Grade 4 to 6 integrated NST curriculum as a whole. Upon further analysis of the CMs of PSTs 12 and 33, it can be deduced that there was no coherence in sub-topics under Grade 4 to 6 NST topics and concepts. PST 12 focused on Grade 10 physics and biology under NS and the design process under TECH. It appears that PST 33 may have a vague and incoherent structure of the Grade 4 to 6 topics and concepts in NS. It is important to highlight that PSTs 12 and 33 recalled some of the Grade 6 NS topics and concepts. PST 12 further mentioned Grade 6 topics and concepts, such as water pollution, and matter and materials, while PST 33 mentioned Matter and Materials, separation of mixtures and solutions, filtration, evaporation, water and purification or cleaning. It must be noted that only PST 6's CM had similar Grade 6 Term 2 TECH topics and concepts to Category 1. This finding suggests that PST 6 gained a good understanding of Grade 6 NS topics and concepts pertaining to Matter and Materials.

W.r.t. the TECH topics and concepts, PSTs 6 and 33 covered only 10% of Grade 6 TECH topics and concepts from CAPS. They were followed by PSTs 12 and 14 who covered 0% of Grade 6 TECH topics and concepts from CAPS. It is important to note that PST 6 linked Grade 6 mixtures of materials to Grade 5 raw materials under Processing. Separation of mixtures was also linked to physical separation, sorting, and filtering under Materials in TECH. However, it is interesting to note that PST 6 did not attempt to link separation methods to water pollution. The evidence suggests that PST 6 did mention that water pollution was caused by impure solutions which needed to be purified by chemical separation methods such as evaporation, distillation, and chromatography. This points to PST 6 ability to recall prior knowledge of separation methods, such as distillation, and chromatography, which were possibly covered in physical science in high school.

- *Which Natural Science and Technology topics and concepts are foregrounded i.t.o. "OTHER"?*

In terms of the "OTHER" NS topics and concepts, it is interesting to note that PSTs 12 and 33 mentioned the highest percentages of 57% and 48%, respectively, of "OTHER" Grade 4 to 6 NS topics and concepts pertaining to matter and materials, energy and change, life and living, and planet earth and beyond. PSTs 6 and 14 mentioned 22% and 17%, respectively, of other Grade 4 to 6 NS topics and concepts in all four themes as well. PST 12 obtained the highest percentage of "OTHER" NS topics and concepts, recalled prior knowledge of the sub-topics under physics and biology. This finding suggests that although PST 12 mentioned water pollution and matter and materials, he/she did not appear to have a good foundational Grade 6 Term 2 NS CK from primary school.

In terms of "OTHER" TECH topics and concepts, both PST 6 and PST 12 covered 32% and 42%, respectively, of "OTHER" TECH topics and concepts in comparison to the Grade 6 TECH covered in CAPS. PSTs 14 and 33 both covered 26% of "OTHER" TECH topics and concepts which was comparatively higher than the Grade 6 TECH topics and concepts in CAPS. It is interesting to note that PST 12 also mentioned Grade 6 Term 1 food processes (p.

49) and Term 2 processes to purify water (p. 55) under TECH. It is important to highlight that PST 12 was the only one who mentioned that the design steps in the canning industry was an example that was used as a link to Grade 5 food processing. Interestingly, PST 14 also mentioned under TECH, systems for looking into space and systems to explore the Moon and Mars which is found in Grade 6 Term 2 (pp. 63–64). This suggests that PST 14 did not recall prior knowledge in Grade 6 Term 2 TECH topics and concepts. The finding also reveals that PST 14 may have formed early misconceptions during primary school. The data indicates that PST 14 may have possibly misinterpreted the topic of Grade 6 Processing and Processes to Purify Water with Grade 6 Term 4 Systems and Control and Grade 5 Food Processing due to not being taught the differences between these topics in Grades 4 to 6 in primary school.

(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

The link made between NST knowledge strands is foregrounded in content integration of different Grade 4 to 6 topics and concepts within the NST curriculum as contained in CAPS. The PSTs in Category 8 displayed a general knowledge of mostly the topics that are to be taught in an integrated NST curriculum in Grades 4 to 6. It was encouraging to note that PSTs 6 and 14 linked some Grade 4 and 6 topics and concepts in Matter and Materials under NS to Materials and Processing under TECH. However, the central focus for PST 6 was content integration and PST 14 mentioned life and living. These findings suggest that the PSTs in Category 8 attempted to show an understanding of topics and concepts within an integrated Grade 6 NST curriculum. However, the data reveals that the PSTs in this category could not recall prior knowledge of Grade 6 topics and concepts in Matter and Materials and Processing as they could not indicate the link between Grade 4 to 6 topics and concepts on their CMs. There also seems to possibly be some confusion as to how the Grade 4 to 6 topics and concepts need to be taught in an integrated way in NST.

Furthermore, ***none of the Grade 6 NST PSTs in this Category 8 showed problematisation and contextualisation*** to water and sanitation in rural communities in South Africa. W.r.t. how the relationship between the two strands was conceptualised by the PSTs, we see that all four PSTs did not use problem identification. The focus was on teaching NST and content integration was foregrounded. Figure 6.16 below illustrates PST 12's CM.

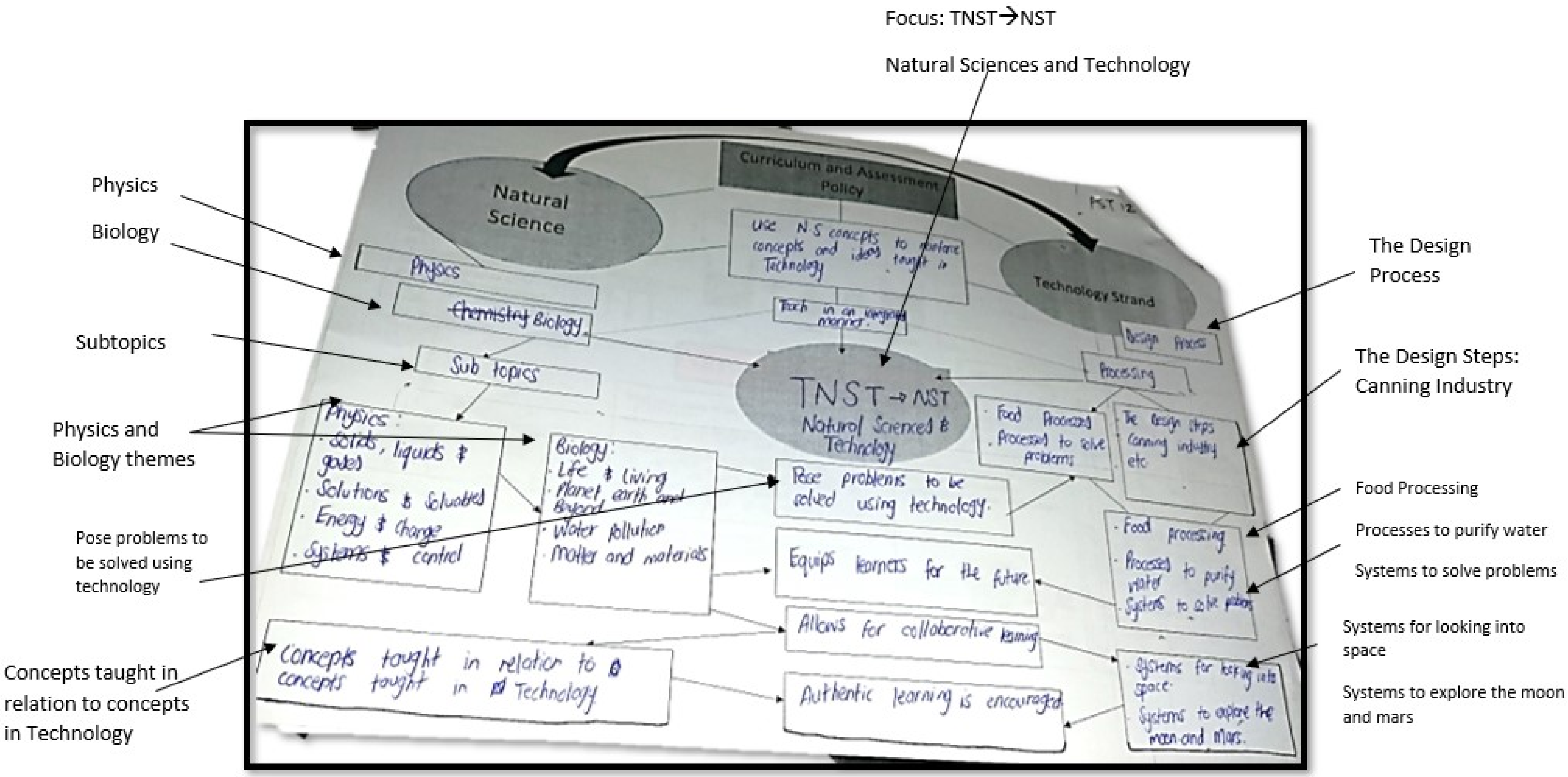


Figure 6.16: Example of PST 12's Completed CM Highlighting the NST Topics, Content, and Concepts in Category 8

PST 33 included separation of Grade 6 mixtures and solutions and linked these topics and concepts to elements in the atmosphere and the solar system. Water was also linked to making the solar system, however, PST 33's link appears unclear. PST 33 may possibly have a misconception that the solar system is made up of water from possibly being taught this in primary school, which was not corrected in high school. It must be noted, however, that PST 33 also linked water to water purification by the Grade 6 processes of filtration and evaporation. This evidence confirmed that PST 33 recalled some Grade 4 and 6 NST topics, content, and concepts, and showed no understanding of the topics and concept pertaining to an integrated Grade 6 NST curriculum.

6.9. Conclusion

This chapter presented the results of **how Grade 6 NST PSTs represented their understanding of an integrated Grade 6 NST curriculum through the use of CMs.**

Table 6.3: Summary of Findings of the Eight Categories Generated from the Grade 6 NST Pre-Service Teachers' CMs in Matter and Materials and Processing

SUMMARY OF FINDINGS

Category	1	2	3	4	5	6	7	8	
NS-TECH strands	Matter and Materials (NS) and Processing (TECH	Matter and Materials (NS) and Processing (TECH)	Matter and Materials (NS) and Processing (TECH)	Matter and Materials (NS) and Water Pollution (TECH)	Arrangement of Particles (NS) and Processing (TECH)	Raw Materials (NS) and Man-made or Manufactured Materials (TECH)	Raw Materials (NS) and Man-made or Manufactured Materials (TECH)	Various Topics (NS) and Various Topics (TECH)	
Understanding of integration as derived from what was foregounded	**It's an integration of two Grade 4 to 6 NS and TECH processes: Scientific and Design processes**	**It is an integration of the Grade 6 NS topics of Dissolving , Mixtures and water resources and Grade 6 TECH topic of processes to purify water and the concept of clean water.**	**It is an integration of the Grade 6 NS topic of Solids, liquids and gases , Mixtures and water resources, concepts of the arrangement of particles and Grade 6 TECH topic of processes to purify water and concept of clean water supply.**	**It is an integration of Grade 6 NS topic of Mixtures and Solutions as special mixtures, concepts of soluable substances and saturated solutions and Water Pollution with a particular focus on the topic of Separation. Also, includes the integration of Grade 6 TECH topic of processes to purify water.**	**It is an integration of Grade 6 NS concepts of arrangement of particles, mixtures of materials, solutions and the Grade 6 TECH topic of processing with a particular focus on the concept of crystallisation**	**It is an integration of NS & TECH Grade 5 topics and concepts**	**It is an ntegration of NS & Tech Grade 5 topics and concepts**	**It is an integration of different NS & Tech topics and concepts from Grades 4 to 6**	
%	**22.5%**	**7.5%**	**10%**	**10%**	**10%**	**17.5%**	**12.5%**	**10%**	**100%**
NS topics and concepts foregrounded i.t.o. Grades 4- 6 CAPS	Grade 6 - Sem 2: Topics and Concepts	Grade 6 - Sem 2: Topics and Concepts	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	
% Range	**C (95% to 65%) - IC (20% to 15%)**	**C(70% to 75%)-IC(40%)**	**C-60%-50%**	**IC-55%-25%**	**C-45%-40%**	**C-O%**	**IC-0%**	**C-25%-0%**	
Tech topics and concepts foregrounded i.t.o. Grades 4-6 CAPS	Ranged from Grade 4-6	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	Grade 6 Term 2	
% Range	**C(56%-44%) - IC (11%)**	**C(67%-33%) -IC (33%)**	**C(57%-14%)**	**IC-(50%)**	**C(30%-0%)**	**C(83%)**	**IC(83%-33%)**	**C(42%-26%)**	
NS topics and concepts foregrounded i.t.o. Grades 4 - 6 OTHER	Ranged from Grade 4-6	Only Grade 6	Grades 4-6	Grades 4-6	Grades 4-6	Grade 5 Term 2	Grade 5 Term 2	Grades 4-6	
% Range	**C(56%-44%) - IC (11%)**	**C(0%) -IC (100%)**	**C-(43%)**	**IC-(80%-20%)**	**C(100%)**	**C-(100%)**	**IC-(76%-35%)**	**C-(57%-17%)**	
Tech topics and concepts foregrounded i.t.o. Grades 4-6 OTHER	Ranged from Grade 4-6	Only Grade 6	Grades 4-6	Grades 4-6	Grades 4-6	Grade 5 Term 2	Grade 5 Term 2	Grades 4-6	
% Range	**C(56%-44%) - IC (11%)**	**C(67%-33%) -IC (33%)**	**C(57%-14%)**	**IC-(50%)**	**C(30%-0%)**	**C(83%)**	**IC(83%-33%)**	**C(42%-26%)**	
Link - Did they use problem identification and/or contextualisation	Yes	No	No	No	No	No	No	No	
Link used	linked the problem of Water Pollution to Mixtures and Arrangement of Particles under NS topic of Matter and Materials to different ways of Separating clean water from contaminated water under the topic of Processing in TECH using Filtration and Evaporation as Methods to purify water.	No link	No link	used the rates of dissolving as a Grade 6 topic as a link to the topics, content and concepts relating to NS Matter and Materials and TECH Processing	used the term integration and crystallisation to link the topics and concepts under Matter and Materials in NS to topics and concepts of processing separation of mixtures in TECH	there was no evidence of concepts that linked to the problem identification of water and sanitation in rural communities in South Africa.	there was no evidence of concepts that linked to the problem identification of water and sanitation in rural communities in South Africa.	could not recall prior knowledge of Grade 6 NS topics and concepts in Matter and Materials and TECH topics and concepts in Processing and could not indicate the link between Grade 4 to 6 NST topics and concepts	

As mentioned earlier, two understandings of integration were elicited which were spread through the eight categories.

Understanding 1: Integration of 2 processes: Scientific and design processes

Understanding 2: Integration of NST – there is a variation in the way the groupings of PSTs described the topics and concepts on their CMs.

Understanding 1 was held by nine (22,5%) of the NST PSTs, whilst understanding 2 was held by 31 (77,5%) of the NST PSTs. The variation observed in the second understanding revealed that Categories 2 to 8 focussed on various NST topics and concepts from Grades 4 to 6.

Categories 2 to 4 focussed on various NS topics and concepts as well as the topic of processing in TECH to purify water. Category 5 also focussed on the various topics and concepts, however, w.r.t. the topic of processing in TECH, the emphasis was on crystallisation as opposed to the purification of water as seen in Categories 2 to 4. Categories 6 to 8 focussed on various NST topics and concepts from Grades 4 to 6 Matter and Materials and Processing. With regards to Categories 6 and 7, the emphasis was similar and focussed on a recall of prior knowledge of Grade 5 Term 2 Matter and Materials topics, such as metals, non-metals, elements, and compounds under NS, and man-made or manufactured materials of physical and chemical changes by use of TECH. In Category 8 the emphasis was on a variety of Grade 4 to 6 topics and concepts in NST as opposed to the Grade 5 topics and concepts mentioned in Categories 6 and 7.

W.r.t. NS topics and concepts foregrounded i.t.o. Grades 4 to 6 CAPS, Category 1 covered the highest percentage in the range of 95%–65% as opposed to Categories 2 to 8. In Categories 6 and 7 there was no mention of any Grade 6 Term NS topics and concepts from CAPS (0% range) as opposed to Category 8 range of Grade 4 to 6 topics and concepts (25%–0%). Categories 1 and 4 mentioned Grades 4 to 6 “OTHER” NS topics and concepts in the range of 11% and 80%–20%. Category 4 covered the highest percentage of Grade 5 Term 2 “OTHER” NS topics and concepts in the range of 80%–20%, followed by Category 7 in the range of 76%–35%, and Category 1 covered Grade 4 to 6 “OTHER” topics and concepts in the range of 11%.

Category 7 covered 83% of Grade 5 TECH topics followed by Category 6 PSTs who covered a range of 30%–0%. Category 3 covered the highest percentage of Grade 4 to 6 TECH “OTHER” topics and concepts in the range of 57%–14%, whereas the PSTs in Category 5 covered the lowest percentage range of 30%–0%. Category 2 covered a range of 67%–33% of Grade 6 TECH "OTHER" topics and concepts as opposed to categories 1, 3, 5, 6 and 8 which focussed on Grade 4 to 6 TECH "OTHER" topics and concepts. Category 6 was the only category with 83% of completed Grade 5 Term 2 TECH "OTHER" topics and concepts as opposed to Categories 7 and 8.

In Category 1, NST topics and concepts were linked to problem of the Grade 6 NS topic of Water Pollution under Matter and Materials to the Grade 6 TECH topic of Processes to Purify Water. In Category 1, the understanding of integration was focussed on problem identification and contextualisation of water and sanitation in rural communities in South Africa as opposed to Categories 2 to 8 which was not the case. Categories 2, 3, 6, 7 and 8 did not mention a link that was used to integrate the NST knowledge strands as opposed to Categories 1, 4 and 5 which contained various links between NST topics and concepts. In Category 4, the emphasis was on the Grade 6 NS topic of Dissolving and concepts of the rates of dissolving, and soluble and saturated solutions as a link to the TECH topic of processes to purify water as opposed to the Category 5 which focussed on "integration", the NS concepts of arrangement of particles, pure, and impure solids (soluble and insoluble), and water pollution under Matter and Materials and the Grade 6 concept of "crystallisation" (p. 53). In Categories 6, 7 and 8 there were no links used to integrate the NST knowledge strands. In Categories 6 and 7, the focus was on Grade 5 Term 2 topics of Metals and Non-Metals, and the scientific and design processes as opposed to Category 8 which focussed on a general high school physics and chemistry knowledge and used the link of "content integration".

The phenomenon of "topic specific pedagogical content knowledge" (TSPCK) was first identified by Geddis and Woods (1997) and Ball et al., (2008, p. 400). Mavhunga and Rollnick (2011, p. 2) also referred to TSPCK as a form of "specialized content knowledge" that teachers were required to develop before teaching specific content to learners. The five components of TSPCK as described by Mavhunga and Rollnick (2011; 2013) were used in my study to enhance the Grade 6 NST PSTs integrated TSPCK in specific topics and concepts of Matter and Materials in NS and Processing in TECH. The five components as described by Mavhunga and Rollnick (2011; 2013) stated that a teacher's professional CK comprised of the knowledge of a learner's prior knowledge, curriculum saliency, what made the topic easy or difficult, representations, and conceptual teaching strategies. The five components of TSPCK as described by Mavhunga and Rollnick (2011; 2013) formed an integral part in my study which was linked to a four-phase engagement (Wang, 2019). The Grade 6 NST PSTs' understanding of an integrated NST curriculum was explicated by the use of a CM activity as follows: 1) The NST PST's prior knowledge was elicited from the recall of misconceptions and alternative preconceptions of Term 2 Grade 4 to 6 NST topics on Matter and Materials and Processing through peer interaction in groups of three, questioning prompts, and an excursion to the Sugar Mill; 2) the specific aims of Grade 4 to 6 NST curriculum as contained in the NST CAPS was used to explain the link between metals and non-metals in NS in comparison to processed materials and construction in TECH; 3) more complex Grade 6 NST concepts were introduced and explained such as "pure" and "impure substances", "solubility", Particle Nature of Matter, its properties and phases, "dissolving", and "chromatography"; 4) a variety of representations ranging from the use of the whiteboard photographs and graphical images from the Grade 6 NST PSTs CMs captured the Grade 6 NST PST's understanding of the Grade 4 to 6 NST topics and concepts of Matter and Materials and Processing of an integrated curriculum; 5) the instructional strategies guided by a social constructivist approach promoted active learning through peer interaction during whole class and small group discussions as well as cooperative learning in a social setting of the lecture room.

In the next chapter, we will provide a detailed discussion of the findings and implications for this study in the training and the development of future Grade 6 NST PSTs' understanding of an integrated Grade 6 NST curriculum and what it entails. It is hoped that future Grade 6 NST PSTs' understanding of integration could be derived from developing a CK of topics and concepts pertaining to Matter and Materials and Processing under the knowledge strands of NST. By developing a sound CK of topics and concepts within Grade 6 Matter and Materials and Processing as contained in CAPS, future Grade 6 NST PSTs will be prepared to teach more complex and abstract topics and concepts pertaining to Matter and Materials and Processing under the knowledge strands of NST in an integrated way.

The findings and implications of my study from Chapter 6 will be discussed in detail in the next chapter.

CHAPTER 7

RESEARCHER'S REFLECTIONS ON THE FINDINGS THE INTEGRATION OF NST: A CASE OF MATTER AND MATERIALS AND PROCESSING

Introduction

This chapter seeks to provide a case for the teaching of difficult topics in NST. It provides my reflections as a researcher on the affordances and challenges of the process of engagement that was used to elicit the NST PSTs' understanding of an integrated NST. It argues for the place and space for a trained specialist NST teacher with an integrated understanding of Matter and Materials and Processing that could plan, design, implement, and reflect on using suitable instructional strategies and classroom activities that would promote an understanding of the required NST concepts of matter and materials, and processing to PSTs, as contained in CAPS (DoBE, 2011) for the Intermediate Phase.

As an academic discipline, "natural science" involves the understanding of the natural world in Physics, Chemistry and Biology (Essien & Okon, 2016). However, not enough has been done in the teaching of NS in the Intermediate Phase in Grades 4 to 6 (Bantwini, 2017). NS focuses on discovery through investigations and leads to investigative and logical thought processes (DoBE, 2011, p. 9). According to CAPS, "technology", on the other hand, deals with understanding the need for human-made objects and environments to solve problems, making products through design, invention, and production methods, leading to practical, solution-oriented processes (DoBE, 2011). According to the CAPS document, the two disciplines are supposed to complement each other as explained in Table 7.1 below.

Table 7.1: How Natural Sciences and Technology Complement Each Other

	NATURAL SCIENCES	TECHNOLOGY
Goal	Pursuit of new knowledge and understanding of the world around us and of natural phenomena	The creation of structures, systems and processes to meet peoples' needs and improving the quality of life
Focus	Focus is on understanding the natural world	Focus is on understanding the need for human–made objects and environments to solve problems
Developmental methods	Discovery through carrying out investigations	Making products though design, invention and production
Major processes	Investigative and logical processes • planning investigations • conducting investigations and collecting data • evaluating data and communicating findings	Practical solution-orientated processes • identifying a need • planning and designing • making (constructing) • evaluating and improving products • communicating
Evaluation methods	Analysis, generalisation and creation of theories	Analysis and application of design ideas

(Source: DoBE, 2011, p. 9)

This study was conducted to develop an integrated NST TSPCK in topics of Matter and Materials and Processing in Grade 6 PSTs. The literature review suggested that PSTs lack the required NST prior CK and PCK (specifically the CK aspect of PCK) (Mavhunga, 2014; Mavhunga & van der Merwe, 2017). As a teacher-trainer at a private HEI, I observed that Grade 6 NST PSTs found challenges in developing TSPCK in the understanding and application of NST topics such as Matter and Materials and Processing in Grades 4 to 6 (see Table 7.2 below).

Table 7.2: Matter and Materials Grades 4 to 6

TERM 2 Matter & Materials	• Materials around us • Solid materials • Strengthening materials • Strong frame structures	3 ½ 2 2 2 ½ **(10 weeks)**	• Metals and non-metals • Uses of metals • Processing materials • Processed materials	2 2 ½ 3 ½ 2 **(10 weeks)**	• Solids, liquids and gases • Mixtures • Solutions as special mixtures • Dissolving • Mixtures and water resources • Processes to purify water	½ 1 2 ½ 1 2 ½ 2 ½ **(10 weeks)**

(Source: DoBE, 2011, p. 15)

The topic of Matter and Materials in Grade 6 Term 2 was chosen for this study, as chemistry is a difficult aspect of the NS subject discipline. Negative primary school experiences included being taught by non-specialist primary school NST in-service teachers who repeatedly used direct instruction as a teaching strategy to teach these two subject disciplines separately. Thus, many of these PSTs in primary school resorted to learning abstract, complex NST concepts by rote learning and memorisation. Also, NST concepts and content were contained separately in outdated textbooks with complex definitions that were not taught in an integrated, simplified way by these primary school NST in-service teachers.

Due to a lack of conceptualisation of NST, most PSTs also experienced difficulties in visualising and differentiating between multiple macro and micro levels of particle arrangement in matter and materials. Smith et al., (2017) also explained that learners referred to the term “particles” as pieces rather than atoms, ions, or molecules, and lacked knowledge of the forces in the arrangement of the states of matter, phases of matter, and the movement of particles. PSTs’ inability to draw, describe, and explain this concept of particle arrangement at a higher cognitive level, suggested that there were misconceptions and gaps in their PCK, which might have developed earlier in their primary school years of being taught the topic of Matter and Materials in NS. According to CAPS (DoBE, 2011), Matter and Materials and Processing are part of the NST strands for Grades 5 and 6 (p. 14).

In Grade 5, Matter and Materials contain the sub-topics of metals and non-metals, and Processing contains the sub-topics of the processing of materials and processed materials. In Grade 6, there is an increase in the level of complexity of the sub-topics. Matter and Materials in NS (Grade 6) contain sub-topics such as solids, liquids, and gases, and mixtures, solutions as special mixtures, dissolving, and mixtures and resources of water. Processing in TECH (Grade 6) deals with the sub-topic of processes to purify water. CAPS (DoBE, 2011, p. 14) explicitly states that a teacher must be able to “expand concepts and design and organise learning experiences according to their own local circumstances”. Also, Indigenous knowledge examples should be included to incorporate different cultural groups in South Africa and should “link to specific content in the natural sciences and technology” (p. 14).

7.1 Grade 6 Term 2: NS Topics and Concepts of an Integrated Curriculum

This section discusses a number of topics and concepts included in the integrated Grade 6 NST curriculum. These are discussed below under their respective sub-headings.

7.1.1 Mixtures and solutions

It is interesting to note that a few Grade 6 NST PSTs linked the water molecule, dissolving, separation, water pollution, and crystallisation to Grade 6 topics, content, and concepts of mixtures and solutions under Matter and Materials and Processing in TECH. According to

Chang (1994), heterogenous mixtures are made up of a separate component, whereas homogenous mixtures have a uniform composition and appearance throughout. Both these types of mixtures can be separated physically. Therefore, any homogenous mixture of two or more substances is called a *solution*. Any substance mixed with water is referred to as an *aqueous solution*. Solutions consist of two components, namely, a *solute* and *solvent.* The solvent is the substance that is in a larger amount, whereas the solute is the component that is usually in the smaller amount. The process where one substance dissolves into another is called *dissolution*. Chemical compounds are symbolised by chemical formulas. Figure 7.1 below illustrates the different types of compounds according to the Grade 10 physical science curriculum:

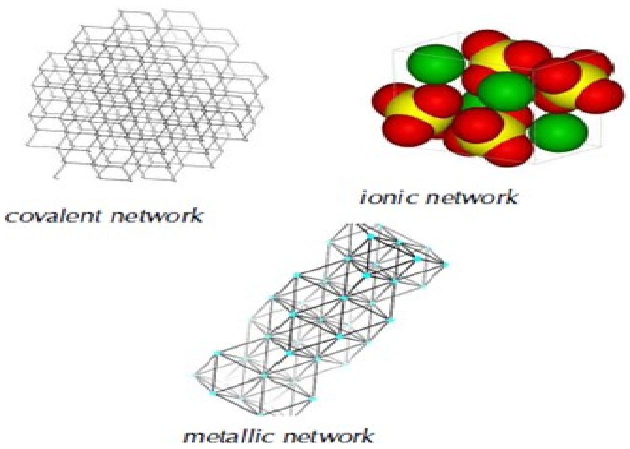


Figure 7.1: The Different Types of Compounds

(Source: Siyavula &Volunteers, 2015a, p. 205)

Figure 7.2 below provides a visual representation of the three types of network structures of compounds:

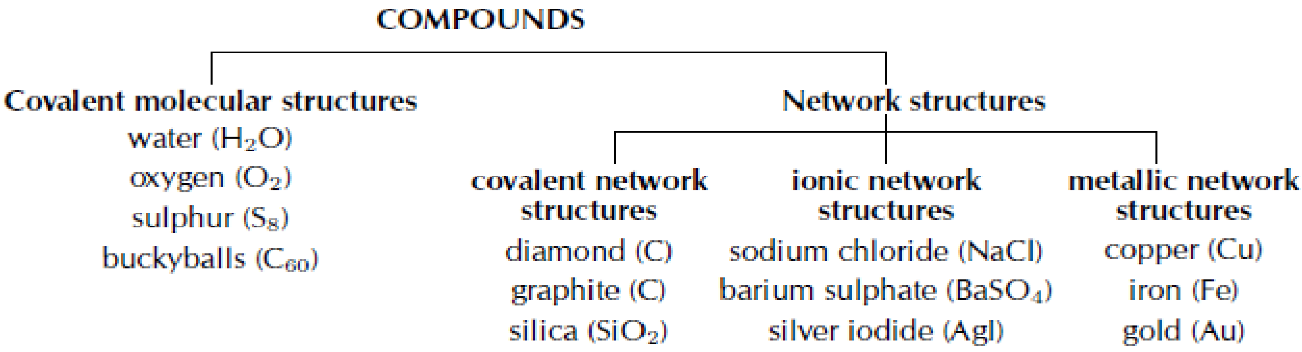


Figure 7.2: Visual Representation of The Three Types of Network Structures of Compounds

(Source: Siyavula & Volunteers, 2015a, p. 201)

It can be concluded that covalent and ionic network structures of solids would dissolve more easily in water when compared to the interwoven network of metallic network structures. Metallic structures are held together with strong electrostatic forces which also allows for rigidity and toughness, as confirmed by Siyavula and Volunteers (2015a).

7.1.2 The water molecule

The Grade 6 NST PSTs also used the chemical formula of the water and included the chemical formula for water that is H_2O. This possibly suggests that the Grade 6 NST PSTs could recall prior chemistry CK regarding atoms, molecules, and chemical formulae under Matter and Materials in NS. Figure 7.3 below illustrates the structure of a water molecule from the Grade 11 physical science curriculum.

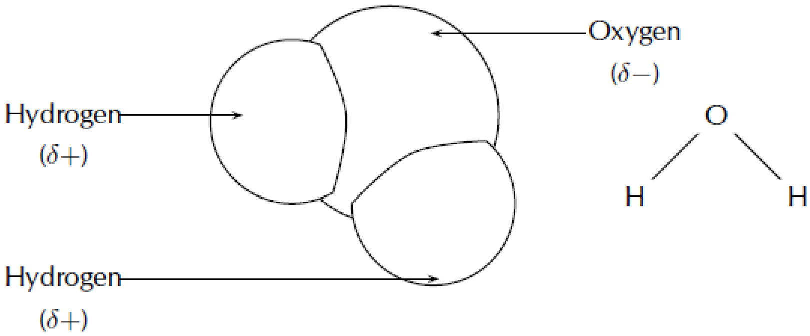


Figure 7.3: Illustration of the Dipoles in the Water Molecule

(Source: Siyavula & Volunteers (2015b, p. 184)

According to Figure 7.5 above, the water molecule is made up of two slightly positive dipoles being attracted to a slightly negative dipole of the oxygen atom. Due to the two hydrogen atoms being strongly attracted to the oxygen atom, the water molecule has an angular or bent shape as contained in Pang (2013); (Siyavula & Volunteers, 2015b, p. 184).

According to first-year college chemistry, water exists in three states, namely, *solid* (ice), *liquid* at room temperature, and *gas* as steam or water vapour. In the kinetic theory of matter, according to Chang (1994), atoms and molecules are in constant motion and can change their states, resulting in a phase change. The Grade 6 NST PSTS also mentioned that water is a molecule. They also described the water molecule being made up of two hydrogen atoms and one oxygen molecule, and showed this understanding by the chemical formula, H_2O.

Figure 7.4 shows the different phases of water in a graphical representation at a molecular level of a solid, liquid, and gas, which is from the Grade 11 physical science curriculum.

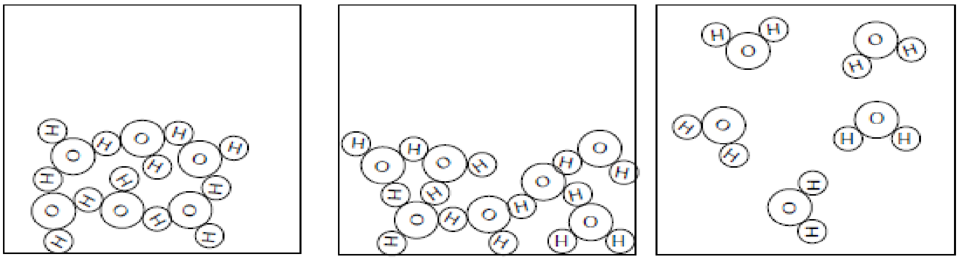


Figure 7.4: The Different Phases of The Water Molecule in a Graphical Representation at a Molecular Level of a Solid, Liquid and Gas

(Source: Siyavula and Volunteers, 2015b, p. 173)

7.1.3 Water pollution

The Grade 6 NST PSTs also linked mixtures to water pollution caused by soluble substances, such as soaps, acids, and fertilisers; and insoluble substances, such as oil, plastic, and tires. According to Singh and Gupta (2016), water is known as a universal solvent, and due to its chemical nature, allows for substances to dissolve in it. Toxic substances from homes, industries, and farms can also easily dissolve in water, causing water pollution. Singh and Gupta (2016) also points out that water quality is important and that water quality in rivers needs to be protected as there is a growing lack of water resources globally. Only three participants (PSTs 1, 3 and 37) were able to list the different type of mixtures that are homogenous and heterogenous. According to college chemistry, Chang (1994) stated that pure substances are either elements or compounds. However, it is interesting to note that PSTs 1, 3 and 37 appear to have some understanding of heterogenous and homogenous mixtures as the different combinations of these mixtures are mentioned, for example, solid and solid (heterogenous), solid and liquid (hetero/homogenous), and liquid and liquid (homogenous).

7.1.4 Graphical representation of particles of matter

Only one participant, PST 3, used a graphical representation of the molecular representation of mixtures and compounds. According to Pomfret (2015), water purification is a process whereby contaminants from water are removed by methods of separation. In this case, four participants (PSTs 1, 3, 37 and 45) mentioned filtration and evaporation as methods of purifying water and linked this to the problem of water and sanitation in rural communities in the context of South Africa. This implies that four participants (PSTs 1, 3, 37 and 45) had a good overall integrated understanding of NST concepts and can apply this understanding to try to find a solution to a localised problem. The other four participants' (PSTs 29, 42, 43 and 44) CMs also indicated that greater understanding of concepts such as solutions and mixtures under both Matter and Materials and Processing were required, as there were spaces where these four participants could not provide examples or detailed explanations. However, four participants (PSTs 29, 42, 43 and 44) were not able to complete the types of separation methods, nor could they name the processes to purify water. In addition, they were also unable to apply this CK in both Matter and Materials to solving the water and sanitation problem experienced by most rural communities in South Africa.

According to Chang (1994), experimental science of chemistry takes place in three steps. The first step is *observation*, where the chemist observes changes in appearance of the substance. The second step is r*epresentation,* which involves recoding and describing the experiment using shorthand symbols and equations. The third step is *interpretation*, where the chemist attempts to explain the phenomenon. Observation is also linked to the macroscopic world where we can use our five senses during observation. Representation and interpretation are linked to the microscopic world where chemists have knowledge of atoms and molecules which are extremely small and are not visible with the naked eye. Also, chemists represent and interpret the behaviour of atoms and molecules within substances to gain a better understanding of the properties of the substances in the solid, liquid, or gaseous state.

It is interesting to note that PST 3 used drawings of atoms by using circles to represent the atoms enclosed in square boxes. This graphical representation implies that PST 3 attempted to explain the difference between compounds and mixtures. Also, PST 3 drew individually separated circles showing that in heterogenous mixtures, the particles are different, whereas in mixtures and compounds, they are joined. According to Chang (1994), a compound is a substance that contains two or more elements that are chemically combined in fixed proportions, whereas a mixture is a combination of two or more substances that retain their identity. PST 3's graphical representations of a mixture and compound further shows this, using shaded and clear circles in the enclosed boxes. However, in comparison to PST 1, PST 3 links the problem of water and sanitation in rural communities to the chemistry nature of substances; that is, being dependent on the bonds between the substances, which affects their ability to mix and separate.

7.1.5 Sources of heavy metals in polluted water

According to Gupta (2016), there are two types of pollutants, namely, *organic* (compounds that contain carbon, hydrogen, oxygen, nitrogen, and sulphur) and *inorganic* (all other compounds). Both these compounds are released into rivers by runoff after heavy rains. Most of these compounds originate from industries as chemical waste, and may contain heavy metals, such as arsenic, lead, cadmium, nickel, mercury, chromium, cobalt, zinc, and selenium, which are toxic to humans and animals, even in small quantities. "Heavy metals", according to Koller (2018), is defined as a naturally occurring element, having a high atomic weight and density that is greater than water.

This means that these heavy metals have strong metallic bonds. As defined in the Grade 10 chemistry curriculum, a "metallic bond" is "the electrostatic attraction between the positively charged atomic nuclei of metal atoms and the delocalised electrons in the metal" (Siyavula & Volunteers, 2015a). According to Koller and Saleh (2018), heavy metals originated from asteroids and became embedded in the earth's crust, and was released into the soil, rivers, and groundwater through weathering and erosion. The removal of these heavy metals in the past using separation techniques such as physical, thermal, chelating, and other chemical techniques were unsuccessful. Koller and Saleh (2018) suggest using "modern physical and chemical approaches that involve nano-carriers, ion exchange techniques, removal via advanced membrane filtration techniques, electrodialysis, or photocatalysis.

7.1.6 Chemical bonding

It is also interesting to note that PST 3 was able to recall chemical bonding which was done in Grade 10 physical science (Siyavula & Volunteers, 2015a). This possibly suggests that PST 3 recalled topics, content, and concepts due to a high school physical science background. However, it is significant to note that PST 3 could not explain in detail processes to purify water in the topic of Processing in TECH.

According to the Grade 11 physical science curriculum (Siyavula & Volunteers, 2015b), intermolecular forces exist within molecules which determines whether their chemical bonds can break. There are different types of chemical bonds such as covalent (weak), polar (slightly strong), ionic (very strong) and metallic bonds (electrostatic force), as well as different types of intermolecular forces, for example, water is composed of strong hydrogen bonds between the hydrogen and oxygen atom which are weaker than covalent and ionic bonds. The following diagram in Figure 7.5 illustrates that the two hydrogen atoms have slightly positive hydrogen atoms which are pulled towards the slightly negative oxygen atom.

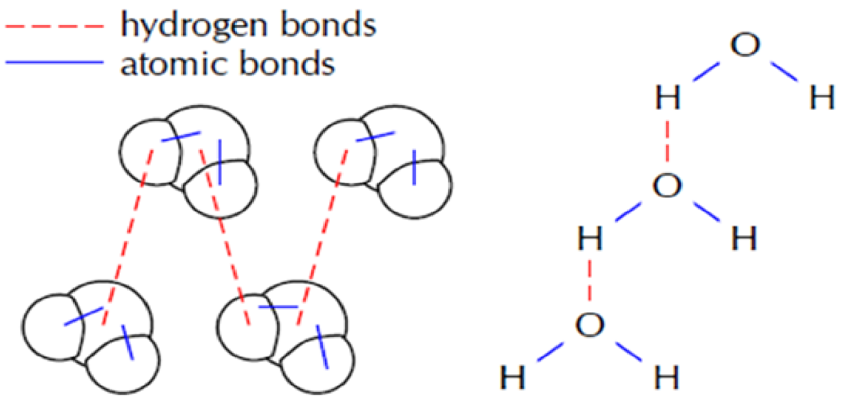


Figure 7.5: Hydrogen Bonds Between Hydrogen and Oxygen Atoms

(Source: Siyavula and Volunteers, 2015b, p. 185)

7.1.7 Hydrogen bonding in the water molecule

The strength of the intermolecular forces and the chemical bonds depend on the attraction of the electrons of each atom on each other which also determines the molecular geometrical shapes. Therefore, water is angular due to both hydrogen atoms being attracted or pulled upwards toward the oxygen atom. For dissolving to occur, one substance (solute) of smaller quantity must dissolve into a larger quantity (solvent), but also energy taken in must overcome the intermolecular forces and chemical bonds of the solute. The higher the temperature, the more energy is taken in by the particles and they vibrate faster and collide with each other and the sides of the container; the intermolecular forces weaken, and chemical bonds are broken easily. Stirring and shaking can also assist in the dissolution process but is not as effective as heating the solution and may require a longer period for particles to break apart and dissolve. The grain size is important due to smaller particles being able to fill the spaces in the solvent faster than larger particles.

According to Sullivan et al., (2005), there are biological contaminants which originate from human waste that give rise to pathogens like bacteria, viruses, and parasites, such as microscopic protozoa and worms. Algae, which is a single celled organism, can also grow rapidly due to nitrogen and phosphorous released from agriculture and industrial waste. Algae overgrowth leads to a decrease in the oxygen supply in the water, resulting in the death of aquatic life. Algae overgrowth can also clog filters in water pipes.

Bacteria are also microscopic and single celled but can cause many diseases, such as typhoid, dysentery, cholera, and gastroenteritis. Viruses are the smallest living organisms capable of producing infection and causing diseases such as Hepatitis and polio viruses in contaminated water. The sources of contamination of water and the environmental and health impact on humans is illustrated in Figure 7.6 below:

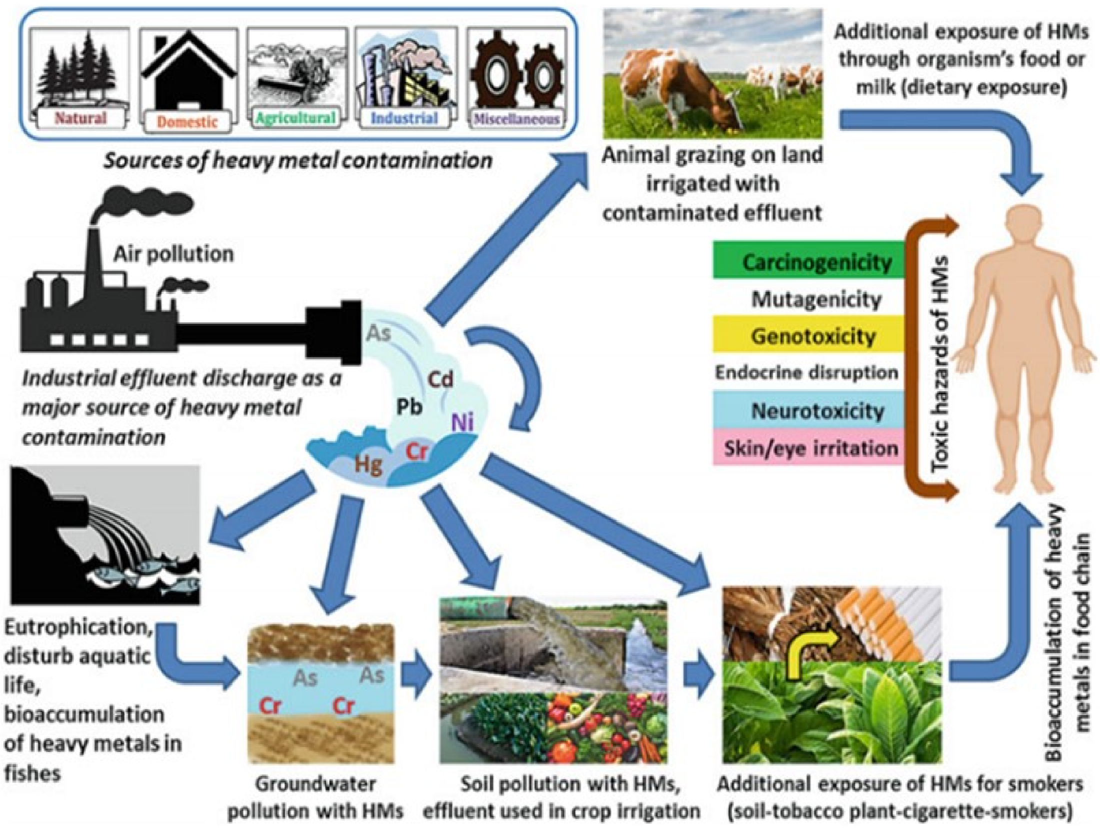


Figure 7.6: The Sources of Contamination of Water and the Environmental and Health Impact on Humans

(Mehmood et al., 2019)

7.1.8 The design process

According to Grade 7 TECH, the design process forms the "backbone" for all technological methods (DoBE, 2012). TECH in Grade 7 (p. 74) emphasises that learners should learn the importance and relevance of applying Indigenous knowledge systems and how materials are used to address human needs and problems**.** The following excerpt is from Annexure E of the Grade 7–9 Technology CAPS (2012) (see Figure 7.7 below). It clearly explains the different steps of the design process, namely, investigate, design, make, evaluate, and communicate (IDMEC). A similar type of Annexure should be included in the CAPS for Grades 4 to 6 of the Intermediate Phase to assist learners and teachers in understanding the steps in the design process.

The Design Process is not linear, usually cyclical. Often it is driven by evaluation.

Evaluation at each stage determines the next step.

Investigate	Problem/need/want Context/impact Research/questionnaire/interview Materials/suitable tools/required skills
Design	Initial ideas Free-hand sketches Design Brief with Specifications and Constraints Plan using systems diagram Trial modelling Budget
Make	Choose tools/method/materials/resources Draw formal plans Draw flow charts/sequence of manufacture Make prototype/model/final product (considering safe working procedures)
Evaluate	Evaluate severity/urgency of problem/need/want. Analyse solution using a systems diagram Evaluate solution in terms of design brief, specifications and constraints Evaluate product/process/manufacturing method/safety Evaluate impact/bias/an indigenous solution
Communicate	Report Present Advertise/poster using artistic graphics

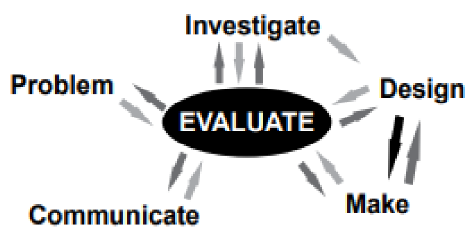


Figure 7.7: Annexure E Grade 7 Technology
(Source: DoBE, 2012, p. 74)

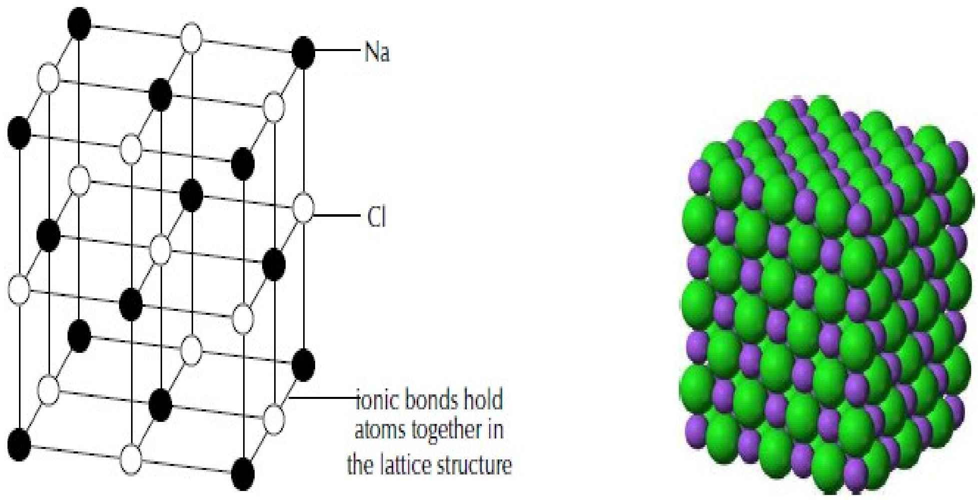
Also, learners should be made aware of the positive and negative impacts of technology and the bias of technological products favoured by certain countries and the dangers of this. Learners should also be taught the various steps, namely: (1) to investigate a problem and solution, (2) design, (3) make, and (4) evaluate a model that could solve the problem, and (5) communicate the ongoing success of the design by recording and reporting. It is interesting to note that the details of how the design process should be taught in Grade 6 is not made explicit as in Grade 7. PST 9 also mentions that integration involves designing, making, and evaluating a simple system to purify water. According to the Grade 6 topic of Processing, learners are required to apply the design process to a simple water filter system that could be used in households, and especially in rural communities in South Africa. PST 9 did have an overall idea of what was required under the topic of Processing, but more explanation and research is needed to develop this TECH knowledge in methods of separation and in finding solutions to the problem of water and sanitation in rural communities in South Africa.

7.1.9 Dissolving

According to Chang (1994, p. 476), a saturated solution contains the "maximum amount of solute in a given solvent at a specific temperature". Once the amount of solute exceeds the amount of solvent, the solution becomes supersaturated or has reached its saturation point. This means that no solute if added will dissolve. The separation methods suggested in the literature for water purification of contaminated water where substances are dissolved include distillation. *Distillation* is the most common method in which the boiling points of the liquid mixtures are considered. It is a process that removes most of the organic components like toxic chemicals, heavy metals, bacteria, viruses, and parasites. However, organic components below 100 degrees Celsius cannot be removed by distillation and researchers suggest the use of activated carbon filters. The distillation process is slow and can be expensive since activated carbon filters need to be replaced continuously. PST 11 also mentioned the terms soluble and insoluble under solutions. However, PST 11 left most of the blocks blank and did not seem to fully integrate the Matter and Materials concepts with the topic of Processing in TECH. This further implies that PST 11 has difficulty explaining and applying NST concepts in an integrated way.

7.1.10 Crystallisation

Four participants in this sub-category used the theme of crystallisation to understand the integration of the topic of Matter and Materials and Processing. Solids can be divided into two categories, namely, *crystalline* and *amorphous* (Chang, 1994). A crystalline structure has repeating structural units that are held together by strong forces forming a three-dimensional network of atoms, molecules, or ions. This three-dimensional network is also called a *lattice,* and the geometric shape of a lattice is dependent on how these unit cells are arranged. The arrangement of the particles in a crystalline solid can be determined by X-ray diffraction also known as the scattering of X-rays by units of the crystalline solid (p. 442). There are different types of crystals, including ionic (NaCl), covalent (diamond), molecular (SO_2), and metallic (metals). Amorphous crystals are not crystalline in structure, for example, glass. The crystal lattice structure of table salt (NaCl) is mentioned in the Grade 10 physical science curriculum. The following diagrams in Figure 7.8 illustrate the (a) network and (b) crystal lattice of table salt.



(a) (b)

Figure 7.8: The Network and Crystal Structures of Table Salt (NaCl)

(Source: Siyavula et al., 2015a, p. 115)

According to first-year college chemistry, Chang (1994) states that the solubility rule "like dissolves in like" depends on the following interactions: solvent-solvent, solute-solute, and solvent-solute (p. 477). Salt dissolving in water resembles the third type of interaction where water represents the solvent and salt represents the solute. *Solvation* is a process in which an ion or molecule is surrounded by solvent molecules. Salt is made up of sodium and chloride ions which become surrounded by hydrogen and oxygen atoms of water and this process is called *hydration*. The salt is dissolved in the water to form sodium hydroxide and hydrogen chloride solutions. Furthermore, three participants (PSTs 25, 34 and 47) provided a chemical equation of the reactants, namely: $NaCl + H_2O$. However, all three participants do not state what the products of this reaction are.

According to Chang (1994), crystallisation is a process whereby a dissolved solute comes out of the solution and forms crystals. A supersaturated solution is prepared and is very unstable. This process is similar to precipitation where solids can be separated from liquids and the particles are small whereas crystallisation allows for large crystals to be formed. Interestingly, according to researchers, precipitation is the simplest way to purify water.

7.1.11 A water purification method

Chemicals are added to soften water to remove phosphorus, fluoride, arsenic, ferrocyanide, and heavy metals. The insoluble contaminants settle at the bottom. The top treated water is reused, and the bottom insoluble layer is disposed of. The Grade 6 NST PSTs in the Matter and Materials and Processing categories also mentioned filtration as a water purification separation method. Clements and Haarhoff (2004) suggests biologically active carbon filtration to purify contaminated water. The process utilises granulated activate carbon (GAC) as its water filtration as illustrated in Figure 7.11. The GAC is made from organic materials with high carbon contents, such as wood, lignite, and coal, and forms a biofilm in which bacteria and fungi cells in the biofilms secrete extracellular polymeric substances to form a cohesive, stable matrix in which cells are held in. The GAC, due to an exposure of a large surface area, absorbs most organic molecules by forming chemical bonds. GAC has many positive benefits as it is economically viable for large water and purification systems where odour and taste must be controlled. However, if this filter is incorporated, then it is costly to replace the filters due to bacterial overgrowth which must be monitored. All four participants may need to acquire a better understanding of the process of crystallisation and how this can be applied to water purification methods that are best suitable to address the water and sanitation problem in South Africa. Figure 7.9 below shows an example of a GAC filter that could possibly be used in the water treatment process.

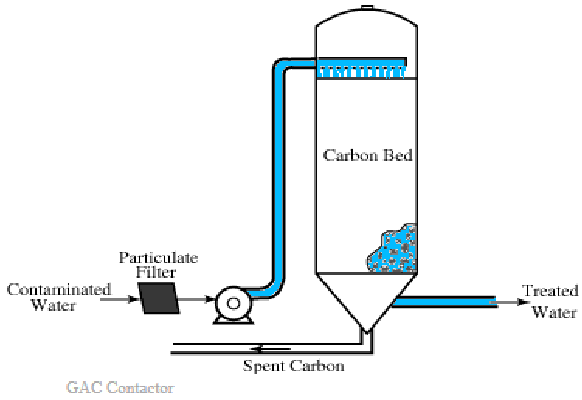


Figure 7.9: Example of a Diagram of Granulated Activate Carbon (GAC) used in the Water Purification Process

(Source: Clements & Haarhoff, 2004)

Regarding the topic of Processing, Grade 6 NST PSTs showed little interest in wanting to learn more about separation methods, such as distillation, and chromatography, as these were difficult for them to understand. Also, Grade 6 NST PSTs could not apply the steps of the design process to construct a model of a water filter. TECH education focusses on the technological process and a systematic way to solve problems in the world. Asunda and Mativo (2016) and Buckley et al., (2019) agree that technology is a new learning area that has been globally recognised for being a student-centred outcome-based practical approach in which assessment is ongoing.

When NST are integrated into topics of Matter and Materials, it resembles that of Materials Science and Engineering (MSE). MSE is an interdisciplinary field of science and engineering that also deals with the synthesis and processing of different types of material structures. The term "structure", in this case, refers to the detailed level of arrangement of atoms. Material scientists and engineers also synthesise, process, and transform different materials into useful devices and structures. The term "synthesis" refers to how materials are made from naturally occurring or manmade chemicals, and "processing" means how materials are shaped into useful components to cause changes in the properties of different materials (p. 4). Buckley et al., (2019) report that TECH and TECH education, being a new learning area, has limited knowledge that was misunderstood over the years and has given rise to misconceptions and misinterpretations. These misconceptions and misinterpretations together with a lack of laboratories and practical material resources contributed to the inhibited growth of this learning area in schools in South Africa.

A trained specialist NST teacher with an integrated understanding of Matter and Materials and Processing, therefore, could plan, design, implement, and reflect on using suitable instructional strategies and classroom activities that would promote an understanding of the required NST concepts of matter and materials, and processing to PSTs, as envisioned in CAPS (DoBE, 2011) for the Intermediate Phase. According to the Technology for All Americans Project, published in 1996, the incorporation of TECH education also aims to make learners aware of how technological knowledge could be used with science and other subject disciplines to impact society, leading to more technologically literate individuals who could make better decisions for a country in the future. Future studies could involve using computer software that could be accessed by pre-service teachers and completed electronically. HEI’s could purchase concept map software (Cañas & Novak, 2008) such as Coggle to enhance the design of electronic CMs with access to many features. The electronic maps could be emailed to the lecturer, evaluated and graded electronically and the feedback given to PSTs could be instantaneous. Based on the insights obtained above, a few concluding remarks follow next.

7.2 Conclusion

The challenge in South Africa is how PSTs receive NST curriculum training in HE. Acquiring an integrated NST TSPCK could also assist in the development of critical thinking skills. Critical thinking skills and concept mapping (Cañas & Novak, 2008) are important, as NST PSTs must be trained on how to change their perceptions and thinking about the difficulty of understanding an integrated NST curriculum, its content, pedagogy, and integration of topics and sub-topics across NST.

To date, there is insufficient research on how South African NST PSTs must receive training to develop a sound integrated TSPCK in an integrated NST education, as stipulated in CAPS (DoBE, 2011) for Grades 4 to 6. Hence, an integrated NST PST training programme should strive to produce primary school learners who appreciate the value and relevance of applying science and technology to their everyday lives and environments.

In the next chapter, the discussion of the findings is used to determine whether the Grade 6 NST PSTs in this study reached an understanding of an integrated Grade 6 NST curriculum and to determine how they represented their understanding in the topics, and concepts of Matter and Materials in NS and Processing in TECH using a concept mapping activity.

CHAPTER 8

DISCUSSION OF FINDINGS, RECOMMENDATIONS, LIMITATIONS & CONCLUSION

Introduction

This chapter presents a discussion of the findings to determine whether the Grade 6 NST PSTs in this study reached an understanding of an integrated Grade 6 NST curriculum and to determine how they represented their understanding in the topics and concepts of Matter and Materials in NS and Processing in TECH using a concept mapping activity. The problem that currently exists in primary schools is that NST in-service teachers and NST PSTs in teacher training programmes, for example, at the selected HEI in this study, do not appear to fully understand the meaning of an integrated NST curriculum. As a result, these in-service teachers cannot apply PCK to the teaching of NST topics and concepts particularly in Matter and Materials and Processing in an integrated way. In an attempt to contribute to scholarship on how to develop NST PSTs' understanding of an integrated curriculum, I engaged NST PSTs in active learning through peer interaction to discuss and elicit their understanding of an integrated NST curriculum and sought to explore how they represented their understanding of an integrated NST curriculum using a concept mapping activity.

The following research questions guided this exploration:

c) How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?

d) How do NST pre-service teachers represent their understanding of an integrated NST curriculum?

The key findings that arose from Chapters 5 and 6 are discussed in more detail below. The purpose of the study was to further promote the development of an integrated TSPCK in Grade 6 NST PSTs with a focus on the teaching of specific topics and concepts in Matter and Materials and Processing under the knowledge strands of NS and TECH. TSPCK, as explained by Mavhunga's model (Mavhunga, 2014, cited in Kirschner et al., 2015), is a specialised form of subject matter knowledge that is based on a teacher's understanding of the content and concepts within a specific topic. The teacher, however, must be able to use suitable teaching practices to bring about comprehension of these concepts within a specific topic. In a study conducted by Mavhunga and Rollnick (2013) to highlight the importance of the application of TSPCK to South African contexts, they argued that TSPCK is driven by five components. These include: "(i) Student's Prior Knowledge including Misconceptions; (ii) Curricular Saliency; (iii) What makes a topic easy or difficult to understand; (v) Representations including analogies and (v) Conceptual Teaching Strategies" (p. 115).

This study argues that a transformed PCK could lead to the use of suitable teaching strategies such as whole class and small group discussions and co-operative learning in the way NST topics and concepts in Matter and Materials and Processing are taught in a future integrated NST curriculum. Hence, a combination of transformed pedagogical content knowledge and the use of suitable instructional strategies could be developed in NST PSTs to cultivate a good conceptual understanding of NST topics and concepts in a specific topic within a framework of TSPCK. The term "pedagogical reasoning" introduced by Shulman (1987, as cited in Mavhunga & Rollnick, 2013) suggested that South African PSTs should be trained to think about and reflect on the suitable teaching strategies that could be used to bring about a change in conceptual understanding within a specific topic. "Pedagogical reasoning" was used in this study in which instructional strategies such as whole class and small group discussions and co-operative learning were carefully researched and reflected upon before and during the concept mapping activity. The findings in this Chapter shows potential for more research to be done in the development of TSPCK in other important NST topics such as Energy and Change, Planet Earth and Beyond, Systems and Control and Structures. In this way, future NST PSTs could be trained in the application of "pedagogical reasoning" in the gradual development of one topic at a time in accordance with CAPS for Grades 4 to 6 in the Intermediate Phase (DoBE, 2011).

The outline of this final chapter is as follows. Following the introduction, the chapter discusses the findings of the study in terms of each research question – Research Question 1 (sections 8.1) and Research Question 2 (section 8.2.). The implications of the study are then explained (section 8.3.), along with the contributions (section 8.4.) and limitations (section 8.5.) of the study. The penultimate section presents recommendations for further research (section 8.6), followed by a final conclusion (section 8.7).

8.1 Summary and Discussion of the Results from Research Question 1

This section presents a summary and discussion of the first research question, namely:

How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?

The research question explored how Grade 6 NST PSTs' understanding of an integrated curriculum could be developed, and the various stages of engagement which led to the elicitation of Grade 6 NST PSTs' understanding of an integrated curriculum were presented.

To elucidate this further, the various stages of engagement were presented in Chapter 5, which led to the elicitation of Grade 6 NST PSTs' understanding of an integrated curriculum. The various stages of engagement were adapted from Wang (2019) and comprised four parts, namely: the preparation phase, the interactive phase, the feedback phase, and evaluation phase. In my study I argued that the four phase engagement process of using concept mapping by Wang (2019) could be adjusted for the purpose of this study and when these phases are combined with a framework of TSPCK as proposed by Mavhunga (2014) and Mavhunga and Rollnick (2013) proved that concept mapping is advantageous as it promotes the graphical representation of facts, concepts, and relationships; aids in the construction and retainment of knowledge and promotes clarity and a deeper meaning of knowledge through communication. The concept mapping activity also assisted the Grade 6 NST PSTs in the improvement of their CK in the NST topic and concepts of Matter and Materials and Processing through recall of prior Grade 4 to 6 NST knowledge and the integration of the NST topics and concepts. The concept mapping activity proved to be challenging as the Grade 6 NST PSTs were more accustomed to using mind maps in their studies in HE. After the CM activity was completed, the Grade 6 NST PSTs had a full view of their prior Grade 4 to 6 CK in topics and concepts pertaining to Matter and Materials and Processing. This holistic view of the CMs also exposed to the Grade 6 NST PSTs various gaps in their prior Grade 4 to 6 CK and misconceptions that may have possibly formed earlier on in primary school. Although concept mapping as a teaching strategy can be subjective and time consuming, Wang (2019) concludes that this type of teaching strategy is a "powerful teaching tool" and must be implemented in schools that are resistant to change their out-dated teaching practices (p. 1198). Hence, the findings were aligned to research question one which suggested that NST PSTs understanding of an integrated NST curriculum could be elicited by engagement using instructional strategies and a concept mapping activity (Wang, 2019) to promote the development of an integrated TSPCK in Matter and Materials in NS and Processing in TECH.

An initial brainstorming session presented feedback from the Grade 6 NST PSTs prior CK in Grade 4 to 6 NST topics and concepts. The elicitation of Grades 4 and 5 NST prior knowledge of topics and concepts by the Grade 6 NST PSTs set the platform for the introduction of more complex Grade 6 NST concepts such as “pure” and “impure substances” and consolidation of the concept of “solubility”. The findings of the brainstorming session highlight that the Grade 4 and 5 elicitation of prior knowledge of topics and concepts in the Particle Nature of Matter; its phases when heat is added or taken away and the properties of Matter were good starting points of discussion for the introduction of Grade 6 NST topics and concepts relating to “substances” and “solubility”. After completion of the feedback session, a whole class discussion was held to clarify the Grade 6 NST topics and concepts. The findings from the feedback suggest that the Grade 6 NST PSTs experienced a discord in understanding and explaining NST topics and concepts in relation to Grade 6 Term 2 mixtures and solutions as well as the reasons for why only some substances dissolve in water. It was interesting to note that another finding points to the use of examples of familiar household crystalline substances such as salt and sugar that were used in an illustration on the whiteboard to explain the topics and concepts relating to Grade 6 NS topic of dissolving and the dissolution process. Another significant finding emerged from the observation made during the practical chemistry investigation. The finding of the observation during the engagement of the Grade 6 NST PSTs in the practical chemistry experiment revealed that all the Grade 6 NST PSTs in the small groups of three, were fully engaged in interactive peer discussions during the practical activity. By carrying out this observation during the practical investigation, the more passive Grade 6 NST PSTs became more actively involved and it was apparent that their curiosity and interest in NST was reignited from the social interaction with their peers. Another noteworthy finding that was aligned to research question one illuminated the Grade 6 NST PSTs’ challenges with the learning of the new Grade 6 NST topics and concepts as well as highlighting of key points relating to the methods of separation of solutions, such as filtration and chromatography. An increased number of Grade 6 NST PSTs in the class (during oral interaction of feedback) indicated that they had some idea of the process of filtration but did not fully understand the separation method of chromatography as they were not taught this type of separation method in primary school.

A finding that must be pointed out is the use of small group discussions which promoted active participation and knowledge construction in the Grade 6 NST PSTs by the sharing of ideas and peer interaction in the social setting of the classroom. Another finding that was emerged from the observation of the Grade 6 NST PSTs peer interaction in the small group discussion and co-operative learning sessions with the CMs, revealed that the Grade 6 NST PSTs did not interact with CAPS and their textbooks as often as they did with their digital devices and online sources to research the new Grade 6 NST topics and concepts and to consolidate prior Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing of an integrated NST curriculum. In addition, an important finding revealed that the Grade 6 NST PSTs also commented that they could not: recall being taught TECH topics and concepts relating to Processing; that the design process steps (IDMEC) seemed vague and confusing, and that they did not fully understand the application of the topics and concepts of Matter and Materials and Processing in an integrated NST curriculum to problematisation and contextualisation with regards to the problem of water and sanitation in rural communities in South Africa.

The findings aligned to research question one suggests that more research is needed in the future training of NST PSTs in the following areas: the development of an integrated TSPCK in abstract Grade 6 Term 2 NST topics and concepts pertaining to Matter and Materials in NS and Processing in TECH; and the application of the design process (IDMEC) to problematisation and contextualisation in South Africa. If we compare the topics covered in Grades 4 to 5 and what the Grade 6 NST PSTs foregrounded, it is encouraging to see that the findings suggest that the Grade 6 NST PSTs could recall all the concepts in Grade 5 NST topics and concepts relating to Matter and Materials and Processing. However, they had difficulties in recalling Grade 4 NST topics and concepts relating to Matter and Materials and Structures. Another finding from the elicitation of Grade 4 to 6 prior knowledge highlights that the Grade 6 NST PSTs linked the recall of Grade 5 NST topics and concepts to the excursion to the Sugar Mill which suggests that the excursion provided a realistic and relevant experience in their lives. With regards to Grade 6 NST concepts pertaining to Matter and Materials and Processing, the findings point to three topics, namely, solutions, dissolving, and processes to purify water that must be explored further to promote the development of TSPCK in future NST PSTs in South Africa.

The objective set out in Chapter 1: *The engagement of NST pre-service teachers in a concept mapping activity to elicit their understanding of an integrated NST curriculum,* was thus achieved.

8.2 Summary and Discussion of the Results from Research Question 2

This section presents a summary and discussion of the results from the second research question, namely: *How do NST pre-service teachers represent their understanding of an integrated Natural Science and Technology curriculum?*

The research question was explored by looking at the following questions:

(i) What was foregrounded in terms of what is being integrated?
(ii) Which NST topics and concepts are foregrounded i.t.o. CAPS and "OTHER"?
(iii) How is the knowledge of the two strands being integrated – what link is used to integrate the two strands?

Two understandings of integration were elicited which were spread through the eight categories.

- Understanding 1: Integration of two processes: the scientific and design processes
- Understanding 2: Integration of NST – there is a variation in the way the groupings of PSTs described the topics and concepts on their CMs.

Understanding 1 was held by nine (22,5%) PSTs, whilst Understanding 2 was held by 31 (77,5%) PSTs. The first understanding was derived from one category where an integrated NST was perceived as an: Integration of two processes: Scientific and Design processes. The second understanding was derived from 7 categories, where an integrated NST was perceived as the integration of Grade 4 to 6 NST topics and concepts as illustrated below:

8.2.1 Understanding 1: Integration of two processes: the scientific and design processes

Category 1: Matter and Materials (NS) and Processing (TECH)

22.5% of the Grade 6 NST PSTs' understanding of integration was derived from the two processes: scientific and design processes. The Grade 6 Term 2 NS topics and concepts mentioned from CAPS ranged from completed CMs (95% to 65%) to incomplete CMs (20% to 15%). In comparison, the TECH topics in CAPS ranged from Grade 4 to 6 completed CMs (56%–44%) to incomplete CMs (11%). The Grade 6 NST PSTs in Category 1 were the only ones to use problem identification and/or contextualisation and link the problem of water pollution to mixtures and arrangement of particles under the topic of Matter and Materials to different ways of separating clean water from contaminated water under the topic of Processing in TECH, using filtration and evaporation as methods to purify water.

8.2.2 Understanding 2 – A variety of conceptions within the various categories

Category 2: Matter and Materials (NS) and Processing (TECH)

The percentage of 7.5% indicated that the Grade 6 NST PSTs' understanding of integration was derived from the integration of Grade 6 Term 2 NS topics of Dissolving, Mixtures and Water Resources and the TECH topic of Processes to Purify Water and the concept of "clean water" as contained in CAPS. The NS Grade 6 topics and concepts were only mentioned from CAPS and ranged from completed CMs (70% to 75%) to incomplete CMs (40%). In comparison, the Grade 6 TECH topics and concepts ranged from completed CMs (67%–33%) to incomplete CMs (33%).

Category 3: Matter and Materials (NS) and Processing (TECH)

In Category 3, 10% of the Grade 6 NST PSTs' understanding of integration was derived from the integration of the Grade 6 NS topics of Solids, Liquids and Gases; Mixtures and Water Resources; and concepts of the "arrangement of particles"; and TECH topic of Processes to Purify Water; and concept of "clean water supply". The Grade 6 Term 2 NS topics and concepts ranged from completed concept maps (60%–50%) as opposed to Grade 6 TECH topics and concepts mentioned from CAPS in the range of incomplete CMs (50%). Grade 4 to 6 "OTHER" NST topics and concepts were mentioned but were a low percentage of completed concept maps. Categories 2 and 3 did not show a link between NST knowledge strands as well as displayed no problematisation and contextualisation of water and sanitation in rural communities in South Africa.

Category 4: Matter and Materials (NS) and Water Pollution (TECH)

Category 4 (10%) was the only category that identified Matter and Materials under NS and Water Pollution under TECH. The Grade 6 NST PSTs' understanding of integration was derived from the integration of the Grade 6 NS topic of Mixtures and Solutions as special mixtures, and concepts of "soluble substances" and "saturated solutions", and "water pollution" with a particular focus on the topic of Separation. Included is the integration of the Grade 6 TECH topic of Processes to Purify Water. It was interesting to note that the Grade 6 Term 2 NST topics and concepts from CAPS ranged from 55%–25% and 50%, respectively, and were incompletely filled CMs. “OTHER” NST Grade 4 to 6 topics and concepts were mentioned in the range of 80%–20% and 50%. A link was used that entailed the use of the rates of dissolving as a Grade 6 topic as a link to the topics, content, and concepts relating to Matter and Materials and Processing.

Category 5: Arrangement of Particles (NS) and Processing (TECH)

In Category 5, 10% of the Grade 6 NST PSTs' mentioned arrangement of particles under NS and Processing under TECH. It must be highlighted that this category was unique in their understanding of integration. Their understanding of integration was derived from an integration of the NS concepts of “arrangement of particles”, “mixtures of materials”, and “solutions”, and the TECH topic of Processing with a particular focus on the concept of “crystallisation”. The NST topics and concepts mentioned from CAPS were in the range of completed CMs of 45%–40% and 30%–0%, with the focus on Grade 6 Term 2. The “OTHER” NS topics and concepts from Grade 4 to 6 outweighed the TECH “OTHER” Grade 4 to 6 topics and concepts. The link was used by connecting the terms “integration” and “crystallisation” to the topics and concepts under Matter and Materials in NS to topics and concepts of Processing Separation of Mixtures in TECH.

Categories 6 & 7: Raw Materials (NS) and Man-made or Manufactured Materials (TECH)

In Categories 6 (17.5%) and 7 (12.5%), the Grade 6 NST PSTs mentioned raw materials under NS and man-made or manufactured materials under TECH. In both categories, the Grade 6 NST PSTs' understanding of integration was derived from an integration of NST Grade 5 topics and concepts. In both categories, there was a 0% range of Grade 6 Term 2 NS topics and concepts from CAPS. However, there was a higher range in the Grade 5 Term 2 topics and concepts from CAPS with completed CMs (83%) in Category 6 and incomplete CMs (83%–33%) in Category 7. There was also higher recall and percentage ranges in Grade 5 Term 2 “OTHER” NST topics and concepts that were mentioned in both categories. There was no evidence of topics and concepts that were linked to the problem identification of water and sanitation in rural communities in South Africa.

Category 8: Various Topics (NS) and Various Topics (TECH)

In Category 8, 10% of the Grade 6 NST PSTs mentioned various topics under NS and various topics under TECH. Their understanding of integration in this category was derived from an integration of different NST topics and concepts from Grades 4 to 6. Surprisingly, some Grade 6 NST PSTs in Category 8 mentioned Grade 6 Term 2 NST topics and concepts in the range of completed CMs: 25%–0% and 42%–26%, respectively. The "OTHER" NS topics and concepts were from Grades 4 to 6 in the range of completed CMs (57%–17%) which was higher than the "OTHER" TECH topics and concepts in the range of 42%–26%. There was no link to problematisation and contextualisation in this category. It appeared that the Grade 6 NST PSTs in Category 8 could not recall prior knowledge of Grade 6 topics and concepts in Matter and Materials and Processing and could not indicate the link between Grade 4 to 6 NST topics and concepts.

The data analysis of the eight categories in Chapter 6 revealed that majority of the Grade 6 NST PSTs could easily recall Grade 4 and 5 prior knowledge of topics and concepts pertaining to Matter and Materials and Processing, as stipulated in CAPS (DoBE, 2011). There was a greater recall and understanding of Matter and Materials concepts, such as the Grade 4 states and phases of matter with regards to solids, liquids, and gases. Grade 6 NST PSTs also indicated on their CMs that understanding how particles were arranged was used to explain the process of dissolving salt crystals in water through a process of crystallisation. However, it was evident form the data analysis that not many Grade 6 PSTs had engaged in practical work or investigations to further explore Grade 6 Term 2 topics and concepts relating to NS solutions, mixtures, dissolving, and crystallisation, as well as TECH processes to purify water and separation methods to purify polluted water, such as filtration, evaporation, distillation, and chromatography. The Grade 6 NST PSTs could not provide links to show their understanding of integration between topics and concepts in NST and could not explain the use of the scientific and design processes in making a simple water filter system to address the water and sanitation problem in rural communities in South Africa. When compared to the TECH aspect of Processing, the Grade 6 NST PSTs could not recall Grade 6 Term 2 content related to TECH education in primary school. This may be the result of being taught NS and TECH as separate subjects, and only in HE, may not have gained CK and pedagogy to be able to see how NST topics and concepts in Matter and Materials and Processing link up in an integrated way.

The data analysis and graphical representations in Chapter 6 of the Grade 4 to 6 NST topics and concepts mentioned in the 40 individual CMs by the Grade 6 NST PSTs suggested that the findings in this study achieved the second objective: *NST pre-service teachers' representation of their understanding of an integrated NST curriculum using concept mapping,* which was also outlined in Chapter 6.

The important finding from Understanding 1 suggests that Grade 6 NST PSTs experienced challenges with the understanding and application of the design process in TECH in category one was highlighted. In my study, the findings from research question two, revealed that most of the Grade 6 NST PSTs could not differentiate between the scientific and technological processes. Interestingly, the Grade 6 NST PSTs CMs revealed that they preferred engaging in the practical scientific investigation and appeared to lack confidence in application of the design steps (IDMEC) in the construction of a water filter system. The findings also revealed that the Grade 6 NST PSTs did not appear to have background knowledge in CAPS and many did not state or explain the three specific aims in the CMs as contained in CAPS. Hence, the findings aligned to research question 2 suggest that the Grade 6 NST PSTs academic performance could be compromised due to the lack of prior knowledge, the inability to transfer concepts from NS to TECH, and the lack of application of the integration of the scientific and technology processes during lesson planning. The findings from category one suggested that since most B.Ed. PSTs show a disinterest in NST, this course should be made compulsory as it is important to develop specialised forms of knowledge in both subject disciplines, especially the scientific and design process to better understand an integrated NST curriculum in the future.

Another significant finding from Understanding 2 revealed that the Grade 6 NST PSTs lack of prior knowledge in Grade 6 NST topics and concepts may be due to being taught by non-specialist NS or TECH in-service teachers. Given the fact that all the in-service teachers started teaching between 1993 and 1996, the finding also suggests that in-service teachers may not have gained specialist training in the understanding of an integrated NST curriculum and in the teaching of Grade 4 to 6 NST topics and concepts. It is concerning to note that some of the Grade 6 NST PSTs CMS indicated that they were unfamiliar with the NS strand Earth and Beyond and the TECH strands of Systems and Control and Structures. This finding also highlights that some of the Grade 6 NST PSTs had difficulties with the recall of Grade 4 to 6 NST topics and concepts of other knowledge strands in NS and TECH as these appeared as vague statements in their CMs. The finding raises some concern in the development of TSPCK in NST topics in an integrated curriculum in NST PSTs who have not received proper training in this area. It could impact negatively on the way intermediate phase learners in Grades 4 to 6 are taught in the future, as the educator is supposed to be an expert in all the knowledge strands of an integrated NST curriculum for Grades 4 to 6 as stated in the CAPS document (DoBE, 2011). In this regard, future NST PSTs need to be trained in the interpretation of the CAPS, other education policy documents and be able to use a variety of sources to gain a deeper integrated understanding of the Grade 4 to 6 NST topics and concepts contained in the NS knowledge strands of Life and Living, Matter and Materials, Energy and Change, Earth and Beyond and in TECH knowledge strands of Structures, Processing and Systems and Control. The findings of Understanding 2 revealed that an understanding of an integrated curriculum was reached through a varied description of the NST topics and concepts by the groupings of the Grade 6 NST PSTs on their CMs.

8.3 Implications of the Study

This section presents the implications of the research and provides recommendations for future policymakers and curriculum designers (sub-section 8.3.1.), future classroom practice in HE (sub-section 8.3.2.), and improved teaching of NST theory (sub-section 8.3.3).

8.3.1 Future policymakers and curriculum designers

Based on the findings in Phase one which focussed on answering research question 1: *How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?* the Grade 4 to 6 NST curriculum needs to be redesigned to focus on the inclusion of contemporary rather than traditional teaching strategies with interactive activities such as active learning techniques, small group discussions, whole class discussions, and co-operative learning. These pedagogies can be included in the suggested activity section in the CAPS, combined with appendices of detailed explanations of abstract chemistry and engineering concepts that are taught in the Senior and Further Education and Training Phases as a supplemental guide on lesson planning and delivery to primary school teachers. Based on the findings of Understanding 2 which focussed on how the Grade 6 NST PSTs represented their understanding of an integrated NST curriculum, curriculum designers need to include simplified graphical representations of abstract chemistry topics and concepts, especially the atom and atomic theory and indigenous knowledge contexts, so as to make the learning of difficult NST topics and concepts more relevant to the learners' lives and hence, reduce the prevalence of misconceptions in learners during the primary school years. The findings from Research Question 2: *How do NST pre-service teachers represent their understanding of an integrated Natural Science and Technology curriculum?* suggest that the Grade 6 NST PSTs understandings of an integrated NST curriculum from the CAPS document should be revised and redesigned by curriculum designers with the following in mind: more visual representations of abstract Grade 4 to 6 NST topics and concepts in Matter and Materials and Processing should be included; examples of cultural and historical contexts in rural communities must be included in the form of case studies and narratives, so that Grade 4 to 6 NST PSTs could also teach primary school learners the importance of an integrated NST curriculum in the understanding of Indigenous knowledge systems in various South African contexts.

The findings from the two understandings of integration which were elicited and spread through the eight categories highlight the importance of the role of specialist NST teacher trainers in HE. Specialist NST teacher trainers in HE is vital, especially in future teacher training programmes in South Africa, as we currently do not have experts who were trained to teach NST in an integrated way. Policy on entry level requirements for the employment of NST experts must be revised. Preferably, future NST in-service teachers must have integrated science and engineering qualifications as the base for an integrated TSPCK, and to be able to teach various levels of complex topics and concepts within natural science, technology and engineering, physical science, chemistry, and life science to primary school learners. Expert NST specialists with a sound integrated TSPCK could guide and develop future NST PSTs' TSPCK in the teaching of more challenging and complex concepts at higher cognitive levels. This could be effectively done by a specialist NST expert who has also implemented sound lesson planning and worksheet activities that cater for all learning styles and cognitive levels. They would also use CMs before and after instruction, as well as design a rubric to assess CMs to see whether conceptual understanding of NST topics and concepts within an integrated NST curriculum as per CAPS for Grades 4 to 6 in the Intermediate phase (DoBE, 2011), has taken place successfully.

It will also give expert NST specialists an opportunity to share their best practice with other NST teachers and trainers on how to improve their TSPCK in the teaching of various topics and concepts, but more especially, in Matter and Materials and Processing in an integrated way. Feedback to policymakers and other stakeholders is also critical, especially on how to improve textbooks so that they are CAPS-aligned; on what type of resources are required for practical activities; and to aid the effective teaching and learning of specific topics, such as Matter and Materials and Processing in teacher training programmes in South Africa. It is hoped that by doing so, future NST PSTs will have a developed TSPCK and understanding of an integrated NST curriculum, which would equip them with a high level of CK and pedagogical skills in the teaching and learning of abstract topics and concepts pertaining to Matter and Materials and Processing in the Intermediate Phase. In this way, future NST PSTs could meet the challenges of the future South African classrooms in a global economy.

8.3.2 Future classroom practice in HE

NST specialists in HEI's must develop interactive and engaging concept mapping activities to improve Grades 4 to 6 NST pre-service teachers' TSPCK in the teaching and learning of abstract topics and concepts pertaining to Matter and Materials and Processing of an integrated NST curriculum. More support and guidance in these concept mapping activities needs to be given to Grade 4 to 6 NST PSTs who are non-English speaking and do not have science backgrounds, so that their CK development may not be hindered due to language barriers. The data analysis of the Grade 6 NST PSTs concept maps revealed that even though concept mapping is a student-centred approach and aims to allow for interaction among peers through co-operative learning and constructivism, some of the Grade 6 NST PSTs still resisted to engage in this type of activity. Hence, more research is needed to explore why some of the grade 6 NST PSTs did not engage in the whole class and small group discussions and co-operative sessions and chose to remain passive during the CM activity. These passive Grade 6 NST PSTs appeared to have incomplete CMs and did not feel confident to submit the CMs at the end of the CM activity. This finding also indicates that the passive NST PSTs might still need a tutor approach with regards to revision, clarification, and explanation of basic and complex concepts from the guidance and coaching from a specialist NST teacher trainer. A specialist NST teacher trainer with a well-developed integrated CK and TSPCK trained in the teaching of a variety of Grade 4 to 6 NST topics and concepts as well as a developed PCK in the implementation of CM activities that promote the engagement of NST PSTs, could prove to be valuable in the training of future NST PSTs in HEIs. In this way, future NST PSTs may possibly be better equipped with CK and gain confidence in the generation of their own NST CMs. It is also hoped that the passive NST PSTs would develop a deeper integrated understanding of NST topics and concepts pertaining to Matter and Materials and Processing as they would feel more confident in teaching abstract NST topics and concepts form various knowledge strands in an integrated NST curriculum to Grade 4 to 6 in primary school learners in the future.

8.3.3 Improved teaching of NST theory

Chemistry is often perceived negatively by first-year college students who may have developed prior misconceptions from primary and high school. Zoller (1990) reckons that prior misconceptions range from the learning of the structure and properties of the atom from the Bohr Atomic Model to the chemical reactivity of single and double bonds within molecules formed earlier in their primary school years. Akgün (2009) also suggests that science PSTs may experience challenges in this area due to the foundation of conceptual understanding not being properly laid down in primary school science, which may have led to misconceptions about the conservation of mass, density, and volume of particles making up substances, and their ability to dissolve to form solutions. To overcome the chemistry misconceptions, I used a brainstorming session with questioning prompts to ascertain the prior NS knowledge of Matter and Materials in the Grade 6 NST PSTs. A few Grade 6 NST PSTs responded to the questions which indicated to me that they may have had good prior NS knowledge either form primary or high school experiences. Since most of the Grade 6 NST PSTs remained passive during the whole class discussion, I began explaining the subatomic particles of an atom and how a chemical reaction could occur using the example of salt (sodium chloride). I also differentiated between atoms, molecules, elements, and compounds, and revised aspects of the periodic table using simple terms and definitions in an attempt for the Grade 6 NST PSTs to familiarise themselves with Grade 4 to 6 NS prior knowledge. I used the whiteboard to write down key topics and used simple diagrams to highlight some topics and concepts in Matter and Materials to assist them in visualisation of the abstract topics and concepts in Matter and Materials since these are not visible to the human eye. Images in a PowerPoint presentation were also used to indicate the type of bonds in different molecules and compounds, for example, water and salt. I also explained the process of dissolving at a microscopic level and how salt particles would dissolve in water, that salt is the solute and water the solvent, and together, these two substances form a solution. Thereafter, I used a videoclip and worksheet activity on dissolving to reinforce and consolidate conceptual understanding. By doing the above, it allowed for conceptual change to occur where the Grade 6 NST PSTs would have understood that dissolving was not melting and that no particles can be lost. I also used practical activities to change the misconception that all particles dissolve at the same rate. I gave PSTs different solids of varying grain size and asked them to measure the time at which these solids dissolved in water. After conducting the experiments, they realised that the rate at which particles dissolve in water is dependent not only on the size of the grains but also on the temperature of the water and how fast it is stirred or shaken. Also, the Grade 6 NST PSTs thought that energy meant temperature. I had to explain to them that temperature was the measure of the average kinetic energy of particles and used the boiling of water in a kettle to describe and explain this concept (Chang, 1994).

The study dealt with the development of TSPCK in Grade 6 NST PSTs regarding the topic of Matter and Materials and Processing. Based on the findings from Research Question 1 and understanding 2, more research is needed on the development of TSPCK in Grade 4 to 6 NST PSTs regarding topics such as the Particle Nature of Matter and Structures. Interestingly, most of the PSTs gained new knowledge on the chemistry of the water molecule and some of the Grade 6 NST PSTs represented their understanding on the CMs; that there are "polar bonds and attractive forces", while others explained that "it allows for dissolving other substances". There were still some challenges in the technology aspect of the water purification process and providing possible solutions of designing a simple water filter system to address the problem of water and sanitation in rural communities in South Africa. The Grade 6 NST PSTs also mentioned "salinity" but did not explore how this concept could be used in the future to obtain clean water from the desalination of saltwater from the ocean, which could possibly address the water and sanitation problem in rural communities in South Africa.

8.4 Contributions of the Study

The contributions of the study are noted in this section. In terms of addressing Research Question 1: *How do we engage NST pre-service teachers to elicit their understanding of an integrated NST curriculum?* this study determined that CMs can be useful for revising Grade 4 to 6 NST prior knowledge of topics and concepts in Matter and Materials and Processing. CMs provided a graphical view of how Grade 6 NST PSTs organised, connected, and synthesised their integrated knowledge of the topics and concepts within Matter and Materials and Processing as contained in the CAPS document. The data analysis and findings of the Grade 6 NST PSTs representation of an integrated curriculum based on the findings of Research Question 2: *How do NST pre-service teachers represent their understanding of an integrated Natural Science and Technology curriculum?* as well as Understandings 1 and 2, highlighted that most of the Grade 6 NST PSTs found CMs to be beneficial to them and assisted them in improving their CK in the NS aspect of Matter and Materials, and TECH aspect of

Processing. By allowing the Grade 6 NST PSTs to work on their CMs in small heterogenous groups, many of the Grade 6 NST PSTs' feedback suggested that their peers assisted them in understanding some difficult Grade 4 to 6 NST topics and concepts and that they enjoyed engaging in co-operative learning.

As a teacher-trainer, concept mapping was used as an instructional tool and assisted me in assessing the Grade 6 NST PSTs' gaps in prior knowledge, misconceptions, and their conceptual understanding of topics and concepts pertaining to Matter and Materials and Processing. The Grade 6 NST PSTs also reflected on their understanding of an integrated Grade 6 NST curriculum and used CMs to represent this understanding. It also assisted me as a NS specialist and teacher trainer to change my understanding and teaching practice of an integrated NST curriculum. As a teacher trainer I focused on the promotion of a more student-centred, interactive, and integrative approach of teaching NST topics and concepts pertaining to Matter and Materials and Processing with the use of small group and whole class discussions, as well as peer interaction with co-operative learning. I found concept mapping to be useful in addressing and changing past primary school perceptions about Grade 6 NST topics and concepts, as well as improving their overall understanding of an integrated NST curriculum. Concept mapping was useful in this study as it also integrated literacy and the communication of complex NST topics and concepts. It provided a starting point for writing about these two subject disciplines as an integrated NST discipline. Thus, it was useful for non-proficient English-speaking PSTs who developed confidence in communicating their conceptual understanding of an integrated NST curriculum through peer interaction using co-operative learning (Malatji, 2016).

8.5 Limitations of the Study

Like all research, this study also encountered some limitations. These are acknowledged in this section. First, the study was limited and applicable to Grade 6 NST PSTs at a private HEI in KwaZulu-Natal and therefore cannot necessarily be generalised to all Grade 6 NST PSTs. In an attempt to gain an insight into the development of TSPCK in Matter and Materials and Processing using a CM activity, I would have liked to explore the topic further with other groups of Grade 6 NST PSTs from other HEIs. The findings from such a study could provide more data on the challenges that other groupings of Grade 6 NST PSTs experience in the learning of NST topics of Matter and Materials and Processing and could also provide evidence as to whether student engagement using a CM activity could promote the development of an integrated TSPCK in Matter and Materials and Processing in Grades 4 to 6. Second, time constraints did not permit me to analyse the suggested activities after the concept mapping and for Grade 6 NST PSTs to complete CMs of their own. Third, I also did not complete the focus group and semi-structured interviews as many of the Grade 6 NST PSTs were unavailable towards the end of the second semester as they were preparing to submit formative assessments.

8.6 Recommendations for Future Research

In light of the above research results and findings, the following recommendations are made for future research. Further research in the application of concept mapping activities to promote the understanding of an integrated Grade 4 to 6 NST curriculum must be conducted in teacher training programmes in other HEI's in South Africa. A pilot study may provide a comparative analysis of Grade 6 NST PSTs in B.Ed. programmes in other HEI's and their engagement in concept mapping activities. The pilot study could also provide valuable information on the progression of Grade 4 to 6 development of an integrated TSPCK in topics and concepts in other knowledge strands such as Life and Living, Systems and Control, and Earth and Beyond. In this way, the effectiveness of how concept mapping could be used in promoting the development of an understanding of an integrated TSPCK in various topics and concepts within the four knowledge strands as contained in the CAPS for the Intermediate Phase. The findings of the pilot study could signal a rapid change in the training of Grade 4 to 6 NST PSTs in the teaching and learning of an integrated NST curriculum for the Intermediate Phase in South Africa. Thematic integrated teaching of NST in primary school could also encourage the development of critical thinking skills in the future (Pursitasari, 2015). Also, how future NST PSTs could use concept mapping to develop higher order thinking abilities so that they can construct their CMs to reflect their thought processes in understanding complex integrated NST concepts within difficult topics in higher grades. The development of higher order thinking by using concept mapping in the teaching of an integrated NST curriculum could also assist in-service teachers to develop an integrated TSPCK in Intermediate Phase primary school learners. The future primary school Intermediate Phase learners would be motivated to study science and technology further in high school and HE in the future as NST topics and concepts would be relevant in their everyday lives. A few concluding remarks follow next.

8.7 Final Conclusion

I would like to close with the following words:

"In the end,

We will conserve only what we love,

We will love only what we understand,

We will understand only what we are taught".

-- Baba Dioum (n.d.)

The quotation summarises my sentiments of my vision for a future integrated NST curriculum in future teacher training programmes and primary schools in South Africa. If teacher trainers enjoy teaching and learning topics and concepts of NS and TECH education, they are most likely to understand the theoretical aspects of CK, PCK and TSPCK and what it means to teach NST topics and concepts in an integrated way. These types of teacher trainers are specialists and most definitely influence and change the negative perceptions held by many NST PSTs in the Intermediate Phase. If the NST PSTs cultivate a love for teaching and learning NST topics and concepts and apply their TSPCK in relevant contexts, they will be prepared to implement learner-centred active learning strategies in primary schools and could possibly enhance their TSPCK by exploring and teaching difficult NST topics and concepts to Intermediate Phase learners. The Grade 6 NST PSTs could have a profound impact on the Grade 4 to 6 learners who would also be motivated to study science and technology in high school and later in science and engineering fields in HE. In this way, the NST specialist both in HE and primary schools will be retained in HE and primary schools producing primary school learners who will contribute to science and technology as well as promote economic growth in the future in South Africa.

Undertaking this study was motivated by my observations of the following problems during my teaching practice as a NST teacher in primary and high schools, and now as a teacher trainer of the B.Ed. Intermediate Phase programme in HE. Firstly, NST PSTs appear to have gaps in prior knowledge of CK, PCK, and TSPCK in topics and concepts of an integrated NST curriculum. Secondly, due to having gaps in their CK of topics and concepts in Matter and Materials and Processing, NST PSTs have carried primary school misconceptions into HE. Thirdly, due to these misconceptions not being corrected, NST PSTs lack understanding of the CAPS document guidelines and activities on how NST topics and concepts could be taught and learned in an integrated manner in the Intermediate Phase. It is important to highlight that some of the Grade 6 NST PSTs in Category 1 could apply their understanding of an integrated NST curriculum to the context of problematisation and contextualisation. In this case, the water and sanitation problem in the uGu district in the KZN region. The area that the Grade 6 NST PSTs found challenging was designing a water filtration system and the steps related to the design process (IDMEC). This resulted in only 14 Grade 6 NST PSTs out of 48 (29%) who attempted the water filtration project as part of the NST formative assessment at the end of the module. More research is needed in teaching the steps related to the design process steps (IDMEC) and how IDMEC could be used to construct a cost-effective water filtration system for use in rural communities that experience water and sanitation problems in South Africa.

The consequences of HE is producing unskilled PSTs who lack TSPCK in primary schools could result in the development of primary school learners who are demotivated about science and technology and might not link and apply their TSPCK to the conceptual learning of NST in an integrated way. When PSTs acquire a deep conceptual understanding of these two subject disciplines, they could, however, make good decisions on designing effective activities related to evolving CK to teach the integration of NST. In teaching practice, PSTs who have developed a strong PCK of integrated NST will begin to motivate Intermediate Phase learners so that these learners will see the relevance and importance of studying science and technology in high school and HE. Consequently, these learners will follow science and technology career paths and may possibly become prolific citizens who could contribute to our country's economic growth in the future.

BIBLIOGRAPHY

Adom, D., Yeboah, A., & Ankrah, A. K. (2016). Constructivism philosophical paradigm: Implication for research, teaching and learning. *Global Journal of Arts Humanities and Social Sciences, 4*, 1-9.

Akgün, A. (2009). The relation between science student teachers' misconceptions about solution, dissolution, diffusion, and their attitudes toward science with their achievement. *Education and Science, 34*(154).

Altrichter, H., Kemmis, S., McTaggart, R., & Zuber-Skeritt, O. (2002). The concept of action research. *The Learning Organisation, 3*, 125-131.

Ankiewicz, P. (1995). The planning of technology education for South African schools. *International Journal of Technology and Design Education, 5*, 245-254. https://doi.org/10.1007/BF00769906

Arthurs, L. A., & Kreager, B. Z. (2017). An integrative review of in-class activities that enable active learning in college science classroom settings. *International Journal of Science Education, 39*(15), 2073-2091. https://doi.org/10.1080/09500693.2017.1363925

Apple, M. W. (2000). Between neoliberalism and neoconservatism: education and conservatism in a global context. In N. C. Burbules & C. A. Torres (Eds.), *Globalization and education: critical perspectives* (pp. 57-77). Routledge.

Apple, M. W., & Bean, J. P. (1995). Lessons from democratic schools. In M. W. A. J. A. Beane (Ed.), *Democratic schools: Lessons from the chalk face* (pp. 118-123). Open University Press.

Arthurs, L. A., & Kreager, B. Z. (2017). An integrative review of in-class activities that enable active learning in college science classroom settings. *International Journal of Science Education, 39*(15), 2073-2091. https://doi.org/10.1080/09500693.2017.1363925

Asunda, A. A., & Mativo, J. (2016). Integrated STEM: A new primer for teaching technology education. *Technology and Engineering Teacher*, *75*(4), 8-13.

Ball, D. L., Thames, M. H., & Phelps, G. (2008). Content knowledge for teaching: What makes it special? *Journal of Teacher Education, 59*, 389–408.

Bantwini, B. D. (2010). How teachers perceive the new curriculum reform: Lessons from a school district in the Eastern Cape, south Africa. *International Journal of Educational Development, 8*, 83–90.

Baxter, P., & Jack, S. (2010). Qualitative case study methodology: study design and implementation for novice researchers. *Qualitative Report, 13*(4), 544-559.

Beane, J. A. (1995). Curriculum Integration and the Disciplines of Knowledge. *The Phi Delta Kappan, 76*(8), 616-622.

Beane, J. A. (1997). Curriculum integration: designing the core of democratic education. https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=4513892

Beane, J. A. (1998). Reclaiming a democratic purpose for education [Editorial]. *Educational leadership,56*(2),8-11. https://ukzn.idm.oclc.org/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=a9h&AN=1228513&site=ehost-live&scope=site

Beane, J. A. (2002). Beyond self-interest: A democratic core curriculum. *Educational leadership, 59*(7), 25-28.

Beane, J. A. (2013). A common core of a different sort: Putting democracy at the center of the curriculum. *Middle School Journal, 44*(3), 6-14. https://doi.org/10.1080/00940771.2013.11461850

Bean, J. P., & Metzner, B. S. (1985). A conceptual model of nontraditional undergraduate student attrition. *Review of Educational Research, 55*(4), 485-540. https://doi.org/10.2307/1170245

Bezuidenhout, W., Bosch, D., Engelbrecht, R., Marchant, J., Scott, A., & Volker, A. (2013). *Solutions for all natural sciences and technology grade 6 learner's book*. Macmillan.

Bibi, T., & Watters, J. J. (2015). Perspectives on Australian, Indian and Malaysian approaches to STEM education. *International Journal of Educational Development, 45*, 42-53.

Blyth, R. (2016). A look at the future of engineering in South Africa : Part 1: engineering in South Africa. *Civil Engineering = Siviele Ingenieurswese, 2016*(1), 37-41.

Booi, K., & Khuzwayo, M. E. (2018). Sciences Teacher education curriculum re-alignment: science education lecturers' perspectives of knowledge integration at South African universities. *Journal of Curriculum and Teaching, 7*(1), 52-63. https://doi.org/10.5430/jct.v7n1p52

Boz, N. B., Y. (2011). Prospective chemistry teachers' awareness of students' alternative conceptions. *Journal of Turkish Science Education, 8*(4), 29-42.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77-101. doi:10.1191/1478088706qp063oa

Brough, C. (2012). Implementing the democratic principles and practices of student-centred curriculum integration in primary schools [Article]. *Curriculum Journal, 23*(3), 345-369. https://doi.org/10.1080/09585176.2012.703498

Buchs, C., Filippou, D., Pulfrey, C., & Volpé, Y. (2017). Challenges for cooperative learning implementation: reports from elementary school teachers. *Journal of Education for Teaching, 43*(3), 296-306. https://doi.org/10.1080/02607476.2017.1321673

Buckley, J., Seery, N., Power, J., & Phelan, J. (2019). The importance of supporting technological knowledge in post-primary education: a cohort study. *Research in Science & Technological Education, 37*(1), 36-53. https://doi.org/10.1080/02635143.2018.1463981

Cañas, J. A., & Novak, J. D. (2008). Facilitating the adoption of concept mapping using cmap tools to enhance meaningful learning. In *Knowledge Cartography, Software Tools and Mapping Techniques* (pp. 1-26). Springer.

Chang, R. (1994). *Chemistry* (5th ed.). McGraw-Hill.

Chisholm, L. (2005). The making of South Africa's National Curriculum Statement. *Journal of Curriculum Studies, 37*, 193-208. https://doi.org/10.1080/0022027042000236163

Chisman, D. G., ICSU, & Education, C. o. S. (1990). *New trends in integrated science teaching* (Vol. 6). https://unesdoc.unesco.org/ark:/48223/pf0000136673

Clements, M., & Harrhoff, J. (2004). Practical experiences with granular activated carbon (GAC) at the Rietvlei Water Treatment Plant. *Water SA, 30*(1), 89-96.

Cohen, L., Manion, L., & Morrison, K. (2011). *Research methods in education*. Routledge.

Committee, S. D. W. (1980). *Drinking Water and Health*. National Academies Press. https://public.ebookcentral.proquest.com/choice/publicfullrecord.aspx?p=3376887

Cresswell, J. W. (2014). *Research Design* (4th ed.). Sage.

Dagar, V., & Yadav, A. (2016). Constructivism: A paradigm for teaching and learning. *Arts and Social Sciences Journal, 7*. https://doi.org/10.4172/2151-6200.1000200

Department of Basic Education. (2011). *Curriculum and Assessment Policy Statement Intermediate Phase Grades 4 to 6*. Pretoria: Department of Basic Education.

Department of Basic Education. (2012). *Curriculum and Assessment Policy Statement : Senior Phase Technology Grades 7-9*. Pretoria: Department of Basic Education.

Dejene, W. (2020). Conceptions of teaching & learning and teaching approach preference: Their change through preservice teacher education program. *Cogent Education, 7*(1), 1-18. https://doi.org/10.1080/2331186X.2020.1833812

Dilke, O. A. W. (1987). Cartography in the Ancient World: An Introduction. In J. B. Harley & D. Woodward (Eds.), *Volume One Cartography in prehistoric, ancient, and medieval europe and the mediterranean*. The University of Chicago Press,.

Dioum.B. (n.d.). *Goodreads*. https://www.goodreads.com/quotes/6430296-in-the-end-we-will-conserve-only-what-we-love

Dole, S., Bloom, L. , & Kowalske, K. (2016). Transforming pedagogy: changing perspectives from teacher-centered to learnercentered. *Interdisciplinary Journal of Problem-Based Learning, 10*(1). https://doi.org/https://doi.org/10.7771/1541-5015.1538

Du Plooy-Cilliers, F., Davis, C., & Bezuidenhout, R.-M. (2014). *Research matters*. Juta.

Dowden, T. (2007). Relevant, challenging, integrative and exploratory curriculum design: perspectives from theory and practice for middle level schooling in Australia. *The Australian Educational Researcher, 34*(2) 51-71.

Dowden, T. (2011). Locating curriculum integration within the historical context: Innovations in Aotearoa New Zealand state schools, 1920s-1940s. *History of Education Review, 40*. https://doi.org/10.1108/08198691111140802

Drake, S., Savage, M. J., & Reid, J. (2015). *Exploring the landscape of integrated curriculum circa 2015*. International Baccalaureate Organization.

Edwards, N. (2015). Multimodality in science education as productive pedagogy in a PGCE programme. *Perspectives in Education, 33*(3), 159-175.

English, L. D. (2017). Advancing Elementary and Middle School STEM Education. *International Journal of Science and Mathematics Education, 15*(1), 5-24.

Eppler, M. (2006). A comparison between concept maps, mind maps, conceptual diagrams, and visual metaphors as complementary tools for knowledge construction and sharing. *Information Visualization, 5,* 202-210. https://doi.org/10.1057/palgrave.ivs.9500131

Essien, E.-S., & Okon, J. A. (2016). Basic concepts in history & philosophy of science. In History and Philosophy of Science (pp. 1-28). Akwa Ibom State University Press.

Fantz, T. D., De Miranda, M. A., & Siller, T. J. (2011). Knowing what engineering and technology teachers need to know: an analysis of pre-service teachers engineering design problems. *International Journal of Technology and Design Education, 21*(3), 307-320.

Fitzgerald, A., Pressick-Kilborn, K., & Mills, R. (2020). Primary teacher educators' practices in and perspectives on inquiry-based science education: insights into the Australian landscape. *Education, 3(13)*, 1-13. https://doi.org/10.1080/03004279.2020.1854962

Fraser, D. (2000). Curriculum integration: What it is and is not. *SET: Research Information for Teachers, 3*, 34-37. https://hdl.handle.net/10289/6833

Fraser, S. P. (2015). Transformative Science Teaching in Higher Education. *Journal of Transformative Education, 13*(2). https://doi.org/10.1177/1541344615571417

Geddis, A. N., & Wood, E. (1997). Transforming subject matter and managing dilemmas: A case study in teacher education. *Teaching and Teacher Education, 13*(6), 611–626.

Goris, T., & Dyrenfurth, M. (2010). Students' misconceptions in science, technology and engineering, Researchgate, 1-16. https://www.researchgate.net/publication/228459823

Gretschel, P., Ramugondo, E., & Galvaan, R. (2015). An introduction to Cultural Historical Activity Theory as a theoretical lens for understanding how occupational therapists design interventions for persons living in low-income conditions in South Africa. *45*, 51-55. https://doi.org/10.17159/2310-3833/2015/v45no1a9

Guerriero, S. (2017). *Pedagogical Knowledge and the Changing Nature of the Teaching Profession*. OECD Publishing. https://doi.org/10.1787/20769679

Hardman, J., & Mpofu, E. (2013). Cultural-Historical Activity Theory. In C. S. Clauss-Ehlers (Ed.), *The Encyclopedia of Cross-Cultural Psychology*. John Wiley & Sons, Inc. https://doi.org/10.1002/9781118339893.wbeccp137

Hattie. J.& Timperley. H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 96-97.

Herschbach, D. R. (1995). Technology as Knowledge: Implications for Instruction. *Journal of Technology Education, 7*(1), 31-42.

Heublein, U. (2014). Student drop-out from German higher education institutions. *European Journal of Education, 49*(4), 497-513. https://doi.org/10.2307/26609238

Hinchliffe, G. (2000). Education or Pedagogy? *Journal of Philosophy of Education, 35*, 31-45. doi:10.1111/1467-9752.00208

Hijmans, E., & Wester, F. (2010). Comparing the case study with other methodologies. In A. Mills, G. Durepos, & E. Wiebe (Eds.), *Encyclopedia of Case Study research.* (Vol. 1, pp. 176-179). Sage.

Hollweck, T. (2016). A Review of Case Study Research Design and Methods *The Canadian Journal of Program Evaluation, 30*(1), 108–110. https://doi.org/10.3138/cjpe.30.1.108

Hsu, M., Purzer, S., & Cardella, M. E. (2011). Elementary teachers' views about teaching design, engineering, and technology. *Journal of Pre-College Engineering Education Research(J-PEER), 1*(2), 31-39 https://doi.org/10.5703/1288284314639

Jacobs, H. H. (1989). *Interdisciplinary Curriculum: Design and Implementation.* Alexandria, VA: Association for Supervision and Curriculum Development.

Khanyile, P. (2016). *Exploring grade six educators' understanding of the integration of the natural sciences and technology in the Mafukuzela – Ghandi circuit, Ethekwini region.* [Master's thesis]. University of KwaZulu-Natal. Durban.

Khabo-Mmekoa, C., & Momba, M. (2019, 08/02). The Impact of social disparities on microbiological quality of drinking water supply in Ugu District Municipality of Kwazulu-Natal Province, South Africa. *International Journal of Environmental Research and Public Health, 16*. https://doi.org/10.3390/ijerph16162972

Khrais, H., & Saleh, A. (2017). The outcomes of integrating concept mapping in nursing education: an integrative review. *Open Journal of Nursing, 7*, 1335-1347.

Killen, R. (2016). *Teaching Strategies for Quality Teaching and Learning.* (2nd ed.). JUTA.

King, N. (2014). Surfacing students' prior knowledge in middle school science classrooms: Exception or the Rule? *Middle Grades Research Journal, 9*, 61-72.

Kirschner, S., Taylor, J., Rollnick, M., Borowski, A., & Mavhunga, E. (2015). Gathering evidence for the validity of PCK measures: Connecting ideas to analytic approaches. In A. Berry, P. Friedrichsen & J. Loughran (Eds.), *Re-examining pedagogical content knowledge in science education* (pp. 229-241). Routledge.

Klaassen, R. G. (2018). Interdisciplinary education: a case study. *European Journal of Engineering Education, 43*(6), 842-859. https://doi.org/10.1080/03043797.2018.1442417

Knut Neumann, Kind, V., & Harms, U. (2018). Probing the amalgam: the relationship between science teachers' content, pedagogical and pedagogical content knowledge. *International Journal of Science Education*. doi:https://doi.org/10.1080/09500693.2018.1497217

Köller, H.-G., Olufsen, M., Stojanovska, M., & Petrusevski, V. (2015). Practical Work in Chemistry, its goals and effects. In I. Maciejowska & B. Byers (Eds), *A guidebook of* *good practice for the pre-service training of chemistry teachers* (pp. 87-106). Faculty of Chemistry, Jagiellonian University in Krakow.

Koller, M., & Saleh, H.M. (2018). Introducing Heavy Metals. *Heavy Metals*: IntechOpen. doi:10.5772/intechopen.74783

Kranzfelder, P., Lo, A. T., Melloy, M. P., Walker, L. E., & Warfa, A.-R. M. (2019, 2019/09/22). Instructional practices in reformed undergraduate STEM learning environments: a study of instructor and student behaviors in biology courses. *International Journal of Science Education, 41*(14), 1944-1961. https://doi.org/10.1080/09500693.2019.1649503

Krathwohl, D. R. (2002). A Revision of Bloom's Taxonomy: An Overview. *Theory into practice, 41*(4). 213-218.

Kucera, J. (2019). *Desalination: water from water* (2nd ed.). John Wiley & Sons, Inc.

Kuhn, D. (2015). Thinking Together and Alone. *Educational Researcher, 44*(1), 46-53. https://doi.org/10.3102/0013189X15569530

Lăcrămioara, O. C. (2015). New perspectives about teacher training: conceptual maps used for interactive learning,The 6th International Conference Edu World 2014 "Education Facing Contemporary World Issues", *Procedia - Social and Behavioral Sciences 180*, 899 – 906.

Lehesvuori, S., Hähkiöniemi, M., Viiri, J., Nieminen, P., Jokiranta, K., & Hiltunen, J. (2019). Teacher orchestration of classroom interaction in science: exploring dialogic and authoritative passages in whole-class discussions. *International Journal of Science Education, 41*(17), 2557-2578. https://doi.org/10.1080/09500693.2019.1689586

Liebech-Lien, B. (2020). The bumpy road to implementing cooperative learning: Towards sustained practice through collaborative action. *Cogent Education, 7*(1), 1780056. https://doi.org/10.1080/2331186X.2020.1780056

Linn, M. C., Gerard, L., Matuk, C., & McELhaney, K. W. (2016). Science education: from separation to integration. *Review of Research in Education 40*, 529 –587. https://doi.org/ 10.3102/0091732X16680788

Loepp, F. L. (1999). Models of curriculum integration. *The Journal of Technology Studies, 25*(2), 21-25. http://www.jstor.org.ukzn.idm.oclc.org/stable/43603912

Ma, Y. (2018). Techne, a virtue to be thickened: Rethinking technical concerns in teaching and teacher education. *Research in Education, 100*(1), 114-129. https://doi.org/10.1177/0034523718762178

Mahajan, A., Magare, S., Malunjkar, S., Bansode, S., Bandgar, R., Kakde, R., & Salunkhe, A. (2018). Design and analysis of efficient potable water filter, *Journal of Applied Science and Computations (JASC)JOURNAL TITLE, 5*, 1683-1685

Maharajh, L., Nkosi, T., & Mkhize, M. (2016). Teachers' experiences of the implementation of the Curriculum and Assessment Policy Statement (CAPS) in three primary schools in KwaZulu Natal. *Africa's Public Service Delivery and Performance Review, 4*, 371. https://doi.org/10.4102/apsdpr.v4i3.120

Malatji, K. S. (2016). Moving away from rote learning in the university classroom: the use of cooperative learning to maximise students' critical thinking in a rural University of South Africa. *Journal of Communication, 7*(1). 34-42.

Maodzwa–Taruvinga, M. C., M. (2017). Jonathan Jansen and the curriculum debate in South Africa: An essay review of Jansen's writings between 1999 and 2009. *Curriculum Inquiry, 42*(1). https://doi.org/10.1111/j.1467-873X.2011.00573.x

Maphosa, C., & Ndebele, C. (2014). Interrogating the skill of introducing a lecture: towards an interactive lecture method of instruction. *Anthropologist, 17*, 543-550. https://doi.org/10.1080/09720073.2014.11891463

Mapplebeck, A., & Dunlop, L. (2019). Oral Interactions in secondary science classrooms: a grounded approach to identifying oral feedback types and practices. *Research in Science Education*. https://doi.org/10.1007/s11165-019-9843-y

Maree, K. (ed). (2016). *First steps in research*. Van Schaik.

Maryani, I., & Martaningsih, S. (2015). Correlation between Teacher's PCK (Pedagogical Content Knowledge) and Student's Motivation in Primary School in Indonesia.

International Journal of Evaluation and Research in Education (IJERE), 4, 38. https://doi.org/10.11591/ijere.v4i1.4490

Masindi, V., & Duncker, L. (2016). *State of Water and Sanitation in South Africa*. https://doi.org/10.13140/RG.2.2.11466.77761

Mathai, S. (2014). The role of science textbooks in influencing pedagogical practices: Implications for teacher education. *In Focus 2.0*.

Mavhunga, E., & Rollnick, M. (2011). The development and validation of a tool for measuring topic specific PCK in chemical equilibrium. Paper presented at the ESERA Conference, Lyon, France.

Mavhunga, E., & Rollnick, M. (2013). Improving PCK of chemical equilibrium in pre-service teachers. *African Journal of Research in Mathematics, Science and Technology Education, 17*(1-2), 113-125. https://doi.org/10.1080/10288457.2013.828406

Mavhunga, E. (2014). Improving pck and ck in pre-service teachers. In H. V. M. Askew, M. Rollnick & J. Loughran (Eds.), *Exploring content knowledge for teaching science and mathematics: windows into teacher thinking.* Routledge.

Mavhunga, E. (2018). Revealing the structural complexity of TSPCK components. *Research in Science Education, 50,* 965-986. https://doi.org/10.1007/s11165-018-9719-6

Mavhunga, E., & Van der Merwe, D. (2017). *Revealing the complexity of pre-service teachers' TSPCK: From reasoning to practice* ESERA, Dublin, Ireland.

Mavhunga, E., & van der Merwe, D. (2020). Bridging science education's theory–practice divide: a perspective from teacher education through topic-specific PCK. *African Journal of Research in Mathematics, Science and Technology Education, 24*(1), 65-80. https://doi.org/10.1080/18117295.2020.1716496

Mentz, E., & Steyn, H. J. (2008). Teacher training in South Africa : the integrated model as viable option. *South African Journal of Higher Education, 22*(3), 679-691.

Mesa, J. C., Pringle, R. M., & King, N. (2014). Surfacing students' prior knowledge bin middle school science classrooms Exception or the Rule? . *Middle Grades Research Journal, 9*(3), 61-72.

Mesutoglu, C., & Baran, E. (2020). Integration of engineering into K-12 education: a systematic review of teacher professional development programs. *Research in Science & Technological Education*, VOL *38*(4), 1-19. https://doi-org.ukzn.idm.oclc.org/10.1080/02635143.2020.1740669

Moulton, J. (1997). How do teacher use textbooks? A review of the literature. *Africa Bureau Information Center (ABIC), 74*.

Msimanga, A., & Lelliott, A. (2012). Making sense of science: Argumentation for meaning-making in a teacher-led whole class discussion. *16*. doi:10.1080/10288457.2012.10740739

Mtsi, N., Maphosa, C., & Moyo, G. (2016). Exploring educators' preparedness to teach Natural Sciences at the senior phase of South African secondary schools. *Journal of Educational Studies, 15*(2), 108-135. https://journals.co.za/content/journal/10520/EJC-50f4344b6

Mudadigwa, B., & Msimanga, A. (2019). Exploring Teacher Pedagogical Practices That Help Learners Make Connections During the Teaching of Reactions in Aqueous Solutions at Senior Secondary Level. *African Journal of Research in Mathematics, Science and Technology Education, 23*(3), 332-343. https://doi.org/10.1080/18117295.2019.1688476

Naah, B. M., & Sanger, M. J. (2013). Investigating Students' understanding of the dissolving process. *Journal of Science Education and Technology, 22*(2), 103-112. http://www.jstor.org.ukzn.idm.oclc.org/stable/23442280

Novak, J., & Cañas, A. (2006). The theory underlying concept maps and how to construct them. http://cmap.ihmc.us/publications/researchpapers/theorycmaps/TheoryUnderlyingConceptMaps.bck-11-01-06.htm

Novak, J., & Cañas, A. (2007). Theoretical origins of concept maps, how to construct them, and uses in education. *Reflecting Education, 3(1)*, 29-42.

Novak, J. D. (1993, August 1-4). *A View on the Current Status of Ausubel's Assimilation Theory of Learning.* The Proceedings of the Third International Seminar on

Misconceptions and Educational Strategies in Science and Mathematics, Ithaca, New York.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge University Press.

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

O'Grady, E., O' Reilly,J., Portelli, J.P., & Beal, C. (2014). Putting the Learner into the Curriculum, not the Curriculum into the Learner: A Case for Negotiated Integrated Curriculum *International Journal of Pedagogical Innovations 2*(2), 52-64.

Ogunleye, B. O. (2013). Theoretical Perspectives of Cooperative Learning: Implications for Effective Science Teaching and Improved Students' Academic Achievement. In *The Pedagogical Psychology* (pp. 311-324). The Learners Support Services, National Open University of Nigeria.

Okorie, E. U., & Ugwuanyi, A. A. (2020). An investigation into the Extent of use of Practical Activities in Teaching Chemistry in Nigerian Schools. *Journal of CUDIMAC (J-CUDIMAC) Vol 6*(1), 39 – 44. http://cudimac.unn.edu.ng/journals-2/

Orb, A., Eisenhauer, L., & Wynaden, D. (2001). Ethics in Qualitative Research. *Journal of Nursing Scholarship, 33*(1), 93-96.

Ozfidan, B., Cavlazoglu, B., Burlbaw, L., & Aydin, H. (2017). Reformed teaching and learning in science education: a comparative study of Turkish and US Teachers. *Journal of Education and Learning, 6*(3). https://doi.org/10.5539/jel.v6n3p23

Pang, X.-F. (2013). *Water: molecular structure and properties.* http://site.ebrary.com/id/10845327

Perin, D. (2011). Facilitating student learning through contextualization: a review of evidence. *Community College Review, 39*(3), 268-295.

Permatadewi, S., Zen, D., & Haryani, M. (2019). Prior knowledge mapping on natural science. *Journal of Biology Education, 8*, 117-125. https://doi.org/10.15294/jbe.v8i1.27304

Philander, S. M. R. (2015). *A Study of the Analysis of Intermediate Phase Natural Sciences Workbooks in promoting the Nature of Sciences* University of Johannesburg. Gauteng.

Pitjeng, P. (2014). Novice unqualified graduate science teachers' topic specific pedagogical content knowledge, content knowledge and their beliefs about teaching. *Taylor and Francis*, 65-83. https://www.researchgate.net/publication/318210360

Pitjeng-Mosabala, P., & Rollnick, M. (2018). Exploring the development of novice unqualified graduate teachers' topic-specific PCK in teaching the particulate nature of matter in South Africa's classrooms. *International Journal of Science Education, 40*(7), 742-770. doi:10.1080/09500693.2018.1446569

Pomfret, M. (2015). Water Purification A guide to methods of water treatment with a focus on distillation. *Bibby Scientific*.

Potgieter, C. (2004). The impact of the implementation of technology education on in-service Teacher Education in South Africa (Impact of Technology Education in the RSA). *International Journal of Technology and Design Education, 14*(3), 205-218.

Pretorius, L. (2017). Effective teaching and learning : working towards a new, all-inclusive paradigm for effective and successful teaching and learning in higher education and training. *Educor Multidisciplinary Journal, 1*(1), 6-29. https://journals.co.za/content/journal/10520/EJC-d8716bc28

Prud'homme, G., xe, xe, & reux, A. (2017). Formulating questions that address student misconceptions in a case study. *Journal of College Science Teaching, 46*(4), 54-60. http://www.jstor.org.ukzn.idm.oclc.org/stable/44579914

Pursitasari, I. D., Nuryanti, S., & Rede, A. (2015). Promoting of Thematic-based integrated science learning on the junior high school. *Journal of Education and Practice 6*(20).

Ramnarain, U., & Padayachee, K. (2015). A comparative analysis of South African Life Sciences and Biology textbooks for inclusion of the nature of science. *SAJE South African Journal of Education, 35*(1), 1-8.

Rannikmäe, M. (2016). Some crucial areas in science education research corresponding to the needs of the contemporary society. *Journal of Baltic Science Education, 15*(1), 97-101.

Reddy, V., Visser, M., Winnaar, L., Arends, F., Juan, A., Prinsloo, C. H., & Isdale, K. (2016). *TIMMS 2015 Highlights of Mathematics and Science Achievement of Grade 9 South African Learners*. http://www.hsrc.ac.za/en/research-outputs/view/8456

Reisman, A., Kavanagh, S., Monte-Sano, C., Fogo, B., McGrew, S., Cipparone, P., & Simmons, E. (2017). Facilitating whole-class discussions in history: a framework for preparing teacher candidates. *Journal of Teacher Education, 69*, 002248711770746. doi:10.1177/0022487117707463

Rice, D. C., Ryan, M.J., & Samson, S.M. (1998). Using concept maps to assess student learning in the science classroom: must different methods compete? *Journal of Research in Science Teaching,* (35), 1103-1127.

Rollnick, M., Bennett, J., Rhemtula, M., Dharsey, N., & Ndlovu, T. (2008). The place of subject matter knowledge in pedagogical content knowledge: A case study of South African teachers teaching the amount of substance and chemical equilibrium. *International Journal of Science Education, 30*(10), 1365-1387.

Romero, C., Cazorla, M., & Buzón, O. (2017). Meaningful learning using concept maps as a learning strategy. *Journal of Technology and Science Education, 7*(3), 313-332.

Reisman, A., Kavanagh, S., Monte-Sano, C., Fogo, B., McGrew, S., Cipparone, P., & Simmons, E. (2017). Facilitating whole-class discussions in history: a framework for preparing teacher candidates. *Journal of Teacher Education, 69*, 002248711770746. https://doi.org/10.1177/0022487117707463

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Researchin Science Teaching, 33*, 569-600.

Sadler, P. M., & Sonnert, G. (2016). Understanding misconceptions: teaching and learning in middle school physical science. *American Educator*, 40(1), 26-32

Saxena, G., Purchase, D., Mulla, S., Saratale, G & Bharagava, R. (2019). Phytoremediation of Heavy Metal-Contaminated Sites: Eco-Environmental Concerns, Field Studies, Sustainability Issues and Future Prospects. Reviews of environmental contamination and toxicology. https://doi.org/10.1007/398_2019_24.

Schau, C., Mattern, N., & Zeilik, M., Teague, K., & Weber, Robert. (2001). Select-and-fill-in concept map scores as a measure of students' connected understanding of science. *Educationaland Psychological Measurement, 61*, 136-158. https://doi.org/10.1177/00131640121971112.

Seale, C., & Silverman, D. (1997). Ensuring rigour in qualitative research. *European Journal of Public Health 1, 7*, 379-384.

Shulman, L. S., & Shulman, J. H. (2004). How and what teachers learn: a shifting perspective. *Journal of Curriculum Studies, 36*, 257-271.

Singh, A. K., Gupta, L. K., & Singh, V. K. (2015, 6th – 7th February 2015). *A review of low cost alternative of water treatment in rural area* 10TH ALL INDIA PEOPLES' TECHNOLOGY, Kolkata. 10.13140/2.1.3970.1287

Siyavula, & Volunteers. (2015a). *Everything Science Grade 10 Physical Science Version 1 CAPS*. Department of Basic Education

Shuttleworth Foundation. https://intl.siyavula.com/read/science/grade-10

Siyavula, & Volunteers. (2015b). *Everything Science Grade 11 Physical Science Version 1 CAPS,* Department of Basic Education

Shuttleworth Foundation. https://intl.siyavula.com/read/science/grade-11

Singh,M.R., & Gupta, A. (2016). Water pollution-sources,effects and control. Researchgate. https://www.researchgate.net/publication/321289637

Sjøberg, S., & Schreiner, C. (2010). *The ROSE project An overview and key findings*. https://www.roseproject.no/network/countries/norway/eng/nor-Sjoberg-Schreiner-overview-2010.pdf

Snyder, M. (2018). A century of perspectives that influenced the consideration of technology as a critical component of STEM education in the United States. *The Journal of Technology Studies, 44*(2), 42-57. https://www-jstor-org.ukzn.idm.oclc.org/stable/26730730

Smith, P. S., Plumley, C. L., & Hayes, M. L. (2017). Methods & Strategies: Much ado about nothing how children think about the small-particle model of matter. *Science and Children, 54*(8), 74-80.

Sozan H, O. (2020). A content analysis of cognitive representations in a ninth-grade science textbook's chemistry of matter unit: Evidence from Saudi Arabia. *Cogent Education, 7*(1), 1808283. doi:10.1080/2331186X.2020.1808283

Soyibo, K. (1995). Using Concept Maps To Analyze Textbook Presentations of Respiration. *THE AMERICAN BIOLOGY TEACHER, 57*.

Stears, M., McKay, J., & Bentham, H. (2011). An analysis of student teachers' understanding of integration of science and technology activities. *Africa Education Review, 8*(1), 38-54. https://doi.org/10.1080/18146627.2011.586141

Stock, P., & Burton, R. J. F. (2011). Defining Terms for Integrated (Multi-Inter-Trans-Disciplinary) Sustainability Research. *Sustainability, 3*, 1090-1113. https://doi.org/10.3390/su3081090

Sullivan, P., Agardy, F. J., & Clark, J. J. J. (2005). *The Environmental Science of Drinking Water*. Elsevier Science & Technology.

Sutherland, C., Hordijk, M., Lewis, B., Meyer, C., & Sibongile, B. (2014). Water and sanitation provision in eThekwini Municipality: a spatially differentiated approach. *International Institute for Environment and Development (IIED), 26*(2), 469–488.

Taylor, N. (2011). *Priorities for Addressing South Africa's Education and Training Crisis.A Review commissioned by the National Planning Commission*. https://www.jet.org.za/

Taylor, N., & Schindler, J. (2016). *Education Sector Landscape Mapping South Africa*. JET. www.jet.org.za

Tinto, V. (1975). Dropout from Higher Education: A Theoretical Synthesis of Recent Research. *Review of Educational Research, 45*(1), 89-125. https://doi.org/10.2307/1170024

Trochim, W. M. K. (1989). Concept mapping. soft science or hard art? *Evaluation and Program Planning, 12*, 87-110.

Tulley, R. (2008). Is there techne in my logos? on the origins and evolution of the ideographic term—technology. *International Journal of Technology, Knowledge and Society, 4*, 93-104. https://doi.org/10.18848/1832-3669/CGP/v04i01/55813

Tümay, H. (2016). Reconsidering learning difficulties and misconceptions in chemistry: Emergence in chemistry and its implications for chemical education. *Chemistry Education Research and Practice, 17*, 229-245. https://doi.org/10.1039/C6RP00008H

Üce, M., & Ceyhan, İ. (2019). Misconception in chemistry education and practices to eliminate them: literature analysis. *Journal of Education and Training Studies, 7*, 202. https://doi.org/10.11114/jets.v7i3.3990

Valadares, J. A. C. S. (2013). Concept maps and the meaningful learning of science. *Journal for Educators, Teachers and Trainers*,49(1)164-179. http://www.ugr.es/~jett/index.php

Diaz Van Lloyd, T. K. (2017). Prior Knowledge: Its Role in Learning. . In *On Prior Knowledge*. University of the Philippines. https://doi.org/10.13140/RG.2.2.26816.69125

Vanides, J. T., Yin, Y., Tomita, M., & Ruiz-Primo, M. (2005). Using Concept maps in the science classroom. *Science Scope, 28*(8), 27-31.

Wallace, J., Sheffield, R., Rénnie, L., & Venville, G. (2007). Looking back, looking forward: re-searching the conditions for curriculum integration in the middle years of schooling. [Article]. *Australian Educational Researcher (Australian Association for Research in Education), 34*(2), 29-49. https://doi.org/10.1007/BF03216856

Wandersee, J. H. (1990). Concept mapping and the cartography of cognition *Journal of Research in Science Teaching, 27*(10), 923-936.

Wang. S-H. (2019). *Instruction Design and Strategy of Concept Mapping.* Advances in Economics, Business and Management Research, 5th International Conference on Economics, Management, Law and Education (EMLE 2019) Vol. 110, 1195-1198.

Williams, A. T., & Svensson, M. (2020). Student teachers' collaborative learning of science in small-group discussions. *Scandinavian Journal of Educational Research*, 1-14. https://doi.org/10.1080/00313831.2020.1788141

Wilson-Lopez, A., Gregory, S., & Larsen, V. (2017). Reading and engineering: elementary students' co-application of comprehension strategies and engineering design processes. *Journal of Pre-College Engineering Education Research, 6*(2), 39-57.

Winarno, N., Rusdiana, D., Riandi, R., Susilowati, E., & Afifah, R. (2020). Implementation of Integrated Science Curriculum: A Critical Review of the Literature. *Journal for the Education of Gifted Young Scientists*. https://doi.org/10.17478/jegys.675722

Yeboah, R., Abonyi, U. K., & Luguterah, A. W. (2019). Making primary school science education more practical through appropriate interactive instructional resources: A case study of Ghana. *Cogent Education, 6*(1), 1611033. https://doi.org/10.1080/2331186X.2019.1611033

Yazan, B. (2015). Three Approaches to Case Study Methods in Education: Yin, Merriam, and Stake. *The Qualitative Report, 20*(2), 134-152. https://nsuworks.nova.edu/tqr/vol20/iss2/12

Yin, R. K. (2014). Getting Started: How to know whether and when to use the case study as a reserach method. In R. K. Yin (Ed.), *Case study research:design and methods* (5th ed., pp. 3-25). Sage Publications.

Zikhali, S., & Malinga, G. (2019). 'No hope' for Ugu District Municipality water crisis. https://www.ecr.co.za/news/news/no-hope-ugu-district-municipality-water-crisis/

Zinn, C., Bailey, R., Barkley, N., Walsh, M. R., Hynes, A., Coleman, T., Savic, G., Soltis, K., Primm, S., & Haque, U. (2018). How are water treatment technologies used in developing countries and which are the most effective? An implication to improve global health. *Journal of Public Health and Emergency., 2*(25), 1-14.

Zoller, U. (1990). Comments and criticism: Students' misunderstandings and misconceptions in college freshman chemistry (general and organic). *Journal of Research in Science Teaching, 27*(10), 1053-1065.

Zoller, U. (1993). Are Lecture and Learning Compatible? Maybe for LOCS: Unlikely for OCS. *Symposium: lecture and learning: Are They Compatible?, 70*(3), 195-197.

APPENDICES

APPENDIX 1: PERMISSION LETTER

THE INDEPENDENT INSTITUTE OF EDUCATION

REF: R.14319
Enquiries: research@iie.ac.za
Date: 17 September 2019

REQUEST TO CONDUCT RESEARCH ON IIE STAFF/ STUDENTS/ARTEFACTS

Dear Ms R Naidoo,

The committee considered your request and have granted permission to conduct research on IIE staff/students/artefacts based on the fact that ethics clearance has been granted and campus permission has been provided. Permission is granted on condition that you strictly adhere to the conditions stipulated below and that the information you have provided is true and factually correct.

.

Approval is granted for:

Initial(s) and Surname:	RC Naidoo
Student number:	N/A
Institution where registered:	University of KwaZulu Natal
Qualification/ Output:	Master's
Year in which research will be conducted:	2019 - 2020
Title of study/ paper:	Exploring the development of TSPCK of Grade Five Natural Science and Technology Pre-service Teachers: A Case for Matter and Materials

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APPENDIX 2: LETTER TO PARTICIPANT

LETTER TO PARTICIPANT

(IIE VARSITY COLLEGE, WESTVILLE)

The Independent Institute of Education

Varsity College Westville

1 Link Road

Westville

3630

01st October 2019

Dear Participant

RE- REQUEST FOR YOUR CONSENT TO PARTICIPATE IN MY STUDY

My name is Rosann Chantel Naidoo a Master's in Education student at the Science and Technology Cluster, School of Education, University of KwaZulu Natal, South Africa (email, rosey1zn@gmail.com, Phone number: 0826004426). My research study is titled: Exploring the development of TSPCK of Grade five Natural Science and Technology pre-service teachers: a case for matter and materials. I hereby seek your permission to conduct my research at your School of Education in Westville in 2019. The proposed action research study is aimed at empowering Grade Five Natural Science and Technology pre-service teachers in developing Topic Specific Pedagogical Content Knowledge (TSPCK) in the topic of matter and materials in an integrated Natural Science and Technology curriculum as stipulated in the Natural Science and Technology curriculum assessment policy for the intermediate phase grades four to six (Department of Basic Education, 2011).

I hereby seek your permission to partake in my research. I wish to have an interview session with Grade five Natural Science and Technology pre-service teachers from the focus groups and the duration of the interview is expected to be one hour each. I would also like to be granted your permission to audio record the small group discussions during lectures as well as focus group sessions after lectures. The study will provide no direct benefits to participants but will be as a guide to science and technology policy and education in the country. There are no known risks associated with this research.

Participation in this research is voluntary and participants may withdraw participation at any point. I guarantee that the information gathered will be used for the purpose of the research only. Privacy of the research participants will be protected as participants identity will not be revealed in any publication resulting from this study. You are kindly requested to fill in the attached declaration and consent form which acknowledges the permission granted to partake in my research. The data will be archived for five years in the university archives at Edgewood campus. After five years all documents will be shredded, and audio recordings will be deleted.

This study has been ethically reviewed and approved by the UKZN Humanities and Social Sciences Research Ethics Committee (approval number HSS/0439/019M). In the event of any problems or concerns/questions you may contact me rosey1zn@gmail.com , 0826004426 or the UKZN Humanities & Social Sciences Research Ethics Committee, contact details as follows:

HUMANITIES & SOCIAL SCIENCES RESEARCH ETHICS ADMINISTRATION

Research Office, Westville Campus

Govan Mbeki Building

Private Bag X 54001 Durban 4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557- Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

Yours sincerely,

____

Ms. Rosann Chantel Naidoo

DECLARATION

As the participant, I understand that:

- I am not being forced to take part in this study;
- Anonymity will be guaranteed at all times, the name of my colleagues and myself will not be revealed on any documents to be completed or in the study.
- Confidentiality will be guaranteed at all times, information gathered will only be used for the purpose of this study.
- If I have any further questions/concerns or queries related to the study I understand that I may contact the researcher; Miss Rosann Chantel Naidoo (rosey1zn@gmail.com , 0826004426).
- 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

Govan Mbeki Building

Private Bag X 54001 Durban 4000

KwaZulu-Natal, SOUTH AFRICA

Tel: 27 31 2604557 - Fax: 27 31 2604609

Email: HSSREC@ukzn.ac.za

I hereby provide consent to:

Audio-record my interview / focus group discussion YES / NO

Video-record my interview / focus group discussion YES / NO

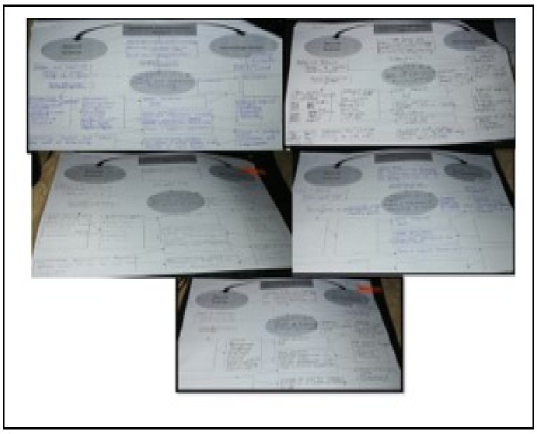
______________________ ______________________

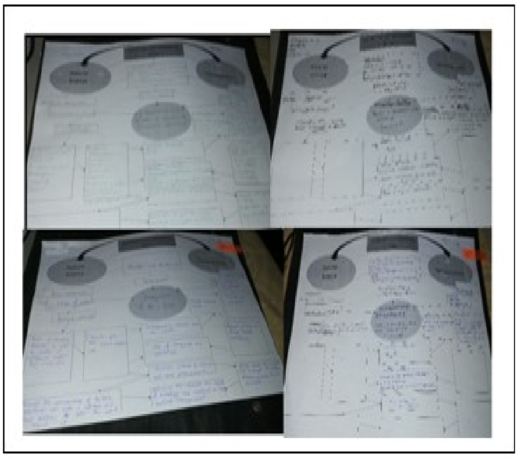
Signature of Participant **Date**

APPENDIX 3: PHOTOGRAPHS OF 40 CMS BY GRADE 6 NST PSTS

Category 1 Matter and Materials (NS) and Processing (TECH)

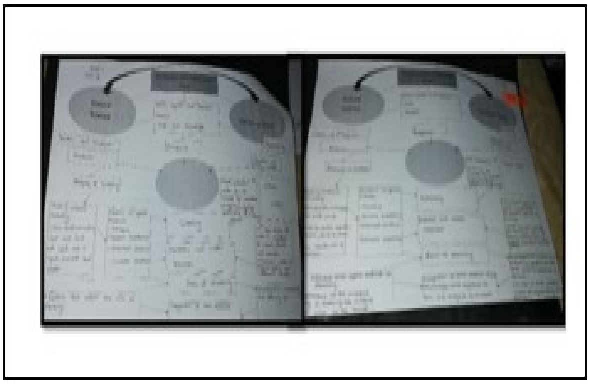
(PST 1,3,22,29,37,42,43,44,45)





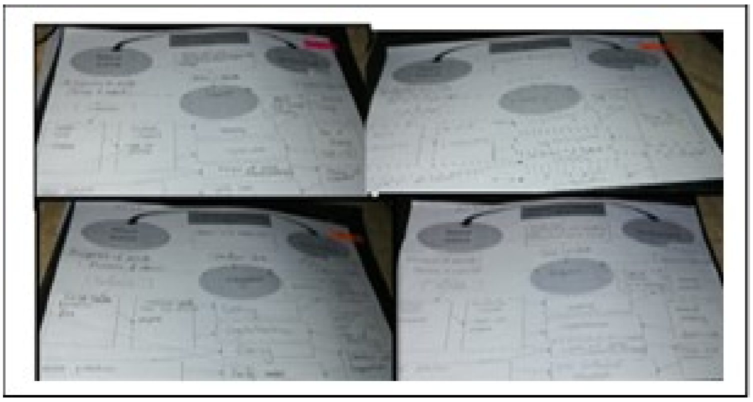
Category 2 Matter and Materials (NS) and Processing (TECH)

(PST 8,26,38)



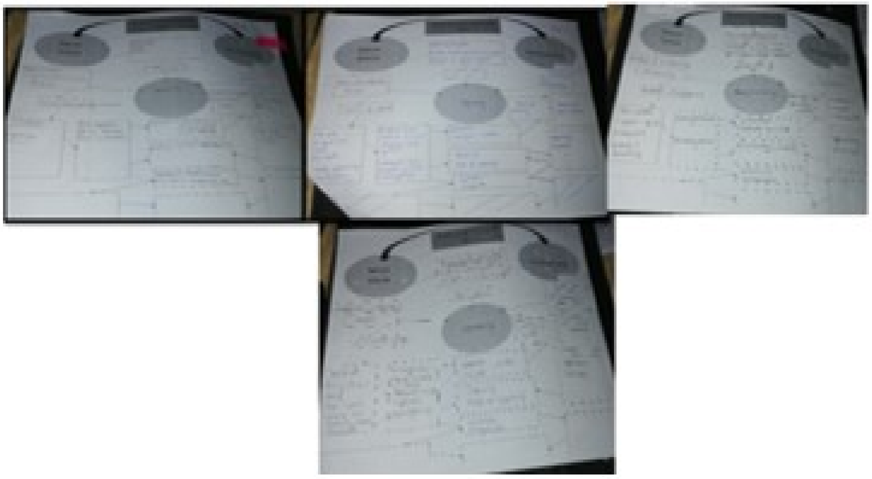
Category 3 Matter and Materials (NS) and Processing (TECH)

(PST 5, 9, 28 and 39)



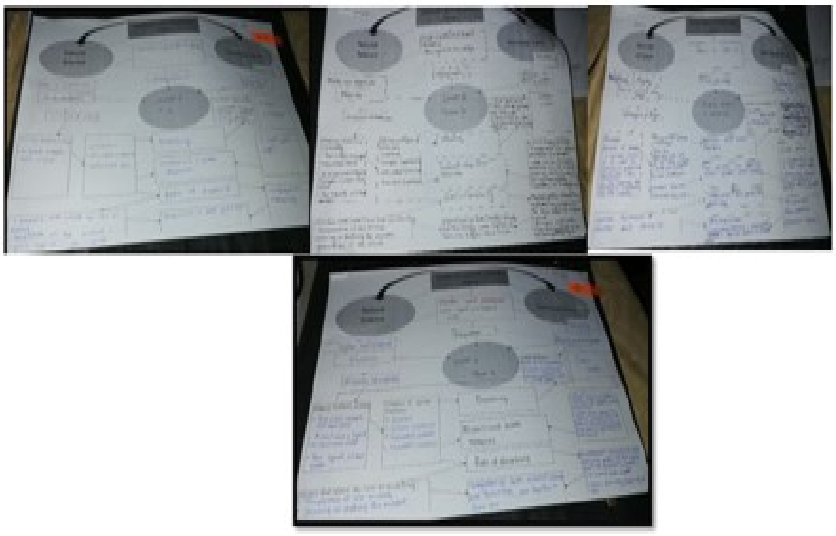
Category 4 Matter and Materials (NS) and Water Pollution (TECH)

(PST 11,15,16,23)



Category 5 Arrangement of Particles (NS) and Processing (TECH)

(PST 25,34,40,47)



Category 6 & 7

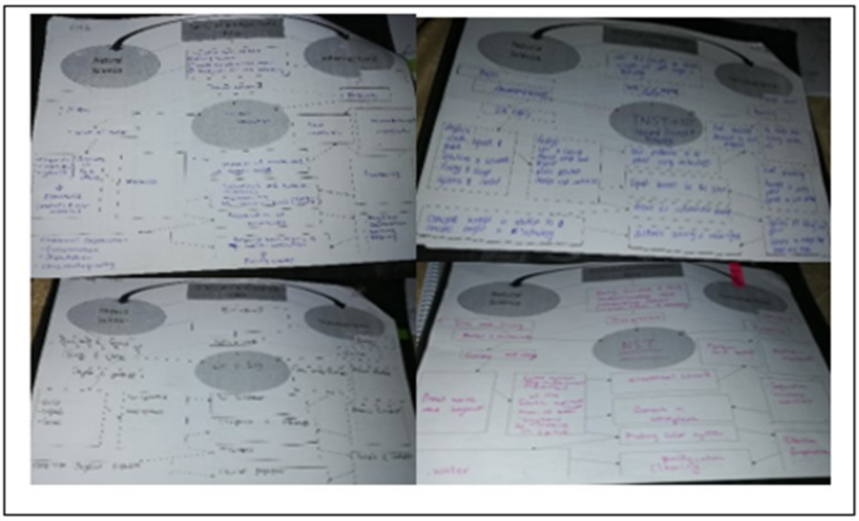
Raw Materials (NS) and Man-made or Manufactured Materials (TECH)

(PST 4, 13, 17, 19,20,24,30,31,32,35,36,41)

Category 8

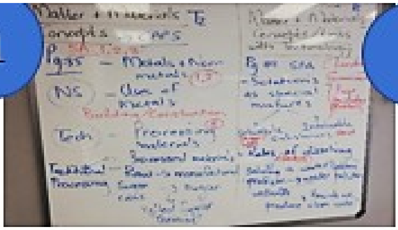
Matter and Materials (NS) and Processing (TECH)

(PST 6,12,14,33)



APPENDIX 4: COLLAGE OF WHITEBOARD IMAGES

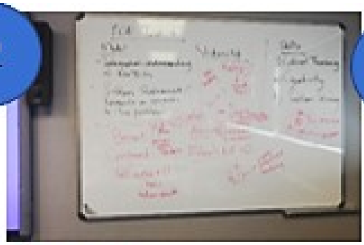
1



04/10/2020

Eliciting NS and TECH Grade 4 and 5 prior knowledge

2



04/10/2019

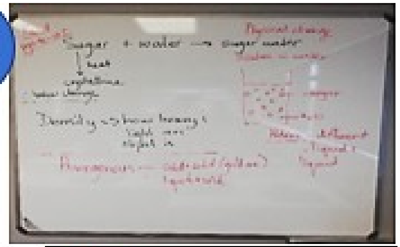
Introduction to POE assessment

3

7/10/2019

Recap of Grade 4/5Matter and Materials solids, liquids, and gases

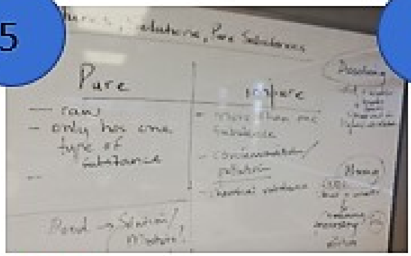
4



7/10/2019

Grade 6 Solutions and dissolving

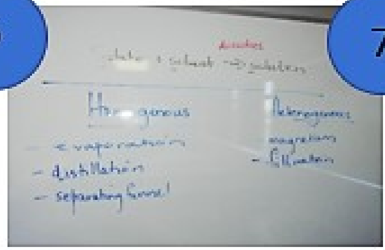
5



8/10/2019

Grade 6 Pure and Impure substances

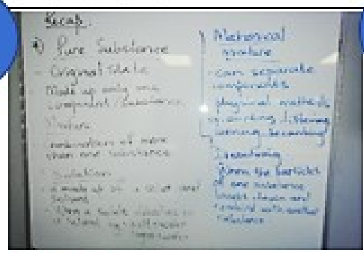
6



18/10/2019

Grade 6 Types of Solutions and Separation methods

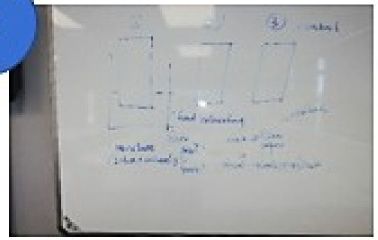
7



18/10/2019

Grade 6 summary of definitions

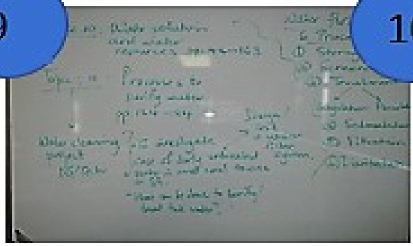
8



24/10/2019

Grade 6 Illustration of chromatography separation method

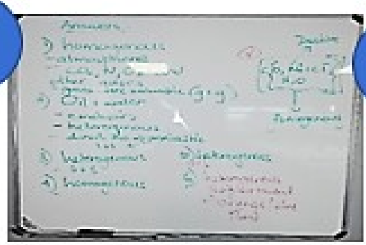
9



25/10/2019

Grade 6 Water Pollution and Processes for water purification

10



25/10/2019

Grade 6 Classroom Consolidation Activity from textbook

11

31/10/2019

Teaching of Chemistry of Water Molecule and Sodium Chloride Crystal

12

31/10/2019

Discussion of Technology Design Process Steps (IDMEC)

APPENDIX 5: RUBRIC FOR DATA ANALYSIS

Rubric used to show how the two knowledge strands (NS and TECH) were integrated and what link was used to integrate the two strands.

Category 1	Integrated NS and TECH	NS Strand - CAPS	NS Strand - OTHER	TECH Strand - CAPS	TECH Strand - OTHER	Linking NS to TECH
PST CM Response	What is being integrated?	Topics/concepts w.r.t. CAPS	Topic/concepts w.r.t. OTHER	Topics/concepts w.r.t. CAPS	Topics/concepts w.r.t. OTHER	How are the two being linked?

Category	NS Strand	PST Response	Link	PST Response	Tech Strand	PST Response	What is being integrated?	PST Response	Other	PST Response
	Matter and Material		**Problem identification**		**Processing of Mixtures**		**Science and Design**		**CAPS SA**	
	3 Phases of Matter		Sanitation and water purification in rural		**Mixing of different**				Mentions 3 SA of NST	
	Liquid				Solutions					
	Gas				Mixtures					
	Solid									
	Particle		**Water Filtration**		**Physical**					
	Heterogenous		Soluble substances		Evaporation					
	Homogenous		Insoluble		Decanting					
	Compounds				Distilation					
	Elements		Pure + Impure Substances		Filtering					
	Mixtures		**Processes to purify water**		**Processes of purifying**					
	Heterogenous				Filtrations					
	Homogenous				Evaporation					
	Emulsion									
	Immisible									
	Suspension									
	Mixtures include:									
	Sloid + Liquid									
	Liquid + Liquid									
	Solid + Solid									
	Dissolving									
	Factors that affect dissolving									

APPENDIX 6: EDITOR'S LETTER

PROOF-READING

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30 May 2021

TO WHOM IT MAY CONCERN

RE: LANGUAGE EDITING

This letter serves to confirm that I have edited the thesis titled:

Exploring the development of TSPCK of Grade Six Natural Science and Technology pre-service teachers: A case for matter and materials

By

Rosann Chantel Naidoo

Please feel free to contact me if you need any further information.

Yours sincerely,

Dr Lee-Anne Roux