Teachers' perceptions and implementation of formative feedback during the early phases of the design process

by

Nelé Loubser

Submitted in partial fulfilment of the requirements for the degree

Master of Education

Department of Science, Mathematics and Technology Education

Faculty of Education

University of Pretoria

Supervisor:

Prof. WJ Rauscher

Co-Supervisor:

Dr NW Blom

July 2021

DECLARATION OF ORIGINALITY

I declare that the dissertation titled "**Teachers' perception and implementation of formative feedback during the early phases of the design process**" which I hereby submit for the degree Master of Education at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at this or any other tertiary institution.

Nelé Loubser

Nelé Loubser

August 2021

ETHICAL CLEARANCE CERTIFICATE

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA
Faculty of Education

RESEARCH ETHICS COMMITTEE

CLEARANCE CERTIFICATE	CLEARANCE NUMBER: **SM 19/05/03**
DEGREE AND PROJECT	MEd Teachers' perceptions and implementation of formative feedback during the early phases of the design process
INVESTIGATOR	Ms Nelé Loubser
DEPARTMENT	Science, Mathematics and Technology Education
APPROVAL TO COMMENCE STUDY	30 May 2019
DATE OF CLEARANCE CERTIFICATE	25 August 2021

CHAIRPERSON OF ETHICS COMMITTEE: Prof Funke Omidire

CC

Ms Thandi Mngomezulu
Prof. WJ Rauscher
Dr. NW Blom

This Ethics Clearance Certificate should be read in conjunction with the Integrated Declaration Form (D08) which specifies details regarding:

- Compliance with approved research protocol,
- No significant changes,
- Informed consent/assent,
- Adverse experience or undue risk,
- Registered title, and
- Data storage requirements.

ACKNOWLEDGEMENTS

Throughout the writing of this dissertation, I received a great deal of support and assistance. I wish to express my gratitude to the following people who contributed towards this study:

- I would like to thank my supervisors, Professor Willem Rauscher and Doctor Niekie Blom, whose expertise was invaluable in completing this study. Your insightful feedback, continued support and encouragement to think bigger and push further has brought my thinking to a higher level.
- To my friends and family who encouraged me despite my absence in their lives.
- I would especially like to thank my parents for being my voice of reason and teaching me the value of hard work and perseverance.
- The Department of Basic Education, who allowed me to conduct this study in South African schools.
- The schools and participants involved in this study. Thank you for sharing your knowledge and experiences with me.
- Finally, I give thanks to my heavenly father who blessed with the opportunity to develop my strength, knowledge, and wisdom through this study. This study is proof that “I can do all things through Him who gives me strength” (Philippians 4:13).

ABSTRACT

The purpose of this study was to explore and describe how technology teachers perceive and implement formative feedback during the Early Phases of the Design Process (EPoDP) in technology classrooms. Formative feedback is essential to support and facilitate technology learners' activities during design problem solving as learners often have difficulty exploring the design problem and generating novel solutions. However, the Curriculum and Assessment Policy Statement (CAPS) for technology stipulates that teachers should provide learners with the opportunity to identify and solve design problems. However, there are limited pedagogical guidelines available to guide technology teachers on implementing effective feedback strategies to support such problem solving. Without guidance on how to implement formative feedback, technology teachers assess the learners' design outcomes summatively and only provide formative feedback on teamwork and managerial aspects of the design process. It is important to understand how teachers perceive and implement formative feedback during design problem-solving activities. Without effective formative feedback, learners may have difficulty in successfully exploring design problems and generating novel solutions. This means that learners often explore known problems and generate obvious or existing solutions to problems.

The conceptual framework used in this study was based on three existing frameworks, namely: Eris' design inquiry-driven model; Hattie and Timperley's conceptualised levels of formative feedback; and Goel and Pirolli's description of the early design phases.

This study utilised a qualitative approach within the interpretivist paradigm, and followed a descriptive case study design. A combination of convenience and purposive sampling methods was used to select senior phase technology teachers as participants. The data were collected through 11 semi-structured interviews and five non-participant technology classroom observations.

An inductive thematic analysis of the interview data revealed three themes concerning technology teachers' perceptions of formative feedback. These themes revealed that senior phase technology teachers view formative feedback through giving compliments and criticism, dialogic questioning, providing examples of existing products, and an intuitive process. Although technology teachers view formative

feedback as necessary, time limitations for completing design tasks and working through formative feedback result in lower feedback rates.

A deductive analysis of the observational data showed that technology teachers' formative feedback consists of a range of low-level questions and comments, Deep Reasoning Questions (DRQs), and Generative Design Questions (GDQs). Formative feedback questions and comments were observed at the task level, process level, self-regulative level, and self-level during the EPoDP. The findings of this study were used to develop a framework for investigating and supporting teacher's formative feedback practices in technology classrooms. Recommendations for future research include a study to develop and explore the feasibility of a tool for planning and implementing formative feedback in the technology classroom. Additional research is also required to explore and describe the effect that formative feedback in the EPoDP has on learners' design outcomes in senior phase technology classrooms.

Keywords: Deep Reasoning Questions, early phases of design, formative feedback, Generative Design Questions, process-level feedback, self-regulative feedback, self-level feedback, technology teachers, task-level feedback

EDITING AND FORMATTING CERTIFICATE

Exclamation Translations

To whom it may concern

The dissertation entitled, "Teachers' perceptions and implementation of formative feedback during the early phases of the design process" has been edited, proofread, technically formatted, and reference control has been carried out as of 03 September 2021.

As a language practitioner, I have a Basic degree in Languages, an Honours degree in French and a Master's degree in Assessment and Quality Assurance. I have been translating, editing, proofreading, carrying out reference control, and technically formatting documents for the past 11 years. Furthermore, I am a member of the Professional Editors' Guild (PEG).

Please take note that Exclamation Translations takes no responsibility for any content changes made to the document after the issuing of this certificate. Furthermore, Exclamation Translations takes no responsibility for the reversal or rejection of the changes made to this document.

Kind regards

Melissa Labuschagne

Melissa Labuschagne trading as Exclamation Translations
info@exclamationtranslations.co.za

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

CAPS	Curriculum and Assessment Policy Statement
DoBE	Department of Basic Education
DRQs	Deep Reasoning Questions
EPoDP	Early Phases of the Design Process
GDQs	Generative Design Questions
IDMEC	Investigate, Design, Make, Evaluate, Communicate
PAT	Practical Assessment Task

LIST OF FIGURES

LIST OF TABLES

LIST OF EXCERPTS

CHAPTER 1
ORIENTATION OF THE STUDY

1.1. CHAPTER OVERVIEW

The purpose of this chapter is to provide an overview of technology as a school subject in the South African curriculum. This chapter further provides an insight into the existing literature on formative feedback in school-based design settings and professional design practice. I start this chapter with an overview of the background of this study, and a discussion of the problem statement and rationale. More specifically, I focus on the general scarcity of pedagogical guidelines in both international and national curriculum documents to facilitate learners' design processes through formative feedback. This is followed by a description of the purpose, aims and objectives, as well as the primary and secondary research questions guiding this study. Thereafter, I declare my working assumptions and explain the significance of the study. I also describe the context of the research and my methodological choices. Finally, I conclude this chapter by explaining the key terms and outlining the organisation of this dissertation.

1.2. BACKGROUND OF THIS STUDY

The role of formative feedback in learners' design processes has gained the attention of several researchers in professional and school-based design settings (Cardoso et al., 2016; Cardoso et al., 2014; de Vries, 2018; Hattie & Clarke, 2019; Schut et al., 2018; Stables, 2017a, 2017b; Stables et al., 2016; Yilmaz & Daly, 2014a, 2014b, 2016). Educational studies have shown that feedback is one of the most effective tools for enhancing student learning in any subject (Hattie & Clarke, 2019; Hattie & Timperley, 2007; van den Bergh et al., 2013). There have been some studies in design and technology education that recommend the use of formative feedback to support learners' thinking during designing (Dym et al., 2014; Stables et al., 2016; Yilmaz & Daly, 2014, 2016). However, research on teachers' perceptions and implementation of formative feedback is still emerging.

Some researchers describe formative feedback as moving from desk to desk, observing where learners are in their design process and during a dialogue, and identifying what opportunities there are for future design actions (Adams et al., 2016; Cardella et al., 2014; Goldschmidt et al., 2014). More specifically, instructors engage with aspects of their students' design processes and products to point out features that could be inappropriate or improved upon, and engage in dialogue to move the learning process forward (Adams et al., 2017; Cardella et al., 2014). Instructors also provide students with opportunities to make productive mistakes, or allow students to reveal how they developed their design solutions (Adams et al., 2017; Cardella et al., 2014). Instructors also look for and complement promising aspects of students' designs (Adams et al., 2017).

In the South African context, teaching and learning in technology are underpinned by the design process (Department of Basic Education (DoBE), 2012). To facilitate the teaching and learning process, the Department of Basic Education (2012) prescribes a design process model that consists of five iterative phases: investigating; designing, making; evaluating; and communicating. Teachers provide learners with design tasks, allowing learners to solve real-world problems (DoBE, 2012). Design tasks or Practical Assessment Tasks (PATs) are the main forms of formal assessment of learners' skills and knowledge during each term. These PATs can cover some or all the phases of the prescribed design process (DoBE, 2012). To support and facilitate learners' design activities, the DoBE suggests that formative assessment should be used to provide formative feedback in the form of questions, comments, explanations, and demonstrations to learners during designing. The outcomes of these formative assessment activities should then inform teaching interventions (DoBE, 2012).

In this study, I focus on how technology teachers perceive and implement formative feedback during the Early Phases of the Design Process (EPoDP). The EPoDP involves problem structuring and preliminary problem solving (Goel, 1995; Goel & Pirolli, 1992; Blom et al., 2018). In the EPoDP, learners explore the scope of the problem, the user's needs, the design specifications and constraints, existing solutions, preliminary solutions; they then make preliminary design decisions (Goel, 1995, 2014; Goel & Pirolli, 1992; Visser, 2009). Currently, the nature of teachers' formative feedback practices in questioning and commenting during the design process is a developing and emerging field in both professional design education

(Adams et al., 2017; Goldschmidt et al., 2014) and school-based design (Schut & Blom, 2019; Schut et al., 2018; Schut et al., 2020). Goldschmidt et al. (2010) note that the current conception of formative assessment practices during designing is an understudied 'black box', and is usually determined by a teacher's style and own disciplinary knowledge. Recently, there has been a cross-disciplinary interest in uncovering the nature of formative assessment during professional design students' design processes (Adams & Siddiqui, 2016). However, limited studies have focused on the nature of formative feedback during school-based design activity.

Many of the current technology teachers in South African schools have not received a formal educational qualification in technology or design education (Engelbrecht et al., 2007; Gumbo, 2016, 2020; Potgieter, 2004; Rauscher, 2016; Reitzma & Mentz, 2009). There is a need to address the need for the professional development of technology teachers. In order to do so, various in-service training opportunities have focused on developing technology teachers' understanding of technology as a learning area, specifically, the content of concepts in technology (Ankiewicz, 2020; Engelbrecht et al., 2007; Gumbo, 2020; Potgieter, 2004; Reitzma & Mentz, 2009). Furthermore, the focus of professional development courses includes applying the design process, planning, and implementing learning programmes based on design projects and pedagogic knowledge (Ankiewicz, 2020; Engelbrecht et al., 2007; Gumbo, 2020; Potgieter, 2004; Reitzma & Mentz, 2009). It seems that these professional development courses for teachers do not adequately address the use of formative assessment and formative feedback to support learners' design activities. As such, research is needed to explore how design tasks are supported in South-African technology classrooms.

1.3. PROBLEM STATEMENT AND RATIONALE

Despite the DoBE's (2012) requirement for teachers to engage in formative assessment to support learners' design activities, there seem to be limited guidelines to plan and implement formative assessment and feedback in technology classrooms. Scholars in technology education have noted the need for technology teachers to assess learners' design processes and products to support the development of learners' design literacy and capabilities (Reitzma & Mentz, 2009; Stables, 2017b; van Niekerk et al., 2010). Although the DoBE provides guidelines for setting pen-and-paper

tests in technology (National Professional Teachers' Organisation of South Africa, 2018), they do not provide guidelines for formative assessment and feedback during designing. Engelbrecht et al. (2007) have found that when technology teachers are not guided on what is required in terms of assessment, they only engage in summative assessment of design outcomes and fail to support learners' design processes. Similarly, Moreland and Jones (2000) found that teachers often engage in praise as formative feedback and assessment rather than focusing on the strengths and weaknesses of student work compared to the objective of the task. The authors found that one of the reasons for teachers' formative feedback being limited is that they perceived formative feedback as a factor limiting creativity (Moreland & Jones, 2002). When I searched for the term 'formative assessment' in the CAPS document, I found only three references made to this type of assessment. None of them related to formative assessment associated with designing, or provided guidelines on how formative feedback should be planned or implemented. In a more recent study, Gumbo (2020) reports that Grade 9 technology teachers' training needs are not being met in professional development courses. More specifically, the author explains that teachers have expressed that they have difficulties in structuring activities around the design process, and teaching and assessment of the design process as part of the PATs.

The use of formative feedback as a pedagogic practice in professional design studies is well established (Goldschmidt et al., 2010; Stables et al., 2016). However, it seems to be understudied in technology classrooms (Schut et al., 2019; 2020; Stables et al., 2016). In general, previous studies on formative feedback in design education have focused on the role of questioning (Cardoso et al., 2014), informal formative feedback (Schut et al., 2018), and the nature of design critique sessions (Cardoso et al., 2014). Furthermore, studies have shown that learners can gain a better understanding of design problems and generate design ideas when discussing ideas with their peers and teachers through questioning (Stables et al., 2016). Similarly, a study in professional design education shows that when students were supported during their problem-structuring activities, they explored more sub-problems and generated more creative solutions (Creeger et al., 2019). However, these studies have not addressed what questions were asked during specific design activities in the early design phases. Moreover, they did not provide practical guidelines for planning and implementing formative feedback comments and questioning as a method of formative feedback

during design. In this study, I aimed to explore and describe the nature of formative feedback implemented by South African technology teachers during the initial phases of the design phases.

The findings from this study may contribute to the larger body of research related to the implementation of formative feedback during designing in the technology classroom. An enhanced understanding of how formative feedback could be implemented to support learners' early design phases may reduce fixation on design solutions and increase exploration of creative and novel solutions. If formative feedback procedures are successfully implemented, learners could be guided towards self-regulative learning through receiving constructive formative feedback from their teachers. It is, therefore, necessary to investigate how senior phase technology teachers perceive and implement formative feedback. I thus aimed to, inter alia, develop guidelines to plan formative feedback in order to support novice designers during the EPoDP.

1.4. STATEMENT OF PURPOSE

The purpose of this study was to explore and describe technology teachers' formative feedback practices during the initial phases of designing. More specifically, this study set out to determine technology teachers' perceptions of formative feedback and how they implement formative feedback during the EPoDP. To this end, I utilised semi-structured interviews to investigate how teachers describe formative feedback, the rationale of providing learners with formative feedback, and how teachers perceive formative feedback being implemented. Furthermore, I used non-participatory observations to investigate how formative feedback is implemented during design tasks. The findings of this investigation could enhance our understanding of technology teachers' formative feedback practices during the problem structuring and preliminary problem-solving phases of the design process. The findings of this study contribute to the development of a framework that can support pre-service and in-service teachers' planning and implementation of formative feedback.

1.5. AIMS AND OBJECTIVES

The primary aim of this study was to explore and describe technology teachers' perceptions and implementation of formative feedback in the EPoDP. To achieve this

aim, I sought to collect and analyse data that revealed how technology teachers describe their formative feedback in the technology classroom, and how they implement formative feedback during designing. More specifically, I wanted to investigate teachers' formative feedback in the problem structuring and preliminary problem-solving phases. I carried this out by exploring the different levels of formative feedback implemented by the participating technology teachers. In addition, I wanted to explore what types of formative feedback questions and comments were frequently used to support learners' design activities.

The second aim of this study was to develop practical guidelines to support technology teachers in planning and implementing formative feedback that supports learners' design activities. To address this aim, I required a conceptual framework that would assist me to observe and describe the design phases, levels of feedback, and the types of questions and comments the technology teachers made during the EPoDP (see Figure 1.1). The conceptual framework allowed me to identify instances of formative feedback during a design lesson. However, it did not apply to analysing and interpreting the participants' perceptions of formative feedback as their perceptions were based on their varying experiences. The integrated conceptual framework and the findings of this study will form the basis of the proposed framework for technology teachers to plan and implement formative feedback. The conceptual framework will contribute to the development of a framework for planning formative feedback. It will do so by providing a guideline for selecting different questions and comments to target learners' task, process, and self-regulative needs during their problem-structuring and preliminary problem-solving activities. The findings of this study will be used to develop question and comment prompts at the task level, process level and self-regulative level during the EPoDP.

1.6. RESEARCH QUESTIONS

The following primary research question was central to this study:

How do technology teachers perceive and implement formative feedback during the early phases of the design process?

To address the primary research question, I was guided by the following secondary research questions:

1. How do technology teachers conceptualise formative feedback as part of supporting learners' early design processes?

2. What is technology teachers' rationale for implementing formative feedback during the early phases of the design process?

3. How do technology teachers use formative feedback to support learners' design processes at the task, process, self-regulative, and self-levels?

4. What types of formative feedback questions and comments do technology teachers implement to support learners' design processes?

1.7. WORKING ASSUMPTIONS

Based on existing literature in the field of formative feedback in school-based design settings, I kept the following assumptions in mind when undertaking this study:

- Design is a complex problem-solving activity, and design problems are open-ended and ill-structured.
- Learners need support from their teachers to guide them through their problem structuring and preliminary problem-solving activities.
- Technology teachers' understanding of the design process and the design task would impact how they guide learners through the design process.
- The participants' perceptions of formative feedback may be guided by their practice. Therefore, the participants may not share the same views on formative feedback and the implementation thereof.
- Formal teacher training and professional development courses might not have adequately prepared these technology teachers to implement formative feedback. However, I assumed that the teachers' experience in teaching technology and facilitating design tasks might enhance their formative feedback practices.
- These technology teachers did not have any guidelines on how to implement formative feedback during the EPoDP.

- The participants' formative feedback questions and comments would be based on the context of the design task and the group of learners' design literacy and capabilities.
- The integrated conceptual framework for this study may provide a way to understand how formative feedback is implemented during the EPoDP.

1.8. SIGNIFICANCE OF THE RESEARCH

During my preliminary literature review, I noticed a shortage of empirical studies on guiding learners through the EPoDP by means of formative feedback. I further discovered a paucity of literature on the limited pedagogical guidelines available for implementing formative feedback in technology classrooms. The findings of this study could thus contribute to the emerging body of knowledge on formative feedback in the technology classroom in both a theoretical and practical manner.

In a recent study, Brooks et al. (2019) developed a conceptual matrix of feedback that included the formative feedback levels and feedback prompts based on Hattie and Timperley's (2007) Model of Feedback. The conceptual model proposed by Brooks et al. (2019) can support teachers in providing formative feedback in subjects that deal with closed-ended problem solving. Nonetheless, it has not yet been contextualised for school subjects focused on creative, open-ended problem solving. Therefore, this framework may not provide the necessary support for teachers to effectively implement formative feedback during the EPoDP. Other studies (Schut et al., 2020; Tawfik et al., 2020) provide question taxonomies for studying formative feedback during open-ended tasks, but these frameworks have not been used during the EPoDP. Additionally, none of these have the categorised feedback in terms of its different levels of implementation. In this way, theoretically, my study contributes to the emerging field of formative feedback in technology classrooms. The theoretical contribution of this study entails an increased understanding of the nature and types of formative feedback implemented in technology classrooms. As an outcome, this study proposes a conceptual framework for investigating teachers' use of formative feedback questions across four distinct levels to guide learners through problem-structuring and preliminary problem-solving activities.

In terms of this study's contribution to professional practice, I was able to formulate a framework for pre-service and in-service teachers to plan and implement formative feedback during design projects. This could support the development of the formative feedback capabilities of both pre-service and in-service teachers. More specifically, the framework will help teachers make informed pedagogical choices about what formative feedback prompts to use, and when to use these prompts during specific design activities.

1.9. RESEARCH DESIGN AND METHODOLOGY

In this section, I provide an overview of the research design and methodological assumptions that guided this study.

1.9.1. Research paradigm: Interpretivism

To gain insight into technology teachers' perceptions of formative feedback strategies, and the manner in which they implemented this, I adopted an interpretivist stance (Lincoln & Guba, 1985; Mettenfelner & Ravitch, 2018). In taking an interpretivist stance, I viewed the technology teachers as actors in a social context (Cohen et al., 2018; Lincoln & Guba, 1985; Mettenfelner & Ravitch, 2018). I consequently considered them to be knowers of formative feedback strategies, and active agents who are able to implement formative feedback (Cohen et al., 2018; Lincoln & Guba, 1985). In line with the interpretivist view, I attempted to interpret reality as being constructed by the participants based on their experiences of planning and implementing formative feedback, and the meanings they attached to their provision of formative feedback during design tasks (Given, 2012; Lincoln & Guba, 1985). Interpretivism also allowed me to utilise various modes of data collection, which supported my interpretations and allowed me to provide a detailed and thick description (Lincoln & Guba, 1985; Patton, 2015) of the teachers' formative feedback practices in technology classrooms. In this way, I was able to address my research purpose to explore and describe how technology teachers implement formative feedback during the EPoDP. The research paradigm that I followed in this study is further explained in Section 3.2.

1.9.2. Research approach: Qualitative research

For this study, I followed a qualitative research approach due to my belief that the nature of technology teachers' perceptions and how they implement formative feedback is understood through my subjective interpretations of this reality (Cohen et al., 2018; Flick, 2018). Furthermore, I believe that these realities are collected through my involvement rather than being pre-existing realities that are yet to be discovered (Niewenhuis, 2007, as cited in Maree, 2020). Since a qualitative approach can provide a framework for investigating teachers' perceptions and their implementation of formative feedback, I considered a qualitative approach to be appropriate. I further elaborate on the research approach followed in Section 3.3.

1.9.3. Research design: descriptive single-case study

I selected a descriptive single case study design as this allowed me to investigate the perceptions and activities of the teacher participants as they experienced and engaged with a real-world phenomenon in the context of their natural settings (Stake, 1995; Yazan, 2015; Yin, 2018). Selecting this design allowed me to generate new knowledge and understanding (Stake, 1995; Yazan, 2015; Yin, 2018) and set a standard for good teaching practices by developing practical guidelines for implementing formative feedback based on the current practices in technology classrooms (Mills et al., 2012). The focus and boundaries of this study were set to include senior phase technology teachers where twelve participants were chosen to be interviewed and five were chosen to be observed. The selection of interview participants allowed me to gain an insight into technology teachers' perceptions of formative feedback. In addition, a descriptive single case study design further allowed me to conveniently and purposefully select five participants. I then studied them further by means of observations to gain an in-depth and holistic understanding of how they implemented formative feedback in the senior phase technology classroom (Yin, 2018). The research sites for these case studies were secondary schools located in Gauteng (specifically, Pretoria and Johannesburg). The selection of participants allowed me to interview and observe the participants in a naturalistic environment. This encouraged them to feel comfortable sharing their views of formative feedback and implementing their formative feedback questions and comments during a design problem-solving task.

1.9.4. Selection of cases and participants

The ten schools that became the research sites in this study were conveniently selected (Cohen et al., 2018; Frey, 2018). This selection was also based on the willingness of the teachers to participate in the study and their proximity to the researcher. The twelve participants involved in the interviews were conveniently and purposefully selected based on voluntary participation. The participants involved in the observations were purposively selected from the interviewed participants, who were five senior phase technology teachers. The participants were selected based on the alignment of the design task learners would be required to engaged with in the second term of the school calendar according to curriculum requirements. Specifically, teachers who teach Grade 8 technology would need to support learners in solving an ill-structured design problem-solving task that is related to structures. Similarly, teachers who teach Grade 9 technology would need to facilitate the completion of design tasks about mechanical systems and control. The participant selection process is further elaborated on in Section 3.5.

1.9.5. Data collection and documentation

I utilised semi-structured interviews and non-participant observations as data collection methods in this study. During the semi-structured interviews, I attempted to understand the participants' perceptions of formative feedback. I utilised non-participant observations to gain a comprehensive overview of how these teachers used formative feedback questions and comments across different levels to guide learners' problem-structuring and problem-solving activities. In doing so, I took on the role of a complete observer to minimise the disruption of teachers' natural formative feedback practices. The data collection processes of this study are further discussed in Section 3.6.

1.9.6. Data analysis and interpretation

The data analysis and interpretation were guided by an inductive thematic analysis and a deductive analysis. This was done using a multi-level coding scheme based on the conceptual framework of this study. Thematic analysis and deductive analysis allow data to be reduced to manageable chunks without losing complexity (Cohen et al., 2018; Creswell et al., 2016). The results of the analysis provided a detailed view

of the technology teachers' perceptions of formative feedback. It also provided insight into the questions and comments that these teachers used to give formative feedback to learners in the preliminary design phases. These procedures are elaborated on in Section 3.7.

1.9.7. Quality assurance

I adhered to the criteria of credibility, transferability, dependability, confirmability, and authenticity (Lincoln & Guba, 1985) to enhance the trustworthiness and rigour of this study. Furthermore, the research was conducted in the participants' natural environments, which allowed me to provide a comprehensive and rich description of the participants' formative feedback behaviour. The quality assurance measures taken in this study are further discussed in Section 3.9.

1.9.8. Ethical considerations

Regarding ethical protocols, I followed the principles of informed consent, voluntary participation, privacy, trust, and safety from harm (Babbie & Mouton, 2006, Cohen et al., 2018). Before I started collecting data, I obtained permission to conduct this study from the Ethics Committee of the University of Pretoria's Faculty of Education, the Gauteng Department of Education, the District Directors of the different areas in which each school was situated, each of the five school's principals, and School Governing Bodies. In addition, I requested informed consent from the participants. I obtained informed consent from the parents of the learners who were present in the class during the recorded design activities, as well as assent from the learners themselves. The informed consent letters included information about the purpose and procedures of the study, the rights of the participants, and the ethical principles followed (Babbie & Mouton, 2006, Cohen et al., 2018). These principles included voluntary participation, safety during participation, privacy, and trust. The ethical principles are further discussed in Section 3.10.

1.10. EXPLANATION OF KEY TERMS

1.10.1. Early phases of the design process

The early phases of the design process (EPoDP) refer to the problem structuring and preliminary problem-solving phases of any process of designing (Goel, 1995; Goel &

Pirolli, 1992). During the problem structuring phase, designers typically frame, define and structure design problems by investigating stakeholder needs, requirements, and constraints that need to be satisfied to solve the design problem (Goel, 1995; Goel & Pirolli, 1992; Visser, 2009). During the problem-solving phase, designers formulate their design briefs and specifications, and engage in design concept generation (Goel, 1995; Goel & Pirolli, 1992; Visser, 2009).

In this study, I considered the initial phases of designing as corresponding to the EPoDP "*investigate*" and "*design*" prescribed by the Department of Basic Education (DoBE, 2011). Typical activities that learners engage in during these phases include identifying and explaining the design problem, gathering information about the design problem context, analysing existing solutions, practical testing, conducting research, writing a design brief, developing the design specifications and constraints, exploring, and generating ideas, and making design decisions.

1.10.2. Formative feedback

Formative feedback is defined by Hattie and Timperley (2007, p. 82) as "information provided by an agent (teacher, peer, book, self) regarding one's performance or understanding". According to Hattie and Timperley (2007), formative feedback can occur on four levels: task level, process level, self-regulative level, and self-level. Furthermore, feedback is considered formative when it moves learning forward by answering three fundamental questions from the learners' point of view, these are: 1) Where am I going? 2) How am I going to get there? and 3) What are my next steps? (Hattie & Timperley, 2007, Shute, 2008; Wiliam, 2019). To this end, formative feedback can be provided orally through questions and comments or in a written format. While formative verbal feedback through questioning and commenting is usually immediate and happens more frequently, written feedback is generally delayed and commonly associated with grading (Hattie & Clarke, 2019). Within the context of professional design education and some school-based design settings, learners often receive formative verbal feedback on the progress of their design tasks from clients and teachers. In both professional design settings and school-based design settings, the purpose of formative feedback is often to clarify learners' ideas, to justify their design choices, to interpret and compare learners' designs to previous design work,

and to make recommendations for improvement (Cardella et al., 2014; Schut et al., 2018, 2020; Yilmaz & Daly, 2014a).

For the purposes of this study, formative feedback refers to teachers' use of questions or comments aimed to support the learning process. In this study, formative feedback is viewed at different levels, task level, process level, self-regulative level, and self-level to guide learners' problem structuring and problem-solving activities. Teachers' questions and comments were only considered as formative feedback when these aimed to support learners' understanding of the design problem or supported them during preliminary designing. The conceptual framework of this study, including the questions and comments that were considered as formative feedback, is discussed in more detail in Section 2.8.

1.10.3. Technology education

Internationally, technology is known as design and technology, or technology education. This refers to a school subject with the purpose of developing learners' technological capability and literacy (Kimbell & Stables, 2007; Sanders, 2008). For this purpose, learners are offered the opportunity to solve practical, real-world problems through 'design and make' activities while using and developing their critical and creative thinking skills.

In the South African context, technology refers to a school subject that is compulsory for all Grades 7 to 9 learners. The purpose of technology in the South African school curriculum is to develop learners' technological literacy in recognition of the need to produce future engineers, artisans and technicians (DoBE, 2012). Technology is defined by the Department of Basic Education as "the use of knowledge, skills and values to solve real-world problems, while taking social and environmental factors into consideration" (DoBE, 2012, p. 8).

In this study, I used the term 'technology teachers' to refer to practitioners responsible for delivering instruction and facilitating design tasks in the subject of technology.

1.11. CONCEPTUAL FRAMEWORK FOR THIS STUDY

In this study, I used a combination of existing frameworks to explore and describe the formative feedback practices of technology teachers. Firstly, I utilised Goel and Pirolli's

(1992) characterisation of the EPoDP. This framework allowed me to investigate the nature of technology teachers' formative feedback practices during the problem structuring and preliminary problem-solving phases of the design process.

Secondly, I used Hattie and Timperley's (2007) characterisation of the four levels of formative feedback to explore the different levels at which teachers implement formative feedback. Task-level feedback may include directions to acquire information about the goals of the design task, while process-level feedback is aimed at the skills, strategies and processes that learners need to complete the design task (Brooks et al., 2019; Hattie & Timperley, 2007). Self-regulative feedback relates to autonomy and includes feedback that guides learners in monitoring their design processes in relation to the goals of the design task (Brooks et al., 2019; Hattie & Timperley, 2007). Self-level feedback usually includes positive statements about the learner and does not relate to the design task, the design process, or self-regulation strategies (Brooks et al., 2019; Hattie & Timperley, 2007). The inclusion of feedback levels means that teachers can streamline formative feedback to target individual learners' needs during problem structuring and preliminary problem-solving activities (Brooks et al., 2019).

Thirdly, I used Eris' (2004) Question Driven Design-Based Model adapted by Schut et al. (2020). This allowed me to explore the types of formative feedback questions and comments that the teachers utilised during learners' design tasks. The integrated conceptual framework for this study is illustrated in Figure 1.1.

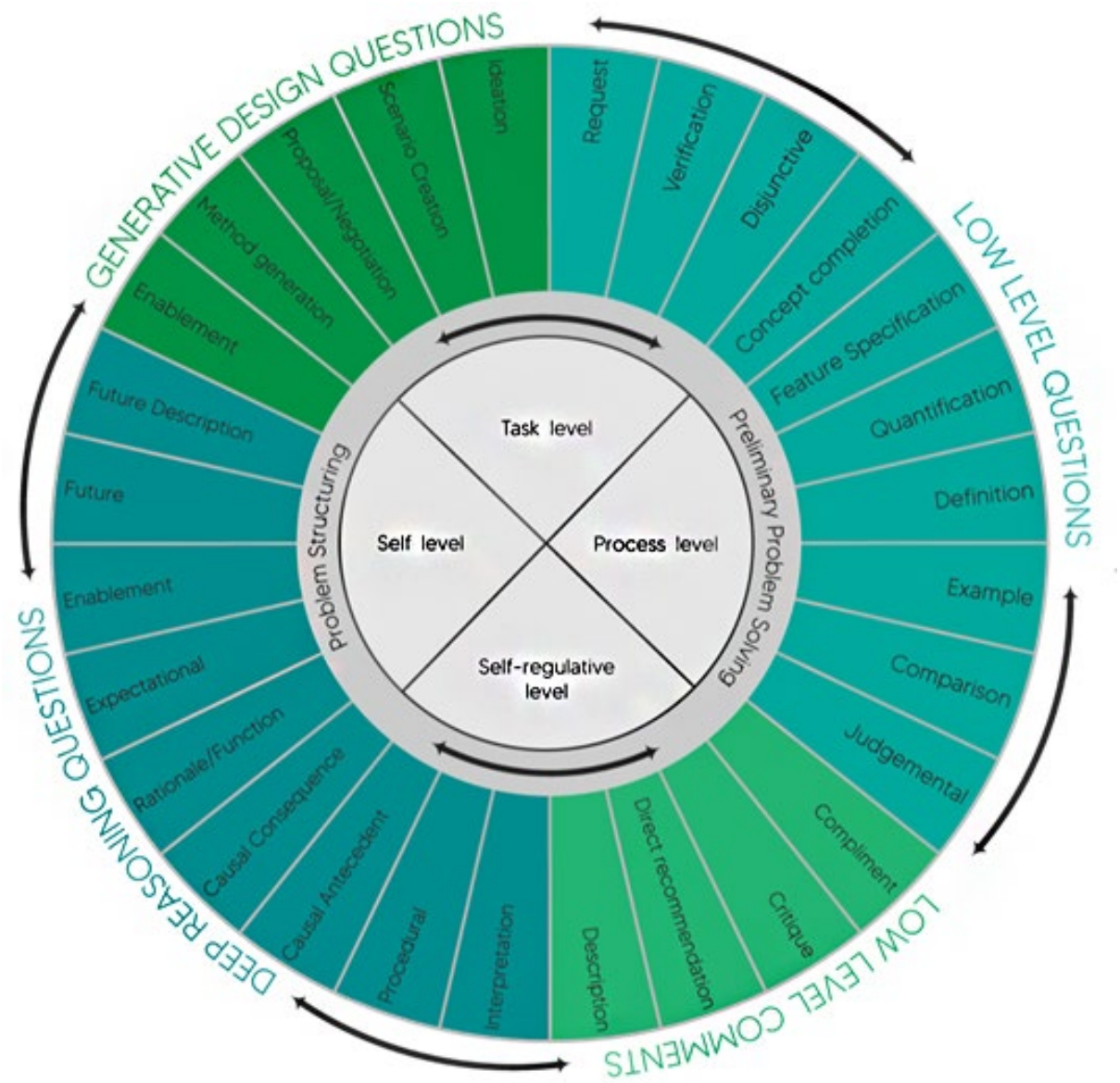


Figure 1.1: Types of formative feedback questions and comments on four distinct levels during the early phases of the design process

Figure 1.1 illustrates the conceptual framework of this study, which was developed by combining Goel and Pirolli's (1992) characterisation of the EPoDP, Hattie and Timperley's Model of Feedback, and Schut et al.'s (2020) feedback model adapted from Eris' (2004) Inquiry-Driven Design-Based Model.

The conceptual framework shows problem structuring and preliminary problem-solving, which make up the EPoDP. Next, the conceptual framework shows the classification of formative feedback levels relating to tasks, processes, self-regulation, and the self. Figure 1.1 further shows the classification of formative feedback questions and comments according to these models. Figure 1.1 illustrates the

classification of questions and comments as being low-level questions, low-level comments, and high-level questions in terms of Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). The conceptual framework is discussed in detail in Section 2.8.

1.12. OUTLINE AND ORGANISATION OF THIS DISSERTATION

This study consists of five chapters organised in the following way.

Chapter 1 Orientation of the study

In this chapter, I provide an overview of the background of the study along with the problem statement, rationale, aims, objectives, and research questions underpinning this study. After formulating the research questions and defining the working assumptions, I explained the significance of this study and explained the key terms used in this study. I conclude this chapter by introducing the conceptual framework of this study where I integrated the works of Goel and Pirolli (1992), Hattie and Timperley (2007) and Schut et al. (2020).

Chapter 2 Literature review

In Chapter 2, I present an overview of technology education in South Africa as the background to this study. I also explore research on design as a problem-solving activity, and formative assessment and feedback in professional and school-based design education settings. This is followed by an overview of formative feedback questions and comments in design learning environments. Next, I discuss the conceptual framework for this study by referring to the prominent frameworks used to understand design talks. This chapter is concluded with a discussion on the need for an integrated framework to explore the implementation of formative feedback in technology classrooms.

Chapter 3 Research design and methodology

In Chapter 3, I describe the research methodology and strategies that guided my study. I explain my paradigmatic and methodological choices, elaborate on the research design, selection of cases and participants, the data collection and documentation strategies, and explain the data analysis and interpretation

procedures. In concluding the chapter, I discuss my role as a researcher, as well as the quality measures and ethical considerations guiding this study.

Chapter 4 Results and discussion

In this chapter, I present the results of this study. This chapter provides an explanation of how I collected and interpreted the data to answer the primary and secondary research questions of this study. In terms of my interpretation of formative feedback during the initial phases of designing, I provide examples thereof during the EPoDP. Thereafter, I provide examples to show the level of formative feedback provided during the preliminary phases of design. Finally, I reveal examples of the specific formative feedback statements and questions the teachers used to guide learning through the initial phases of design.

Chapter 5 Summary, limitations and recommendations

The final chapter of this study presents a summary of the key findings and the conclusions I was able to draw in relation to the formulated research questions. In stating the conclusions of this study, I list the potential contribution this study might make on a theoretical and practical level. I specifically emphasise the formulation of a framework for technology teachers for planning formative feedback, which was one of the aims of this study. I conclude this chapter by acknowledging some of the limitations of my study, and present recommendations for future research in technology education settings.

1.13. CHAPTER SUMMARY

In this chapter, I provided a broad overview of my study. I introduced my focus as technology teachers' perceptions and implementation of formative feedback during the EPoDP against the background of existing literature. I motivated the focus of the study and highlighted the relevance, theoretical, and practical contributions of the study to the field of school-based design education. I formulated the research questions and presented the working assumptions, methodological choices, quality criteria and ethical principles that guided my study. I clarified the key concepts in this study and concluded the chapter by presenting a brief overview of the conceptual framework that guided the data collection and analysis of this study. I conclude this chapter by presenting the outline and organisation of this dissertation.

In Chapter 2, I introduce technology as a school subject in South Africa. This is followed by an overview of existing literature on design as a problem-solving activity, formative assessment and formative feedback in design a setting, and formative feedback questions and comments. I conclude this chapter by presenting the integrated conceptual framework guiding the exploration of technology teachers' implementation of formative feedback during the EPoDP.

CHAPTER 2
LITERATURE REVIEW

2.1. CHAPTER OVERVIEW

Chapter 1 offered an overview of, and background to the study. In Chapter 2, I explore the existing literature on formative assessment and formative feedback in design learning environments. As a starting point, I introduce technology as a school subject within the South African curriculum, and provide an overview of design as a complex problem-solving activity. Next, I provide an overview of the existing literature on the benefits of formative assessment and formative feedback in supporting learners' design processes in technology classrooms. Thereafter, I review and present the key findings on the use of questions and comments to support design learning. I conclude the chapter with a detailed discussion on the integrated conceptual framework of this study.

2.2. TECHNOLOGY AS A SCHOOL SUBJECT IN SOUTH AFRICA

In the Curriculum and Assessment Policy Statement (CAPS), implemented from 2011, Technology is defined as "the use of knowledge, skills values and resources to meet the people's needs and wants by developing practical solutions to problems taking social and environmental factors into consideration" (DoBE, 2012, p. 8). The subject of technology aims to develop learners' technological literacy by giving them opportunities to develop, among other things, "critical and creative thinking skills" (DoBE, 2012, p. 8).

The Department of Basic Education requires that the general aims be met by delivering the core content through the design process (DoBE, 2012). The core content areas include structures, mechanical systems and control, electrical systems, and control and processing. The design process prescribed by the DoBE (2012) consists of the following phases: investigate, design, make, evaluate, and communicate (IDMEC). These phases and the skills associated with the activities in each phase should not be viewed in isolation, but rather as interrelated. As a starting point to the Practical Assessment Tasks (PATs), learners are introduced to a problem,

need, or opportunity (DoBE, 2012). The learners should then use the prescribed design process to explore and present possible solutions to these problems (DoBE, 2012).

The investigation phase of the design process involves an exploration of the design problem, need, or opportunity. During the investigation phase, learners should analyse existing products and solutions that could meet the design requirements. Learners should also perform practical tests with the tools and materials. During the design phase, learners write a design brief, review the design specifications and constraints, explore possible, solutions and make preliminary design decisions. In the making phase, learners refine their design solutions and start prototyping and/or building their design solutions. Evaluation is central to the IDMEC design process prescribed by the DoBE (DoBE, 2012). Learners should be able to evaluate existing solutions and design ideas against the criteria of the design requirements, reflect on their progress, and assess the strengths and weaknesses of their design solutions. Communication is observed and applied throughout the IDMEC design process. Learners should present the development of their design solutions through written and graphical representations.

Although the model of the design process in technology is presented as cyclical and iterative, research indicates that many teachers still approach the implementation of the design process in a linear way (de Jager, 2011; Moreland & Jones, 2000). Teaching design linearly promotes product focused design and neglects a formative assessment of the design process. Neuman (2003) explains that learners often require support and continuous assessment from their teachers to ensure iteration when designing rather than focusing only on the design product. Some scholars have noted that designing creative solutions does not come naturally to novice designers, and should be supported through formative feedback (Schut et al., 2018). This study therefore aimed to explore how technology teachers perceive their formative feedback in technology classrooms and how formative feedback questions and comments are used to support learners' design processes at the task, process, and self-regulative levels.

In the section that follows, I explore the literature related to design problem solving. Specifically, I will describe the nature and structure of design problems and solving design problems.

2.3. DESIGNING AS A COMPLEX PROBLEM-SOLVING ACTIVITY

Design-based learning can be described as an instructional approach where learners engage in a process of solving complex, real-world, ill-structured problems (Doppelt et al., 2008; Goel & Pirolli, 1992; Gomez Punte et al., 2013; Visser, 2009). The advantages of using design-based learning include increased learner motivation, resulting from engaging with authentic problems, promoting active learning, and increasing collaborative problem-solving skills through teamwork (Doppelt et al., 2008). Barak (2010) supports the use of authentic contexts by explaining that learning by doing, rich environments for problem-solving activities, and feedback from teachers and peers provide opportunities for technology learners to become more self-regulative.

2.3.1. The nature of design problems

Problems can be placed on a spectrum from well-structured to ill-structured (Goel, 1995, 2014; Jonassen, 2010). Well-structured problems have well-defined initial states, goals states, and transformative states (Goel, 1995, 2014; Jonassen, 2010): the end goal or solution, and the process of solving the problem are predetermined and clear. Examples of well-structured problems include word problems, as well as mathematical and science problems, which can range in complexity but do not rely heavily on context (Goel, 1995, 2014; Goel & Pirolli, 1992; Jonassen, 2010). In short, well-structured problems can range from being simple to very complex, but the solution is not dependant on the context (Jonassen, 2011).

On the other side of the spectrum, ill-structured problems do not have a defined starting point, solution, and process for arriving at a solution (Goel, 1995, 2014; Jonassen, 2010). Jonassen (2011) explains that with ill-structured problems, the constraints on the problem may not be clear at the start of the problem or may be negotiated in the problem-solving process. Contrary to well-structured problems, ill-structured problems are context dependant and naturally seem to be more complex

(Jonassen, 2011). Furthermore, the context of ill-structured problems will influence the context of the solution (Jonassen, 2011).

Design problems are mostly ill-structured and complex types of problems (Jonassen, 2011). Design problems provide very little information about the goal state, the transformative state, and the solution state. This implies that design problems have very little or vague descriptions of the problem, less information about the solution, and no information about the process that must be followed to find a solution to the problem (Goel, 1992; Jonassen, 2010). Furthermore, design problems are so context dependant that "the problems have no meaning outside the context in which they occur" (Jonassen, 2011, p. 8). Design problems can have many unknown constraints, solutions, problem-solving methods, and evaluation criteria (Jonassen, 2011).

Design problems become more complex as the problem statement may change as design solutions are being considered (Dorst, 2019a, 2019b; Dorst & Cross, 2001; Murray et al., 2018). The co-evolution of design problems and solutions means that iterations occur between problem exploration and the exploration of possible solutions (Dorst, 2019a; Dorst & Cross, 2001). This means that designers will often revisit the problem as they start considering possible solutions, and start to explore solutions as they study the problem (Murray et al., 2018). Cross (2004) found that novice designers spend more time exploring the problem than generating solutions. Further to this, Ahmed et al. (2003) found that novice designers were more likely to revert to 'trial-and-error' when exploring design solutions. Conversely, expert designers were observed to evaluate their decisions before implementation (Ahmed et al., 2003). This finding is confirmed by Blom (2019), as he indicates that novice designers in school environments do not engage in sufficient evaluative thinking while solving design problems.

Although research on the use of formative feedback to support learners' processes is emerging (Schut et al., 2018; Stables, 2017a), further research is needed to understand how formative feedback can be used to support specific problem structuring and preliminary problem-solving activities in technology classrooms. The findings from Blom (2019) and Barak (2010) support undertaking this study to explore the use of formative feedback to increase learners' evaluation thinking and self-

regulation while engaging in design tasks rather than relying on trial-and-error strategies.

2.3.2. Early phases of the design process

Goel (1995, 2014) views design problem solving as a process involving multiple steps: problem structuring; the generation of preliminary ideas; refinement; and detailing. Problem framing and preliminary idea generation are considered to be the early phases of the design process (EPoDP).

The EPoDP can be described as the processes where designers explore the scope of an open-ended design problem and initial design ideas (Blom et al., 2018; Dym et al., 2014; Goel, 2014). These stages are usually iterative, unstructured, and include low levels of commitment to design ideas and decisions (Goel, 2014).

In this study, I focused on the EPoDP as existing studies suggests that novice designers spend more time understanding the problem and exploring preliminary design solutions (Blom, 2019; Cross, 2004; Mentzer, 2014). Therefore, it is important to understand how technology teachers support learners' early design phases to enhance the development of learners' technological literacy.

2.3.2.1. Problem structuring phase

The first phase of the design process entails problem structuring. This typically starts with an interpretation of the context of the problem. Goel and Pirolli (1992) describe problem structuring as a process of inquiry to discern the scope, requirements, specifications, and boundaries of the design problem to be solved (Haupt, 2015).

Although problem structuring commonly takes place at the start of the design process, it can occur at any time in the design process (Goel & Pirolli, 1992). As designers consider possible solutions and refine their design ideas, they further define the problem and negotiate the constraints thereof (Dorst, 2019a; Cross, 2004; Murray et al., 2018). There have been limited studies exploring effective problem structuring strategies, and therefore designers' understanding of the design problem is often measured by the fitness for purpose of their design solutions (Liikkanen & Pertulla, 2009; Shah et al., 2000; Shah et al., 2003). Furthermore, Fogler and LeBlanc (2008) note that design students are often taught strategies to find, explore, and define

problems rather than being supported to identify novel problems and explore creative solutions (Murray et al., 2018). This is supported by research suggesting that teachers use well-structured design briefs as this limits the time spent on identifying and exploring the problem (Blom et al., 2018; Mettas & Norman, 2011).

In technology classrooms, problem structuring occurs during the investigation phase of the design process presented, as is evident in the design process prescribed by the DoBE (2012). When learners engage in the investigation phase, they are required to identify and explore the context of the problem, the nature of the problem or need, the user or stakeholder's requirements, and the expected function of the design solution (DoBE, 2012; Goel & Pirolli, 1992). Problem exploration strategies, such as the five 'Why's', brainstorming, and writing out a design problem have been documented in professional design studies. However, limited studies have explored how novice designers' problem exploration and problem structuring phases is supported by teachers in school-based design settings (Murray et al., 2018; Studer et al., 2018).

2.3.2.2. Preliminary problem-solving phase

During the problem-solving phase, designers generate ideas and select initial ideas that could address the problem (Goel & Pirolli, 1992).

In the design process prescribed by the DoBE (2012), preliminary problem solving takes place in the design phase. Activities associated with the design phase include exploring initial ideas, making freehand sketches of possible solutions, writing a design brief with specifications and constraints, planning the design process using a systems diagram, trial modelling, and budgeting (DoBE, 2012).

Once the learners have explored the design problem, the design brief is written. Learners will then proceed to explore and generate possible solutions to the design problem. In the preliminary problem-solving phase, solutions are collected but not fully developed (DoBE, 2012; Goel & Pirolli, 1992). Once possible solutions have been generated, learners are expected to choose and justify one solution to be developed further (DoBE, 2012).

A previous study has shown that novice designers spend more time exploring and generating possible solutions rather than understanding the design problem (Blom et al., 2018). Teachers' formative feedback help learners navigate through problem

structuring and exploration, and the generation of ideas during the design process (Yilmaz & Daly, 2014a). Although limited studies have reported on teachers' use of formative feedback during designing, Stables et al. (2016) point out that learners require interactions with their peers and their teacher to properly understand the design problem and to start generating design solutions. However, studies have shown that due to time constraints, teachers struggle to provide sufficient formative feedback during designing (Mettas & Norman, 2011).

Having explored how designers approach problem solving in design, I will now discuss the role that formative feedback and formative assessment plays in teaching and learning in technology.

2.4. FORMATIVE ASSESSMENT (FA) IN THE TECHNOLOGY CLASSROOM

In this study, assessment refers to "all those activities undertaken by the teacher, and or by their students, which provide information to be used as formative feedback to modify the teaching and learning activities in which they are engaged" (Black & Wiliam, 1998, p. 7; 2010, p. 82). In technology, learners are assessed on their project work in addition to theory (Gumbo, 2020; Kimbell, 2012; Stables, 2017b). In South African technology classrooms, learners engage in Practical Assessment Tasks (PATs) which are design projects (Gumbo, 2020, DoBE, 2012). These PATs form the main formal assessment of learners' skills and application of knowledge during each term, and are intended to formalise the practical component of technology within a knowledge focus (DoBE, 2012). The DoBE (2012) proposes that enabling activities that precede the PAT should be assessed informally as these are intended to develop the knowledge, skills, and values to the point where learners are ready to be assessed formally. These formal assessments should then be used to provide feedback to learners and inform planning for teaching (DoBE, 2012).

Black and Wiliam (1998, 2010) argue that assessment becomes formative when the evidence collected from the teacher and learner activities are used to adapt teaching and meet learners' needs. Wiliam and Thompson (cited in Wylie et al., 2008) support this notion and suggest that assessment becomes formative when it moves learning forward. This may be achieved by providing information about the learning goals, learners' current level of understanding or performance, and steps to move their learning forward (Black & Wiliam, 2009; Wiliam & Thompson, cited in Wylie et al.,

2008). Table 2.1 shows the framework developed by Wiliam and Thompson (cited in Wylie et al., 2008), which summarises the key strategies in formative assessment.

Table 2.1: Key strategies in formative assessment adapted from Wiliam and Thompson (cited in Wylie et al., 2008, p. 7)

	Where is the learner going	Where is the learner right now	How to get there
Teacher	Clarifying, sharing, and understanding learning intentions	Engineering effective discussions, activities and tasks that elicit evidence of learning	The feedback that moves learning forward

From Table 2.1, it can be seen that formative assessment is based on the communication of learning goals, activities, and feedback about the next steps required to achieve the learning goals. In a recent study, Swathi et al. (2020) developed a formative assessment tool for the primary school technology classroom. The tool uses observation and questions to formatively assess key capabilities of potential behaviours underpinning success in technology. In Swathi et al.'s. (2020) study and previous studies by Fox-Turbull (2019, 2017, 2018), the authors did not present guidelines that were specific to the phases of the design process.

2.5. FORMATIVE FEEDBACK

Shute (2008, p. 153) defines formative feedback as "information communicated to the learner that is intended to modify his or her thinking or behaviour for the purpose of improving learning". Similarly, Hattie and Timperley (2007) define formative feedback as "information provided by an agent regarding aspects of one's performance or understanding" (p. 81). When these definitions are considered, it becomes clear that there are three key components that make up feedback formative: the agent (a teacher, peer, textbook, among others), performance or progress, and a way forward (Hattie & Timperley, 2007; Yilmaz & Daly, 2016). In recent years, many studies have focused on the importance of formative feedback and formative assessment in creating and improving effective teaching and learning (Black & Wiliam, 2009; Hattie & Timperley, 2007). Formative feedback is embedded in formative assessment and

has the most significant impact on learning (Black & Wiliam, 2010; Hattie, 2009; Hattie & Timperley, 2007; Stables et al., 2016).

Hattie and Timperley (2007) developed a framework for formative feedback, illustrated below in Figure 2.1, by considering three fundamental questions from a learners' point of view.

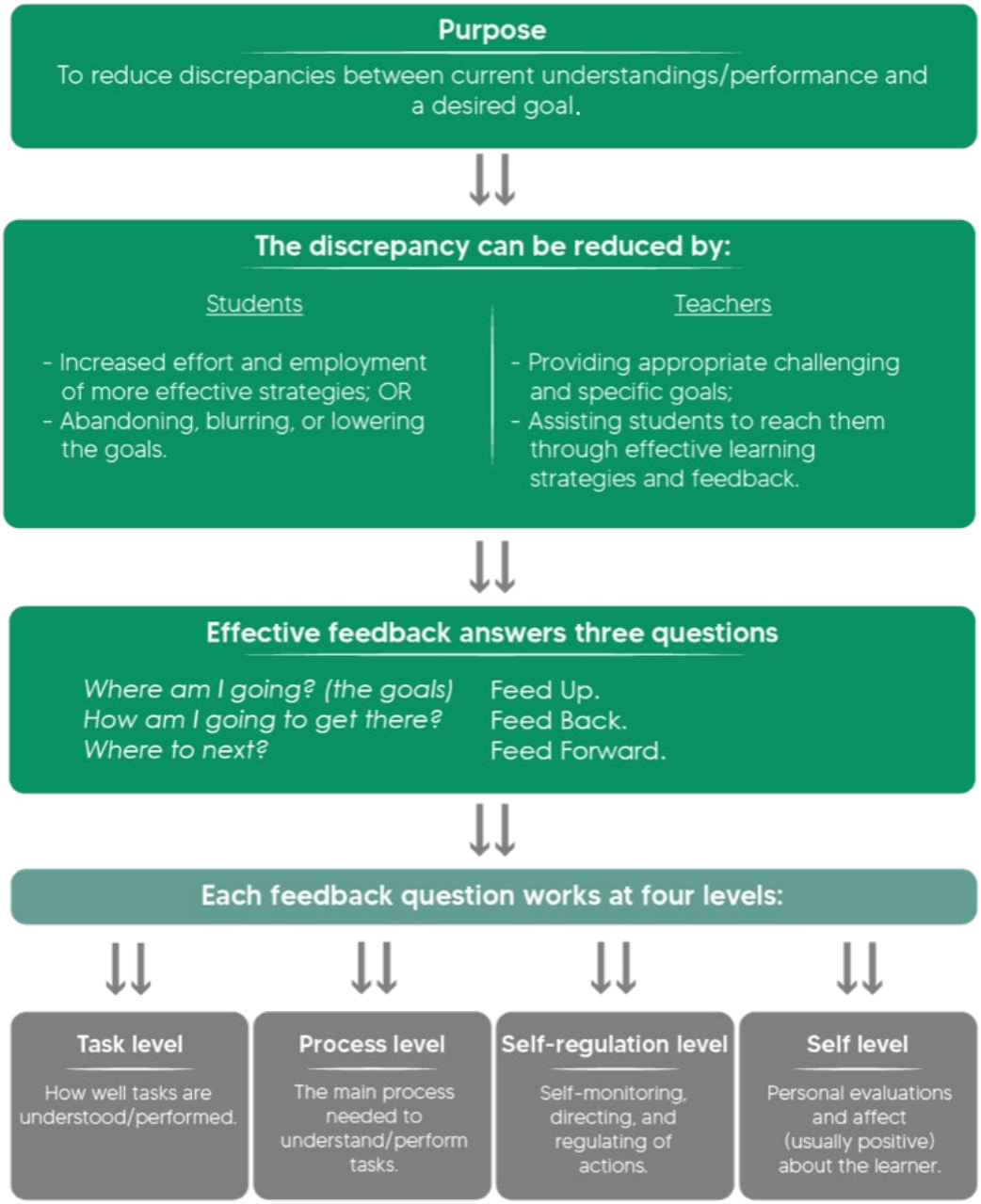


Figure 2.1: Model for formative feedback (Hattie & Timperley, 2007, p. 87)

The model presented in Figure 2.1 indicates that the purpose of formative feedback should be to reduce the gap between learners' current level of understanding and the desired level of understanding. One way in which the learning goal can be reached is through feedback (Hattie & Clarke, 2019; Hattie & Timperley, 2007). Like formative assessment, effective feedback aims to provide information about the learning goals, the learners' progress towards meeting the goals, and the steps taken to reach the learning goals (Hattie & Clarke, 2019; Hattie & Timperley, 2007). The question 'where am I going?' focuses on the goal task's objectives (Hattie & Timperley, 2007). The formative feedback that supports this questions focuses on the objectives that a learner has to meet, and what it will look like if the objective has been achieved (Hattie & Timperley, 2007).

During a design problem-solving activity, feedback may be considered valuable if the information provided supports learners in defining the task's goals. Furthermore, effective feedback will be observed as information that helps learners monitor their progress and identify their next steps. One way to provide helpful feedback during a design task may be to ask learners questions to determine how they define the design problem and the goals of the design task. Questions that determine where the learners are in relation to the learning goals include verification and clarification questions. Studies in school-based design settings have shown that asking questions that encourage learners to clarify their understanding of the design task and design goals is an effective way to start the feedback process (Schut, Van Mechelen, Klapwijk, Gielen, & De Vries, 2021; Stables, 2017a; Stables et al., 2016).

The second question, 'how am I going to get there', focuses on the learners' current level of understanding or performance. Formative feedback that supports this question provides information on learners' progress, promising aspects, and improvement opportunities (Hattie & Timperley, 2007, 2012). Here, the purpose should be to provide learners with information on where they are in relation to the objective and how to proceed in order to achieve these objectives (Hattie & Timperley, 2007, 2012). In a design problem-solving task, questions that encourage reflection and evaluation may be beneficial in supporting learners to consider their progress and level of understanding.

The third question, 'Where to next' is the question that is the most powerful in terms of learning (Hattie & Timperley, 2007, 2012). Formative feedback based on this question guides learners on their next steps to solve an ill-structured design problem. This can be done by calling the learner to action by providing formative feedback about what is and is not understood by learners, providing new processes to complete the task, and enhanced challenges. Guiding learners on their next steps should be an important feature of formative feedback during the design process (Stables et al., 2016). Formative feedback questions that may support learners to plan their next steps could be related to new methods and considering similar problem scenarios.

2.5.1. The four levels of formative feedback

Hattie and Timperley (2007) suggest that formative feedback can occur on four levels, based on the focus of the formative feedback: task level, process level, self-regulation, and the level of the self (see Figure 2.1).

2.5.1.1. Task-related formative feedback

Formative feedback focused on the task level is often considered as corrective formative feedback (Hattie & Timperley, 2007). The purpose of task-level formative feedback is to provide information about the correctness of the task being performed and how well the task is being performed (Hattie & Timperley, 2007). Task-related formative feedback typically provides information to the learner on how well the task has been accomplished or what needs to be done to improve their work (Hattie & Timperley, 2007).

In this study, task-related formative feedback is considered as any information provided by the teacher to distinguish correct from incorrect answers, acquiring specific information, building surface knowledge, and clarifying what a learner needs to do to improve their work (Hattie & Timperley, 2007, 2012). Formative feedback at this level could include compliments, critique, or recommendations for improvement that learners need to make to their work. In addition, formative feedback to help build learners' surface knowledge by asking them to complete concepts, make comparisons, or define terms is also considered task-related feedback. In this study, task-related formative feedback included formative feedback questions and comments

that guided learners' problem structuring and preliminary problem-solving activities. Examples of task-related formative feedback are discussed in detail in Appendix D.

2.5.1.2. Process related formative feedback

Formative feedback on the process level is concerned with how the task was approached, information about alternative strategies of how the task could have been approached, and the relationship between what learners did and how well they did it (Hattie & Timperley, 2007, 2012).

In this study, formative feedback regarding the process relates to information about the methods that learners used to structure the problem and generate preliminary solutions. More specifically, formative feedback questions and comments that support learners' exploration of the methods and processes used in problem structuring and preliminary problem solving are considered to be process-level feedback. The purpose of formative feedback at this level should be to help learners to learn from and detect errors in their methods, to provide cues for the information that learners need to gather to be able to move forward, and to help learners to establish relationships between ideas (Hattie & Timperley, 2007, 2012). Examples of process-level feedback are provided in Appendix D.

2.5.1.3. Self-regulative formative feedback

Self-regulative formative feedback calls learners to action. This encourages them to think about what they did wrong and what their next steps should be to move closer to the learning goal.

The purpose of self-regulative formative feedback should be to allow learners to monitor and assess their own work, and consider how to improve their performance. This formative feedback should help learners to consider their design ideas and decisions regarding the design brief. It will also allow learners to think of ways to develop and improve their ideas further (Hattie & Timperley, 2007). Self-regulative formative feedback is likely to relate to student goals and self-assessment (Brooks et al., 2019).

In the current study, formative feedback questions and comments were considered to be self-regulative when the questions and comments were encouraging students to

be reflective. This means that formative feedback questions and comments could be identified when a teacher prompted their learners to self-evaluate their problem structuring and preliminary problem-solving activities, and consider what their next steps should be to meet the requirements of the task.

2.5.1.4. Formative feedback about the self

Formative feedback about the self often manifests as statements, positive or negative, about the person to whom the feedback is provided. These utterances rarely provide information about a learners' progress on a task or process (Hattie & Timperley, 2007, 2012). These statements seldom have an effect on learners' understanding or engagement with a task. A statement such as "I like that" or "good boy/girl" is considered formative feedback about the self (Hattie & Timperley, 2007, p. 96).

In the present study, formative feedback at the self-level presents as affective statements, usually compliments, about learners or their tasks. Formative feedback statements about learners' tasks that do not support a learner's problem structuring or preliminary problem-solving activities are considered self-level feedback.

In recent years, several studies have focused on the development of tools and frameworks to assist teachers in planning and implementing formative feedback in classrooms (Brooks et al., 2019; Schut et al., 2020, 2021; Stables, 2017a; Stables et al., 2016; Swathi et al., 2020). These studies have shown how formative feedback frameworks can assist teachers to plan and implement feedback at different levels, promote creativity, promote convergent and divergent thinking, and help teachers to provide feedback on key competencies in a subject. Stables (2017a) specifically shows how formative feedback through on-screen avatars can assist learners during their design processes. Although all of these frameworks have proven valuable in assisting teachers in planning and implementing formative feedback, these frameworks did not consider feedback within specific phases of the design process. Except for those of Schut and Blom (2019) and Schut et al. (2018, 2020, 2021), the feedback frameworks presented by the authors listed above only focused on the use of questions as a way of providing feedback, and did not consider the use of statements or comments as a feedback method.

2.6. FORMATIVE FEEDBACK DURING DESIGNING

In design learning settings, formative feedback has been described as an interaction between the instructor and the students. This exchange concerns the students' progress and necessary changes to their design tasks or processes (Yilmaz & Daly, 2016).

Previous studies have shown that feedback is an essential part of the relationship between teachers and learners in design learning environments (McLain, 2021). Within professional design studies, design reviews and design critiques describe the interactions between students and instructors in design studios. Design reviews and design critiques allow instructors to provide formative feedback on students' projects, highlight promising or problematic aspects of the design, or make suggestions for further investigations (Cardella et al., 2014; Cardoso et al., 2014). Formative feedback is commonly provided through design reviews and design critiques and may include oral, written, video-assisted, audio-assisted, and computer-assisted feedback (McLain, 2021; Wisniewski et al., 2020).

McLain (2021) explains that teachers in school-based design education often engage in 'desk crits' (Caldwell et al., 2016), which serve formative feedback purposes. Despite the potential benefits of formative feedback for learning in design learning, studies have indicated that teachers often have difficulty constructing feedback, and learners have trouble receiving and interpreting feedback from their teachers (Cardella et al., 2014; Schut & Blom, 2019; Schut et al., 2018, 2020, 2021; Yilmaz & Daly, 2014b, 2014a, 2016). Therefore, this study may make a practical contribution to the field of formative feedback in technology classrooms. This will be attempted through presenting a framework that can be used to provide learners with formative feedback during these 'desk crits' in the early phase of the design process.

This section reviewed the three main questions that guide formative assessment and formative feedback. What follows is an overview of the role of questioning in technology classrooms, with the purpose of providing formative feedback to learners during their design processes. To this end, I will provide an overview of the questioning models frequently found in classrooms, as well as an overview of Eris' (2004) Inquiry-Based Design Model, which is commonly found in design education settings.

2.7. FORMATIVE FEEDBACK QUESTIONS AND COMMENTS IN DESIGN LEARNING ENVIRONMENTS

Questioning is a popular technique for facilitating the process of problem solving. The use of questions to facilitate design has been the focus of several recent studies (Aurisicchio & Bracewell, 2009; Schut et al., 2018, 2020; Stables, 2017a; Stables et al., 2016). These studies have shown that questions can be used to transform learners' ideas into the development of solutions, and encourage creativity in their designs (Schut et al., 2018, 2020; Stables et al., 2016). To this end, Swathi et al. (2020) developed a framework of questions that technology teachers can use as conversation starters in order to develop learning in technology.

Eris (2004) developed a comprehensive model of questions to characterise the nature of questioning during design. These questions were observed during the design process by professional design students (Eris, 2004). Aurisicchio and Bracewell (2009) and Eris et al. (2007) agree that questioning is a key aspect of the design process, and this therefore requires designers to ask questions continuously through the design process. Eris et al. (2016) suggest that studying the questioning behaviour of designers during the idea generation phase of the design process is important as this phase is most likely to determine the quality of the design outcomes.

According to Eris (2004), questions can be divided into two types depending on their purpose: low-level and high-level questions. High-level questions can further be divided into Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). Low-level questions and Deep Reasoning Questions aim to find a single best solution to a problem or answer to a question (Cardoso et al., 2014; Eris, 2004; Schut et al., 2018). Examples of such questions are multiple-choice questions, true and false questions, and comprehension questions. These questions are often dependent on a truth value (Eris, 2004), and have been linked to evidence of convergent thinking (Eris et al., 2007). In contrast, Generative Design Questions are evidenced by divergent thinking and seek to find multiple solutions or answers to a problem or question. The purpose of Generative Design Questions is to generate as many possible answers or possibilities from a single starting point (Cardoso et al., 2014; Eris, 2004; Schut et al., 2018). The correctness of Generative Design Questions is determined subjectively as such questions are often used to assess design decisions (Eris et al., 2007).

The common characteristic between low-level questions and DRQs is that the answer is known. In other words, the question has a truth value (Cardoso et al., 2014). 'How many wheels do we have?' is an example of a low-level question. The question can be answered by learners counting the number of wheels in the picture before them. An example of a DRQ would be: 'why do we need to attach a wheel?' This question has a known answer, but learners must answer this question based on previously known facts. In other words, this question can be answered by converging facts. The difference between low-level questions and DRQs is that low-level questions are used to confirm or validate what is known, whereas DRQs are used to explain facts or designers' understanding (Cardoso et al., 2014).

In contrast to low-level questions and DRQs, GDQs do not necessarily hold a truth value, but rather seek to elicit multiple known and unknown possible answers to any given question (Cardoso et al., 2014). The purpose of GDQs is to disclose known answers and elicit unknown answers. GDQs can be characterised as questions where the questioner attempts to move away from facts towards possibilities that could be collected from these facts (Cardoso et al., 2014). For example, during the design process, learners might experience an object slipping, which could lead to the question 'how can we stop it from slipping?' This question can be answered by listing a number of non-slip materials or methods. Therefore, there is not only one correct answer, and the answer(s) will depend on the design context and problem.

One of the limitations of Eris' (2004) study is that the taxonomy he created does not differentiate between the questions asked during the two distinct phases of design: problem structuring and preliminary problem solving. In addition, since the taxonomy was developed based on interactions between designers and not between teachers and learners, the author did not consider how the questions related to task, processes, self-regulation, and the self.

In a study focused on formative feedback in primary technology classrooms, Schut et al. (2018), added two categories of low-level questions to the model, 'compliments' and 'critique'. Schut and Blom (2019) further expanded Eris' (2004) model by adding 'direct recommendations' as a category. They also renamed the categories including compliments, critique, and direct recommendations to a more all-encompassing category called 'low-level comments'. In their latest research, Schut et al. (2020)

further adapted the model by including a 'description' as a category in low-level comments, and 'future' and 'future description' under Deep Reasoning Questions. The two original question categories identified by Eris (2004) as low-level questions and high-level questions have subsequently been renamed as low-level feedback and high-level feedback. The Design Feedback Model developed by Schut et al. (2020), built on Eris (2004) Design-Based Inquiry Model, is illustrated in Figure 2.2 below.

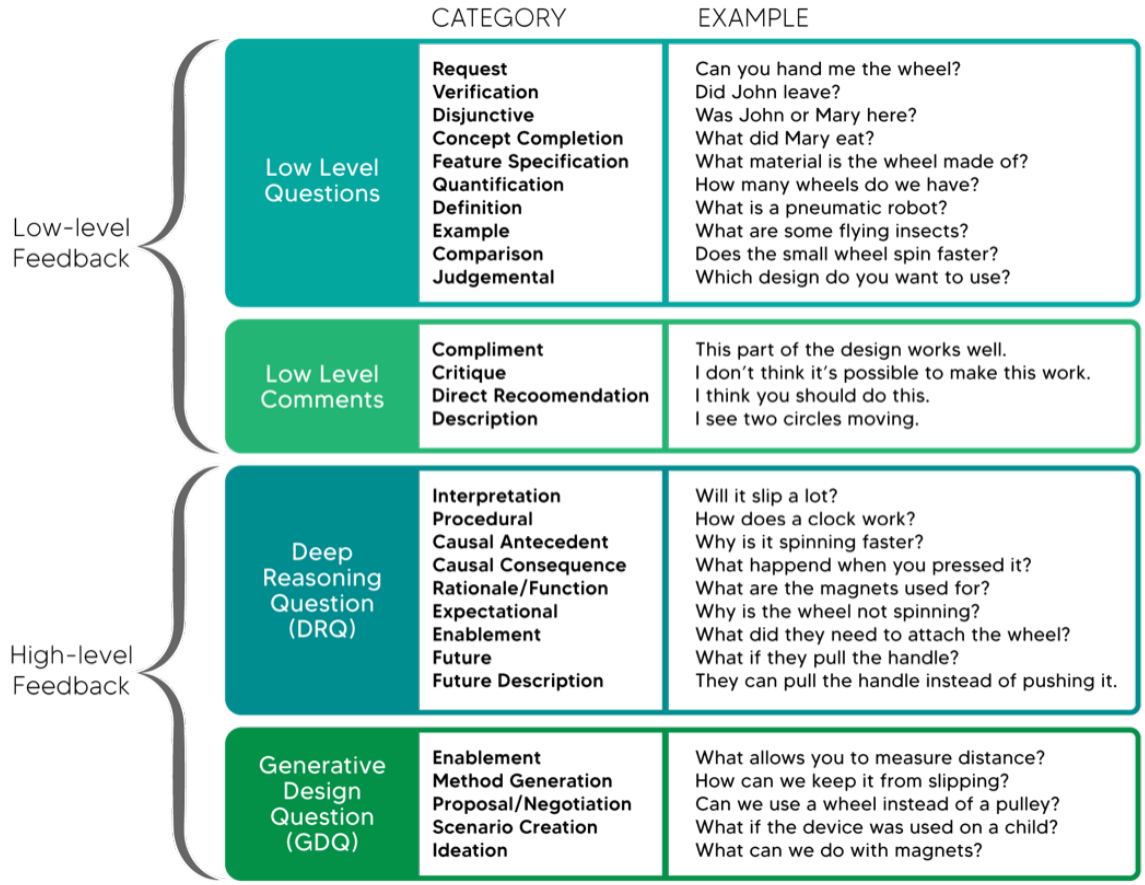


Figure 2.2: Design Feedback Model (Schut et al., 2020)

Figure 2.2 indicates that low-level feedback includes low-level questions and low-level comments. Low-level questions may be characterised as information-seeking questions as these questions usually encourage learners to clarify or verify aspects of their design. Low-level comments are statements that may include suggestions, positive or negative judgements, and descriptions of the learners' designs. Similar to Eris' (2004) model, Schut et al. (2020) divided high-level feedback into Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). High-level

formative feedback requires higher levels of reasoning by focusing on reflection, evaluation, and generation (Schut et al., 2020). DRQs are based on the assumption that a specific answer or answers exist, whereas GDQs prompt idea generation and propose alternative answers (Schut et al., 2020).

The efficacy of introducing an on-screen avatar as a mentor when teachers are not available to assist learners during their design processes has been studied by Stables et al. (2016). The authors argue that there is a need to create a web-based conversation tool to support learners' expression of ideas and challenges, allowing learners to become autonomous in identifying their next steps (Stables et al., 2016). The preliminary questioning framework for the avatars presented by Stables et al. (2016), in part, builds on prior research on the use of hypothetical, powerful questions and speculative language. The authors proposed a questioning framework that is divided into three levels: mind-reading questions, mentoring, and management questions (Stables et al., 2016). Mind reading questions provide information about what the learner is trying to do, whereas managing questions provide information about how the learner will resolve or realise the project. Mentoring questions provide information on what the next steps could be.

Based on these definitions, and Hattie and Timperley's (2007) descriptions of the three fundamental feedback questions, some similarities were observed as illustrated in Table 2.2.

Table 2.2: Similarities between the feedback frameworks

Hattie and Timperley (2007; 2012)	Stables (2016)
Where am I going?	Mind reading questions.
How am I going to get there?	Managing questions.
Where to next?	Mentoring questions.

I suspect that Stables et al.' (2016) mind reading questions could support learners' thinking about their design intentions and may answer the question 'where am I going?' Similar to Stables et al.'s (2016) managing questions, Hattie and Timperley explain that feedback about learners' progress and how to proceed helps learners answer the question, 'how am I going to get there?' Finally, both the mentoring and 'where to next?' questions seem to emphasise learners receiving information on how

to proceed and “greater possibilities for learning” (Hattie & Timperley, 2007, p. 90; Stables, 2017a).

Stables (2017a) provides a more recent framework with a taxonomy of questions found under mind-reading, managing, and mentoring questions. The questions are customised to learners depending on whether they have ideas, are growing ideas, or providing ideas (Stables et al., 2016). The study provided valuable insight into how on-screen avatars can be used to facilitate a designerly way of thinking through dialogic questioning. Although I suspect that there is a link between the question types used by Stables et al. (2016) and those used by Hattie and Timperley (2007), there was no comparison made in the research paper.

The limitations identified in the feedback model identified by Hattie and Timperley (2007) and the models for investigating teacher questions in technology education by Schut et al. (2020) and Stables et al. (2016) necessitated the development of an integrated conceptual framework for this study. The conceptual framework in this study had to enable the exploration of technology teachers’ formative feedback questions and comments at different formative feedback levels to support learners’ problem structuring and preliminary problem-solving activities in technology classrooms.

In the preceding section, I provided a synopsis of the literature on questions and comments as a formative feedback strategy in design learning settings. I also reviewed existing questioning frameworks for investigating and implementing formative feedback in design settings. Finally, I examined the limitations of existing frameworks against the aims of this study. In the following section, I present, discuss, and justify an integrated conceptual framework for investigating the formative feedback practices of technology teachers during the design process.

2.8. TOWARDS A CONCEPTUAL FRAMEWORK

To answer the research questions guiding this study, I developed a conceptual framework to explore how technology teachers use formative feedback to support different levels of learners’ problem structuring and preliminary problem-solving activities. I combined Goel and Pirolli’s (1992) description of the early design phases with Hattie and Timperley’s (2007) Model of Feedback, and Schut et al.’s (2020)

Design Feedback Model. Figure 2.3 illustrates the conceptual framework used to guide this study.

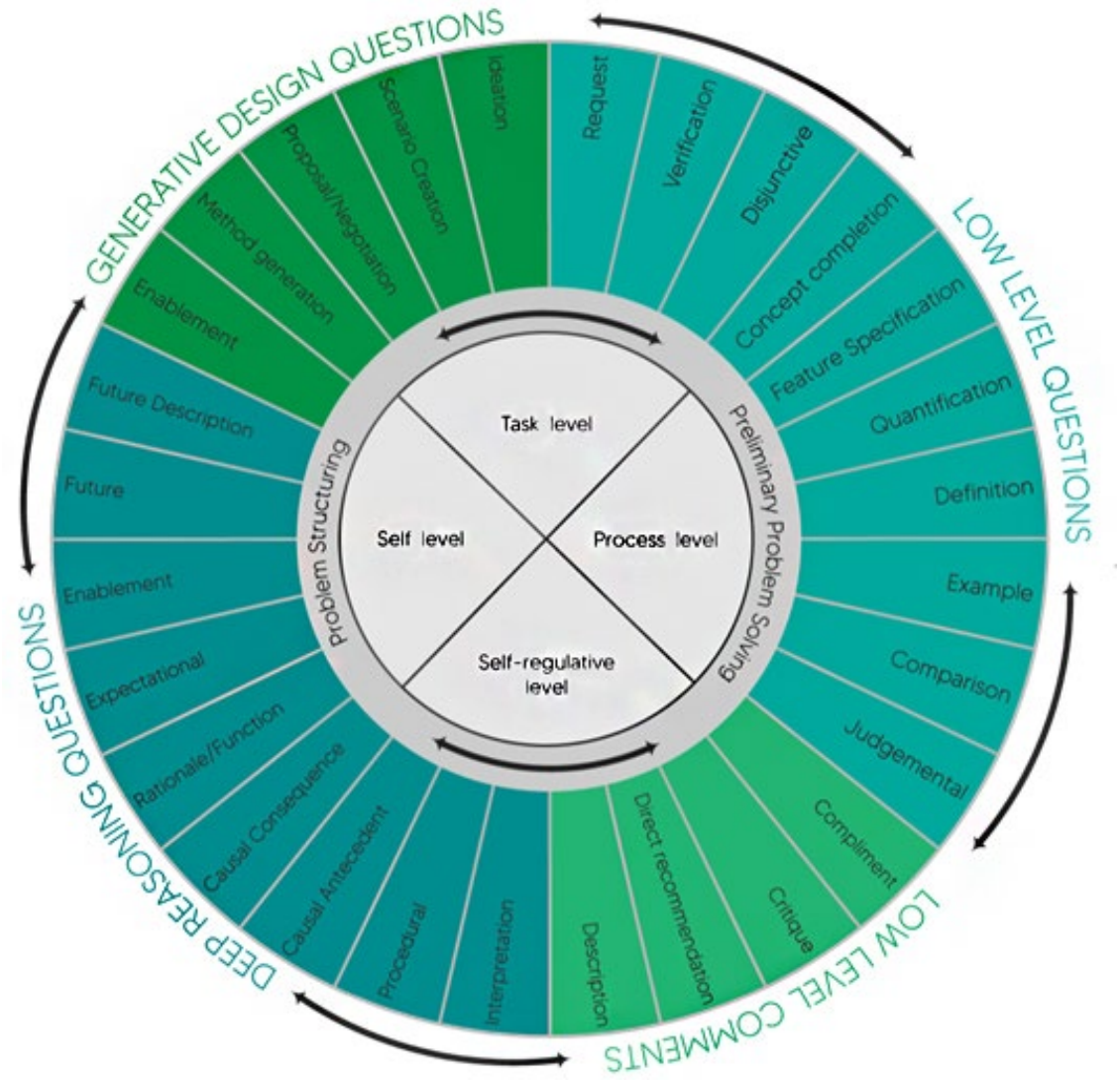


Figure 2.3: Types of formative feedback questions and comments on four distinct levels during the early phases of the design process

The conceptual framework shown in Figure 2.3 allowed me to explore three aspects of technology teachers' formative feedback practices. First, I was able to investigate how technology teachers use formative feedback to assist learners with problem structuring and preliminary problem solving. I defined problem structuring activities as activities related to analysing the scope of the problem, the problem context, users' needs and wants, tools and materials, and the exploration of existing solutions (DoBE, 2012b; Goel, 1995). Activities related to the preliminary design phase included writing a design brief, defining the design specifications and constraints, generating

preliminary solutions, and making preliminary design decisions (DoBE, 2012b; Goel, 1995).

Secondly, I included Hattie and Timperley's (2007) conceptualisation of task, process, self-regulative, and self-level feedback. A recent study identified eight scenarios where professional design instructors needed to support students (Strong et al., 2019). These scenarios included supporting students to consider the learning intent, strategise to realise design goals, make design decisions, take ownership of their design decisions, and be reflective. In the context of school-based design education, researchers have shown that aspects such as time management and teamwork (Moreland & Jones, 2000) are vital when providing feedback. Researchers have also pointed out that assessment and formative feedback are mostly teacher-led and do not support learners developing creative solutions to design problems (Barlex, 2008).

Considering the differences in the focus of formative feedback in professional design practice and school-based design settings, I wanted to explore how technology teachers supported learners at task level, process level, self-regulation level, and self-level (Hattie & Timperley, 2007). Task-level formative feedback provides information about the design task (Hattie & Timperley, 2007; Tawfik et al., 2020). Task-level feedback can include any questions or comments that guide learners in exploring the scope of the problem, the user's needs and wants, tools and materials, existing products, design specifications and constraints, making preliminary design decisions, and generating preliminary design solutions. Process-level feedback is described as any questions or comments that guide learners regarding the processes or procedures that are needed to complete the task (Hattie & Timperley, 2007; Tawfik et al., 2020). In this way, process-level feedback can be viewed as formative feedback questions and comments that guide learners on how to explore the scope of the problem, the user's needs and wants, tools and materials, and existing products. Process-level feedback includes the contemplation of design specifications and constraints, making preliminary design decisions, and generating preliminary design solutions. The third level of formative feedback is self-regulative feedback, which can be described as feedback that guides learners' self-monitoring and self-reflection (Hattie & Timperley, 2007; Tawfik et al., 2020). Therefore, formative feedback questions and comments must be self-regulative if the aim is to guide learners in considering how they can improve their problem structuring and preliminary problem-solving activities, and what

their next steps should be to realise their design goals (Hattie & Timperley, 2007; Tawfik et al., 2020). Lastly, formative feedback at the self-level consists of questions and comments about the learner. Feedback on this level does not relate to the task or processes at hand (Hattie & Timperley, 2007; Tawfik et al., 2020).

Finally, to explore how the participating teachers used questions and comments during the design process, I integrated Schut et al.'s (2020) Design Feedback Model into the conceptual framework of this study. The questions and comments are divided into low-level questions; low-level comments; Deep Reasoning Questions; and Generative Design Questions (Schut et al., 2020).

Low-level formative feedback questions are used to gather information about the design task (Schut et al., 2020). Low-level formative feedback questions can be identified as questions that aim to clarify and verify learners' understanding of the scope of the problem, users' needs and wants, tools and materials, and existing products (Schut et al., 2020). In addition, low-level formative feedback questions may support learners' understanding of design specifications and constraints, making preliminary design decisions, and generating preliminary design solutions (Schut et al., 2020). Low-level comments are statements about the learners' design tasks and can include compliments, criticism, recommendations, and observations about the learners' problem structuring and preliminary problem-solving activities (Schut et al., 2020). Deep reasoning questions can be used to explore learners' reasoning for their problem structuring and preliminary problem-solving activities (Schut et al., 2020). In contrast to low-level questions and comments, and deep reasoning questions, Generative Design Questions can be used to explore methods and procedures to realise design goals (Schut et al., 2020).

2.9. SUMMARY

In this chapter, I explored the existing literature on formative assessment and formative feedback in professional and school-based design settings. As a starting point, I provided a broad overview of technology as a subject in South-African classrooms, design as a problem-solving activity, the nature of design problems in technology, and the phases of the design process. Thereafter, I discussed previous studies that focus on formative feedback in school-based and professional design settings. More specially, I discussed the use of questions and comments as a strategy

to support learners' design processes. I concluded this chapter by presenting and discussing the integrated conceptual framework of this study. The conceptual framework for this study is based on Goel and Pirolli's (1995) characterisation of the EPoDP, Hattie and Timperley's (2007) Model of Feedback, and Schut et al.'s (2020) Design Feedback Model.

In Chapter 3, I discuss and explain the methodological decisions guiding this study. I describe the interpretivist paradigm and the single case study research design that I implemented. I also explain the data collection, documentation, analysis, and interpretation procedures, as well as the quality measures that I used to ensure ethical and rigorous research.

CHAPTER 3
RESEARCH DESIGN AND METHODOLOGY

3.1. CHAPTER OVERVIEW

In Chapter 2, I reviewed the development of technology as a school subject in South Africa and the teaching and assessment methodologies prescribed by the DoBE. Following this, I reviewed the existing literature on design as a complex problem-solving activity, formative feedback during design activities, and formative feedback questions and comments. An explanation of the conceptual framework of this study and the existing frameworks that informed the development of the conceptual framework concluded Chapter 2.

In this chapter, I explain and justify my methodological choices concerning the purpose of this study and the research questions outlined in Chapter 1. In Figure 3.1 below, I present a delineation of the research methodology and the main methodological decisions regarding the study.

Figure 3.1: Overview of the research methodology

Figure 3.1 summarises the research methodology that I followed in this study. In the following sections, I describe and justify my selected research paradigm, research approach, research design, data collection, documentation, analysis, and interpretation procedures. I conclude the chapter with a discussion on the measures implemented to enhance the rigour and ethical protocols enacted when conducting this study.

3.2. RESEARCH PARADIGM: INTERPRETIVISM

I employed an interpretivist paradigm to gain insight into the participants' perceptions and implementation of formative feedback to support learners' design processes. Interpretivism can be described as a worldview in which "individuals seek understanding of the world in which they live and work, they develop subjective meanings of their experiences" (Creswell & Poth, 2018, p. 24). In this study, working within the interpretivist paradigm meant that I assumed that the participants constructed their perceptions and implemented formative feedback through their classroom interactions when facilitating ill-structured, design-based problem-solving tasks. Undertaking an interpretivist stance, I relied on key philosophical assumptions, viz. ontology, epistemology, methodology, and axiology in conducting this study. The key philosophical assumptions and the implications for this study are presented in Table 3.1.

Table 3.1: Philosophical assumptions and implication for practice (adapted from Creswell & Poth, 2018, p. 43; Cohen et al., 2018, pp. 288–289)

Assumption	Questions	Characteristics	Implications for this study
Ontological	What is the nature of reality? What are we trying to understand?	Reality is multiple as it is seen through many perspectives. Meanings and perspectives are context-bound.	I interviewed and observed multiple participants and report on different perceptions and the implementation of formative feedback as themes developed in the data.

Assumption	Questions	Characteristics	Implications for this study
Epistemological	How is knowledge constructed? What evidence constitutes 'knowledge'? How can we know about something?	Subjective evidence from the participants. The researcher aims to lessen the distance between themself and the participants.	I relied on quotes as evidence of formative feedback. I collaborated with the participants by performing member checks to gain their interpretations.
Methodological	What is the process of research?	Inductive logic studies topics in a natural setting and provides "thick descriptions" of the contextualised behaviour.	I did not aim to generalise the findings but to gain a detailed understanding of the participants' perceptions and implementation of formative feedback. I provide detailed descriptions of the context and participants. I was a reflective researcher.
Axiological	What is the role of values and ethics in the research process?	The researcher acknowledges biases and the ethical standards for conducting research.	I declared my working assumptions before data collection. I report possible biases that may have influenced my interpretation of the data. I relied on the ethical principles of permission to conduct research, voluntary participation, safety from harm, confidentiality,

Assumption	Questions	Characteristics	Implications for this study
			anonymity, and the right to privacy. I declared potential benefits for the participants of this study.

Table 3.1 provides an overview of the philosophical assumptions that guided this study by referring to the characteristics of each assumption and the implications for this study. In Sections 3.2.1.1 to 3.2.1.4, I will elaborate on the philosophical assumptions guiding this study and the implications thereof for the research process.

3.2.1.1. Ontological assumptions

Ontology relates to "the nature of reality and its characteristics" (Creswell & Poth, 2018, p. 42). The ontological stance in an interpretivist framework suggests that the meaning that participants actively construct through interactions and interpretations is context-bound and consists of multiple realities (Creswell & Poth, 2018; Denzin & Lincoln, 2018). Therefore, I chose the participants' everyday technology classrooms as the research sites (see Section 3.5.2) to collect interview and observational data about their perceptions and implementation of formative feedback. Creswell and Poth (2018) and Denzin and Lincoln (2018) suggest that qualitative research reports on the multiple realities of the participants by presenting the different themes that emerge. Qualitative research further quotes the participants' words to convey different perspectives of the phenomenon being studied. I assumed that the participants' perceptions and implementation of formative feedback are discoverable through interviews and observations. Hence, I selected 12 participants to interview and five participants to observe. Data analysis within the interpretivist paradigm is typically analysed inductively to identify the themes and related sub-themes to describe the participants' perceptions of formative feedback (Mack, 2010). The interview data in this study were analysed inductively to identify the themes and sub-themes related to the participants' perceptions of formative feedback. I also analysed the observational data deductively against the conceptual framework of this study to present my findings

on the participants' implementation of formative feedback. Finally, I included utterances as examples to present the participants' perceptions and implementation of formative feedback (see Chapter 4), and interpret the results against existing literature.

3.2.1.2. Epistemological assumptions

Epistemology refers to what constitutes evidence of knowledge (Creswell & Poth, 2018). To lessen the distance between myself and the participants, I collected the interview and observational data for this study in the participants' usual technology classrooms. Furthermore, the participants' responses to the interview questions and their verbal utterances towards learners during the classroom observation were deemed as observable evidence. I considered it necessary to gain a deeper understanding of the role of formative feedback during designing (refer to Chapter 2) in an attempt to enhance my understanding of the participants' experiences and challenges in facilitating learners' design processes

Several authors (Denzin & Lincoln, 2005, 2018; Patton, 2002; Cohen et al., 2018) have argued that conducting qualitative studies in the participants' natural contexts allows researchers to gain insights into the participants' experiences, and provides rich and context-specific descriptions of their experiences. Similarly, conducting interviews and observations in the participants' technology classrooms allowed me to gain insight into their perceptions and implementation of formative feedback and provide detailed descriptions of the classroom environment. Collecting data in the participants' day-to-day technology classrooms meant that the results of this study were obtained from a "particular situation as was not reduced to simplistic interpretation" (Mack, 2010, p. 8). Mack (2010) suggests that collecting data in the participants' natural environment within a specific context means that inductive methods should be used to present the findings.

3.2.1.3. Methodological assumptions

Methodology has to do with the research process and how knowledge is constructed (Denzin & Lincoln, 2018). Methodologically, interpretivism allowed me to use various data collection techniques to ensure that multiple views on the use of formative feedback are represented. Since the study was conducted in the participants' natural

setting, I was able to provide thick and holistic descriptions of the context, and continuously revise my experiences in the field. Furthermore, I adhered to the principles of reflexivity by reflecting on my assumptions and biases, being aware of participants' reactivity, and explaining my role as researcher, as Durdella (2019) suggests. By adopting a reflective practice, I was able to ensure that I provided true and full accounts of the participants' perceptions and implementation of formative feedback.

3.2.1.4. Axiological assumptions

The axiological assumptions in qualitative studies correlate with the researcher's assumptions and how these assumptions are implemented in a study (Creswell & Poth, 2018). I presented my working assumptions in Section 1.7, and continuously reflected on how my prior experiences, knowledge of the research topic, values, and biases may have shaped my interpretations. To ensure that my research is conducted ethically, I obtained permission from the University of Pretoria's research ethics committee, the Gauteng Department of Basic Education, school district directors, school principals, the teachers, and parents. I also obtained informed assent from the learners present in the class during the observations. I adhered to the principles of voluntary participation, safety from harm, confidentiality, anonymity, and respect for participants' privacy. Finally, I disclosed any potential benefits that the participants might experience.

One challenge associated with interpretivist research is the theoretical concepts that the researcher brings to the data analysis process (Terry et al., 2017). In taking a data-led approach to the data analysis of the interview data, I addressed this potential challenge by declaring my working assumptions before analysing the data. Following Mack's (2010) suggestions, declaring my working assumptions enabled me to analyse the data and allow my interpretations of the participants' perceptions and practices to be shaped by the data instead of my preconceptions. I conducted a deductive analysis of the observational data to ensure that I was able to triangulate the results obtained in this study. The theoretical concepts in the conceptual framework of the study provided the foundation for the analysis of the observational data (Terry et al., 2017).

The use of multiple data sources and instruments meant that I subscribed to data and instrument triangulation (Cohen et al., 2018). On the one hand, data triangulation

involves using various data collection and analysis methods (Cohen et al., 2018d). On the other hand, instrument triangulation involves the use of multiple data collection instruments (Cohen et al., 2018). Triangulation is further discussed under quality assurance in Section 3.9.

Finally, the lack of generalisability commonly associated with interpretivist studies was addressed by careful selection of the boundaries of the study (Durdella, 2019). The aim of this study was not to generalise the findings, but to gain an in-depth understanding of teachers' perceptions and the implementation of formative feedback. However, the thick and holistic descriptions of the settings and participants may allow for the findings to be transferred to similar contexts (Mack, 2010).

3.3. RESEARCH APPROACH: QUALITATIVE RESEARCH

Qualitative research is concerned with gaining an in-depth "understanding of the meaning people have constructed, that is how people make sense of the world and the experiences they have in the world" (Merriam & Tisdell, 2015, p. 15). Qualitative research aims to understand the phenomenon as part of a particular context through thick descriptions instead of only analysing numerical data (Ary et al., 2006; Cohen et al., 2018; Patton, 1985). Ary et al. (2006) note that the goal of qualitative research is to gain a holistic view of the phenomenon rather than breaking it down into variables. This can be achieved by trying to understand the event from the participants' point of view rather than the researcher's (Hancock & Algozzine, 2011).

In this study, I provided detailed descriptions of the participants' perceptions of formative feedback and their implementation thereof during a design task. More specifically, I focused on describing their formative feedback during the early phases of the design process (EPoDP), the different levels of the formative feedback, and the types of formative feedback questions and comments utilised to support learners' design processes. In concurrence with Cohen et al. (2018), the qualitative data in this study was collected based on the setting and context of the study rather than merely being collected for collection's sake. In this manner, I assumed that the participants' formative feedback would be dependent on the design task. I therefore aimed to collect data about the participants' implementation of formative feedback rather than focusing on the frequency thereof.

Using multiple sources of data and involving multiple participants (Cohen et al., 2018) allowed me to present a holistic account of the participants' perceptions and their implementation of formative feedback during design tasks. Using a qualitative approach allowed me to analyse the data inductively and deductively. The themes that emerged from the inductive analysis of the interview data guided my interpretation and discussion of the results. Analysing the observational data deductively enabled me to provide detailed descriptions of the participants' implementation of formative feedback during the design process.

3.4. RESEARCH DESIGN: DESCRIPTIVE SINGLE-CASE STUDY

I implemented a descriptive single-case study design as described by Yin (2018), Stake (2005), and Creswell (2007, 2014). Creswell (2014) describes case studies as an investigation that is bound by time and activity. A case study is carried out through generating multiple sources of data, and relying on multiple data collection methods. The end-product of a case study is usually a thick case description and case-based themes. A descriptive case study aims to present a complete description of the phenomenon within the context of the study (Yin, 2018; Hancock & Algozzine, 2011). The focus and boundaries of the selected cases are illustrated in Figure 3.2.

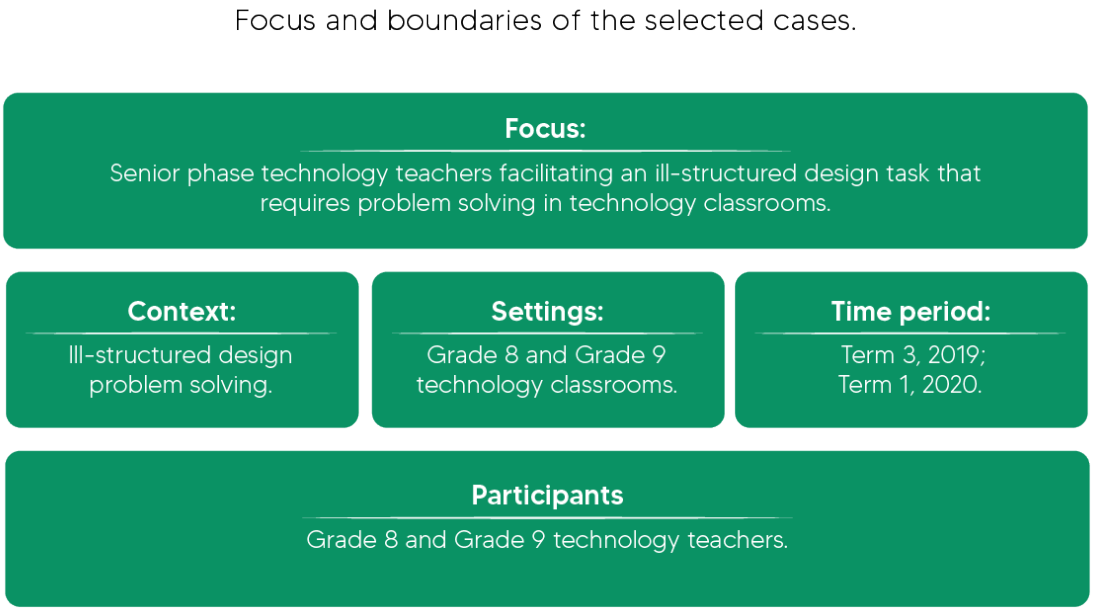


Figure 3.2: Focus and boundaries of the selected cases as suggested by Patton (2015)

In Figure 3.2, I present an overview of the focus, context, settings, periods, and participants that constituted the case in this study. To explore the participants' perceptions and implementation of formative feedback, I considered the context of the Grade 8 and 9 technology classrooms as related to teachers supporting the initial phases of an ill-structured design task that requires problem solving. In line with the focus of this study and the single case study design described by Yin (2018), I collected multiple data sets, employing semi-structured interviews and observations.

Having framed the research paradigm, research approach, and research design of this study, I was able to plan my data collection and analysis procedure. Table 3.2 summarises the process that I followed to address the research questions.

Table 3.2: The research process followed in this study

Phase 1:	**Initial exploration of the field**		
Strategies	**Approach**	**Purpose**	**Rigour**
Literature review		Investigating the technology CAPS document. Extensive literature study on formative assessment and formative feedback in design education contexts.	Rich context descriptions for transferability.
Phase 2:	**Selection of participants**		
Strategies	**Approach**	**Purpose**	**Rigour**
Convenience sampling; Purposive sampling.	The use of criteria to select 12 technology teachers. Five technology teachers facilitating the design process.	Identifying appropriate cases to study to address the research questions.	Informed consent. Trustworthiness; Transferability; Credibility. Richness of data.
Phase 3:	**Concurrent data collection**		
Strategies	**Approach**	**Purpose**	**Rigour**
Semi-structured interviews	Collection of verbal data.	Exploring the participants' perceptions of formative feedback. Exploring the participants' perceptions of the rationale for formative feedback. Exploring the participants' perceived implementation of formative feedback.	Provide background information on the context. Trustworthiness, Transferability, Triangulation.
Non-participant observations	Collection of visual and verbal data.	Observing the introduction of the design task to the learners. Observing the participants' implementation of formative feedback during the design task. Observing the levels of participants' formative feedback during the design task. Observing the questions and comments used as formative feedback during the design task.	Ensure naturalistic formative feedback during the design task. Trustworthiness; Dependability; Credibility; Transferability.

Phase 4:	**Data structuring, analysis, and interpretation**		
Strategies	**Approach**	**Purpose**	**Rigour**
Constructs from the conceptual framework	Segmenting verbal data into utterances based on the content of design phases. Segmenting verbal data into utterances based on the content of feedback levels. Segmenting verbal data into utterances based on the content of question, and comment types.	The individualisation of utterances into segments to investigate the formative feedback in the phases of the design process. The individualisation of utterances into segments to investigate the formative feedback at four distinct levels. The individualisation of utterances into segments to investigate the types of formative feedback questions and comments.	Limiting researcher bias. Credibility. Confirmability. Trustworthiness.
Phase 5:	**Reporting and dissemination**		
Strategies	**Approach**	**Purpose**	**Rigour**
Constructs from the conceptual framework. Tables and graphic representations.	Coding design phases, feedback level, questions, and comments.	Describing participants' formative feedback practices. Identifying patterns and themes. Present qualitative findings. Review the findings in terms of literature. Propose a framework for planning and implementing formative feedback during ill-structured problem-solving activities in the EPoDP.	Confirmatory triangulation. Researcher reflexivity. Trustworthiness.

Single case studies are often critiqued for not being generalisable (Creswell et al., 2016; Stake, 2006; Yin, 2014). However, case studies conducted within an interpretivist paradigm do not aim to generalise their findings from a sample to a population. Instead, interpretive case studies seek to gain an in-depth understanding of specific events and cases.

Given (2012) suggests that although the findings in case studies may not be generalisable, these findings may be transferable to other contexts depending on the contextual boundaries of the findings, and the links between the participants and the context. In this way, it may be possible for some of the findings of this study to be transferred to other classrooms in South Africa. However, I leave it up to the reader to decide as to what extent this is possible.

3.5. SELECTION OF CASES AND PARTICIPANTS

I utilised non-probability methods to select cases and individual participants for this study. The cases were considered information-rich, and the participants could provide an in-depth understanding (Cohen et al., 2018; Patton, 2015).

3.5.1. Selection of cases

A case can be “a single person, a program, a group, an institution, a community or a specific policy” (Merriam & Tisdell, 2015, p. 38). In this study, senior technology teachers constituted a case as this group of teachers were bound to the focus of this study (see Figure 3.2).

In selecting cases for this study, I focused on identifying those that could complement the research questions and the methodology of my study. When selecting cases for descriptive case studies, the cases need to be selected to provide maximum information about specific features and characteristics of the phenomenon (Mills et al., 2010). The criteria for selecting the cases for this study were that the teachers had to have some prior experience with teaching senior phase technology and facilitating an ill-structured design task that requires problem solving.

3.5.2. Selection of technology classrooms as research sites

The setting for this study was senior phase technology classrooms located in private and public schools in Gauteng East, Gauteng West, Tshwane North, Tshwane West, Johannesburg Central, Johannesburg North, Johannesburg West, and Tshwane South. Overall, the classrooms were well equipped with teaching and learning resources that supported learners' engagement with an ill-structured design task that requires problem solving.

The research sites in this study were conveniently and purposefully selected based on the accessibility and availability thereof (Patton, 2015; Ritchie et al., 2014). The convenient selection of senior phase technology classrooms as research sites was based on the accessibility and availability of the research sites from July to September 2019, and January to March 2020. Not all public and private school technology classrooms were selected as research sites for this study as I needed to access research sites and participants that were considered information-rich and met the inclusion criteria (Durdella, 2019). Convenience sampling is often critiqued for not representing a sample that differs from the population (Frey, 2018). Since the purpose of this study was not to generalise findings, representativeness was not considered a challenge in this study. Furthermore, I provide detailed descriptions of the demographics and other characteristics of the cases and research sites. Additionally, I ensured that the selected research sites were relevant and that the selection was not purely based on convenience (Frey, 2018).

To further minimise any potential challenges associated with convenience sampling, I also relied on purposive sampling to select the research sites for my study. Durdella (2019, p. 185) explains that purposeful sampling yields sites and participants "that are consistent with what you want to do".

I relied on the following criteria to purposefully select senior phase technology classrooms as research sites:

- The selected senior technology classrooms had to be situated in primary and high schools in Gauteng.

- The DoBE, School Governing Bodies, principals, and technology teachers had to provide permission for the study to be conducted in specific technology classrooms.
- The language of learning in the participating schools and technology classrooms had to be English or Afrikaans.
- The technology classrooms had to be accessible for data collection during the first term of the school calendar in 2019, and the third term of the school calendar in 2020.

The research site or context has the potential to influence the meaning-making of the participants (Ary et al., 2002, as cited in Cohen et al., 2018; Lincoln & Guba, 1985). Therefore, the research sites were purposefully selected to be the participants' everyday technology classrooms. Before accessing the research cites and participants, I gained permission from the DoBE, the School Governing Bodies, and principals to conduct research at the selected schools.

3.5.3. Selection of participants

Following the selection of cases and research sites, I conveniently and purposefully selected senior phase technology teachers to participate in this study. The goal of this selection method was not to generalise the findings, but rather to identify information-rich cases (Patton, 2015). The selection of participants in qualitative studies is generally guided by the notion of saturation rather than statistical significance (Durdella, 2019). Saturation occurs when the emerging themes are saturated and no new insights are forthcoming (Creswell, 2014; Creswell et al., 2016; Durdella, 2019). Some authors propose that selecting four to 40 participants for a qualitative case study may be sufficient for achieving data saturation (Creswell, 2014; Durdella, 2019; Patton, 2015). In an attempt to achieve data saturation, I selected 12 senior phase technology teachers as interview participants, and five Grade 8 to Grade 9 participants from the interviews to observe.

I employed convenience sampling to invite 12 senior phase technology teachers to participate in an interview through self-selection. The participants were selected based on their willingness and availability for interviews during the third term in the school calendar in 2019. Convenience sampling meant that I could access several

information-rich participants in a short amount of time according to who was available and willing to participate in the study. All of the interview participants had more than one year of experience in teaching technology, and had facilitated an ill-structured design task that requires problem solving at least once. Combining purposive sampling with convenience sampling allowed me to minimise the challenge of representativeness commonly associated with convenience sampling (Cohen et al., 2018; Creswell & Creswell, 2018b; Maree et al., 2016). Following the selection of cases, participants were conveniently selected based on the geographical proximity of the schools, and the participants' availability to participate in classroom observations during the third term of the school calendar (July to September 2019), and the first term of the following school calendar (January to March 2020). By providing detailed and rich descriptions of the participants being studied and ensuring that the participants selected from the cases were relevant to the study (Frey, 2018), the limitations of convenience sampling were further reduced.

Following the interviews, I conveniently and purposefully selected five Grade 8 and 9 technology teachers to participate in classroom observations. The participants were conveniently selected based on their willingness to participate in classroom observations.

I used the following criteria to purposefully select the participants to be observed in their technology classrooms while learners were engaged in an ill-structured design task that requires problem solving:

- The participants had to be senior phase (Grade 7 to Grade 9) technology teachers in one of the selected schools.
- The participants had to engage in a design task in line with the curriculum requirements during the first term of the school calendar (January to March 2020).
- The initial phases of the design task had to be completed in the technology classroom.
- The participants had to be available for data collection sessions during school hours, and they had to provide informed consent.

- The participants had to indicate that they provided learners with formative feedback to support the EPoDP in their initial interviews.

After obtaining permission from the school principals to conduct research at the selected schools, I scheduled introductory meetings with the senior phase technology teachers. During these meetings, I informed the teachers about the nature and purpose of the study, and their role should they choose to participate (see Appendix B). To ensure that ethical research protocols were followed (Creswell et al., 2016), the teachers were asked to participate in this study voluntarily and without coercion.

3.6. DATA COLLECTION AND DOCUMENTATION

I utilised semi-structured interviews to collect data on the participants' perceptions of formative feedback. Thereafter, I conducted classroom observations to collect data on the participants' implementation of formative feedback. Table 3.3 provides a brief overview of the data collection and documentation strategies I employed to collect data from the five cases I investigated.

Table 3.3: Overview of the data collection and documentation processes

Case	Participants	Data collection method	Documentation
1	Grade 9 Technology teacher	Interview, audio recorded verbal utterances transcribed verbatim.	A structured questionnaire, audio recordings, transcriptions (See Appendix C).
		Observation, video recorded verbal utterances and interactions.	Observation schedule and field notes, video, and audio recordings (See appendix D).
		Follow up-interview, audio recorded verbal utterances transcribed verbatim.	Transcriptions (See appendix C).
2	Grade 8 Technology teacher	Interview, audio recorded verbal utterances, transcribed verbatim	A structured questionnaire, audio recordings, transcriptions (See Appendix C)
		Observation, video recorded verbal utterances and interactions.	Observation schedule and field notes, video, and audio recordings (see appendix D).

Case	Participants	Data collection method	Documentation
		Follow-up interview, audio recorded verbal utterances, transcribed verbatim	Transcriptions (See appendix C).
3	Grade 8 Technology teacher	Interview, audio recorded verbal utterances transcribed verbatim.	A structured questionnaire, audio recordings, transcriptions (See Appendix C).
		Observation, video recorded verbal utterances, and interactions.	Observation schedule and field notes, video, and audio recordings (See appendix D).
		Follow-up interview, audio recorded verbal utterances, transcribed verbatim.	Transcriptions (See appendix C).
4	Grade 9 Technology teacher	Interview, audio recorded verbal utterances transcribed verbatim.	A structured questionnaire, audio recordings, transcriptions (See Appendix C).
		Observation, video recorded verbal utterances, and interactions.	Observation schedule and field notes, video, and audio recordings (See appendix D).
		Follow-up interview, audio recorded verbal utterances transcribed verbatim.	Transcriptions (See appendix C).
5	Grade 9 Technology teacher	Interview, audio recorded verbal utterances transcribed verbatim.	A structured questionnaire, audio recordings, transcriptions (See Appendix C).
		Observation, video recorded verbal utterances, and interactions.	Observation schedule and field notes, video, and audio recordings (See appendix D).
		Follow-up interview, audio recorded verbal utterances transcribed verbatim.	Transcriptions (See appendix C).

The use of multiple data collection methods, as shown in Table 3.3, contributed towards the crystallisation and triangulation of data (Schurink et al., 2011). The role of triangulation and crystallisation is further discussed in Section 3.9. The use of interviews and observations allows the researcher to cross-check, elaborate on, and validate findings (Nieuwenhuis, 2016; Schurink et al., 2011). Furthermore, Patton

(2002) notes that the strength of one data collection procedure may compensate for the weaknesses of another. In this study, observations were used to compare the participants' implementation of formative feedback with their perceptions of formative feedback gathered from the interviews. In addition, interviews reduce the possibility of researcher bias when interpreting the observational data since a second round of interviews is used for member checking (Foster, 2006).

Table 3.4 outlines the data collection methods that I utilised, as well as a description of the purpose of the data.

Table 3.4: Main data collection methods and the purpose of the data

Data collection method	Purpose
Semi-structured interview	Provide: • Context for the research. • Views on formative feedback. • Views on the necessity of formative feedback. • Perceived formative feedback practices.
Structured Observation	Deductive analysis of the phases of the design process according to the conceptual framework of this study. Deductive analysis of the feedback level in the EPoDP based on the conceptual framework of this study. Deductive analysis of the questions and comments according to the conceptual framework of this study. Inductive themes emerging from the deductive analysis.
Follow up interview	Member checking. Further exploration of the views describing formative feedback in the technology classroom.

3.6.1. Semi-structured interviews

Semi-structured interviews are often used to collect verbal data about the participants' beliefs, ideas and opinions regarding a phenomenon (Creswell et al., 2016). In this way, semi-structured interviews were deemed an appropriate data collection method for exploring the participants' perceptions of formative feedback. I audio recorded the interviews and made field notes (see Appendix C) about (1) The demographics of the participants, (2) The participants' perceptions of how formative feedback can be described, (3) The participants' views on the necessity of formative feedback during the design process, and (4) The participants' perceived formative feedback practices in the technology classroom.

The results obtained from these interviews were triangulated through member checking. Member checking adds to the rigour of qualitative studies by reducing researcher bias and participant reactivity (Cohen et al., 2018; Creswell et al., 2016; Durdella, 2019). In line with reflective practice, member checking allows the researcher to consult with the participants on the interpretation of data, and collect additional data from the participants (Durdella, 2019).

The participants who were observed were chosen from the group of participants interviewed. According to Flick (2018), this approach allows the researcher to compare the participants' interview answers to their observed behaviour. Therefore, the semi-structured interviews served two purposes: to collect data about the participants' perceptions of formative feedback; and to compare their perceptions with their actual feedback practices.

Capturing the interviews in audio recordings allows the researchers to actively listen to the participants' responses (Ritchie et al., 2014). I was therefore able to discern whether I needed to clarify or explore the responses further. Audio recordings are often less intrusive than note-taking, and allow for accurate and verbatim accounts of the interviews (Ritchie et al., 2014). To ensure that I asked the same questions to all of the participants in the same order, I used an interview schedule with all of the questions that I wanted to ask (see appendix C). The use of an interview schedule further meant that I was able to keep track of the interviewing process; this was especially helpful in cases where probing questions were asked.

Although interviews are often time-consuming and expensive, I did not view this as a limitation in this study as the schools where the participants were located was near my home and place of work, and I only needed to observe the participants during the EPoDP. The possibility of researcher bias was reduced by reviewing the interviews as a whole and transcribing the interviews verbatim. This enhanced the trustworthiness and credibility of the findings (Cohen et al., 2018; Creswell & Creswell, 2018b).

The participants were interviewed in their day-to-day technology classrooms at a time that was convenient for them. This meant that the risk of interruptions, distractions, and 'stage-fright' could be reduced (Cohen et al., 2018d; Schurink et al., 2011), allowing to the participants to feel at ease (Creswell et al., 2016). Most of the participants preferred that the interviews were conducted after school hours, which further reduced the risk of interruptions and background noise in the audio recordings.

During the initial discussions with the participants, they were informed about the outline of this study. In these discussions, I explained the purpose of the study, the research process, the data collection methods, and the potential benefits of this study (see Section 3.6 and Appendix A). The first phase of the interviews focused on gaining a detailed overview of the participants and their experience in teaching technology (see Appendix C). This data allowed me to provide a detailed description of the context and background of this study. The demographic information also informed my purposive sampling of the participants for classroom observation as one of the criteria was for participants to teach in the senior phase. Following this, I introduced the participants to the topic of 'questions and comments as feedback during the design process'. Introducing the topic ensures that the participants know what to expect with the next series of questions (Cohen et al., 2018d; Schurink et al., 2011). The questions allowed me to get a sense of the participants' use of and focus on formative feedback in the technology classroom. They also enabled me to understand how the participants planned for formative feedback.

In conclusion, I asked the participants to give examples of formative feedback questions they would typically ask while learners engaged in specific design activities. This selection of the semi-structured interview question allowed me to gain an insight into the participants' perceived formative feedback practices during the EPoDP. Next, I explained to the participants that the final series of questions would focus on their

views on formative feedback. These questions focused on how the participants would give formative feedback during the EPoDP, and the necessity of formative feedback in the technology classroom.

The interviews led to a deeper understanding of how technology teachers describe formative feedback, and were consequently used to partially answer my first two research questions: *How do technology teachers conceptualise formative feedback as part of supporting learners' early design processes?* and *What is technology teachers' rationale for implementing formative feedback during the early phases of the design process?*

3.6.2. Non-participant observations

Working within the interpretive paradigm implies the use of multiple data collection methods. In addition to semi-structured interviews, I sought to observe the participants' formative feedback practices during an ill-structured design task that requires problem solving. I needed to gain insight into the participants' implementation of formative feedback during the EPoDP to answer the secondary research questions of this study. I utilised non-participant observations (Cohen et al., 2018), which meant that I observed the participants for one design lesson in their technology classrooms, where they typically engaged with learners during design tasks in the initial phases of designing. I did this without disrupting the workflow.

The use of observations meant that I was able to view the participants' formative feedback practices in their classrooms. It also allowed me to observe the formative feedback practices that occurred during the EPoDP. This was necessary to further highlight aspects of the participants' formative feedback behaviour that may not have been described in the interviews (Ritchie et al., 2014). To ensure that I captured interesting and significant information during the classroom observations, I utilised an observation schedule. The observation schedule allowed me to capture the participants' formative feedback questions and comments during the EPoDP. I was also able to capture instances of feedback at task level, process level, self-regulative, and self-level using the observation schedule. Furthermore, the observation schedule allowed me to capture my initial thoughts on the formative feedback instances I observed in the classroom. I was then able to triangulate these with the data gathered from the audio and video recordings.

I relied on audio and video recordings to document the participants' implementation of formative feedback. These recordings enabled me to capture the participants' physical movement in the classroom as they provided whole class, group, and individual feedback to learners.

Some of the key advantages of utilising video and audio recordings in conjunction with an observation checklist and field notes includes reducing the risk of only observing and recording frequently occurring events (Cohen et al., 2018; Patton, 2015). In addition, video recordings allow for observations in the participants' natural settings without being intrusive. They also provide a full account of interactions, as well as retaining the sequence of events (Cohen et al., 2018; Patton, 2015). Finally, the video and audio recordings enabled me to review the observations at a later stage without having to rely on previous interpretations of the participants' feedback practices.

The use of audio and video recordings as data capturing methods is not without limitations. One of the limitations of video and audio recordings that needed to be addressed was choosing between a fixed or a moveable camera (Cohen et al., 2018; Patton, 2015). While a fixed camera would have ensured that the focus gave a panoramic view of the classroom (Cohen et al., 2018), the risk would be that I might not be able to observe and capture interactions between the participants and the learners at a close range (Cohen et al., 2018). To capture the interactions between the participants and the learners, I initially planned to utilise Go-Pro cameras attached to the participants to record these interactions. The participants did not agree to wear a Go-Pro camera, which meant that I had to reconsider the capturing of observational data. The limitations of fixed cameras and Go-Pros were addressed by using a moveable camera, set up at the back of the class, that tracked the movement of the participants. The camera equipment included a hands-free microphone that hung around the participant's neck, ensuring high quality and clear audio recordings and video recordings. To reduce the risk of participants exaggerating their formative feedback practices during the observations, the participants were informed of the purpose of the study but did not have any further information on the behaviour that would be observed.

My role as a non-participant observer meant that I entered the participants' classrooms to observe their formative feedback practices without getting involved in any of the

classroom activities. This meant that I was not involved in the structuring or implementation of classroom activities or design tasks. I merely provide an overview of the research sites where the observational data was collected and the design tasks in which the participants engaged the learners.

The classroom observations led to a deeper understanding of the level of formative feedback questions and comments, and were consequently used to partially answer the third and fourth research questions of this study (see Section 5.3)

3.6.3. Semi-structured follow up interviews

The final data collection method that I relied on was a second round of semi-structured interviews as the participants did not agree to stimulated recall interviews. Stimulated recall allows participants to explain their cognitive processes by being prompted by a video sequence (Fox-Turnbull, 2009; Lyle, 2003). This challenge was mitigated by conducting a second round of interviews with the participants after the observations were completed. The purpose of these follow-up interviews was two-fold. Firstly, the follow-up interviews allowed me to conduct member checking as recommended by Creswell and Creswell, (2018), and clarify observed instances of formative feedback. Secondly, the follow-up interviews allowed me to probe the participants' perceptions of formative feedback, and their formative feedback practices that were not evident in the first round of interviews and classroom observations. I specifically formulated questions based on the themes that emerged from the thematic data analysis and information not evident in the classroom observations. The generation of data through follow-up interviews allowed me to strengthen my descriptions of the participants' perceptions of formative feedback, the necessity of formative feedback, and how formative feedback could be implemented in technology classrooms. I was also able to triangulate the results obtained from the initial interviews by asking similar questions relating to the participants' descriptions of formative feedback.

3.7. DATA ANALYSIS AND INTERPRETATION

To avoid being overwhelmed by the amount of data collected through multiple methods, I approached the data analysis in a structured and organised manner (Creswell et al., 2016). Figure 3.3 illustrates the data analysis and interpretation process followed in this study.

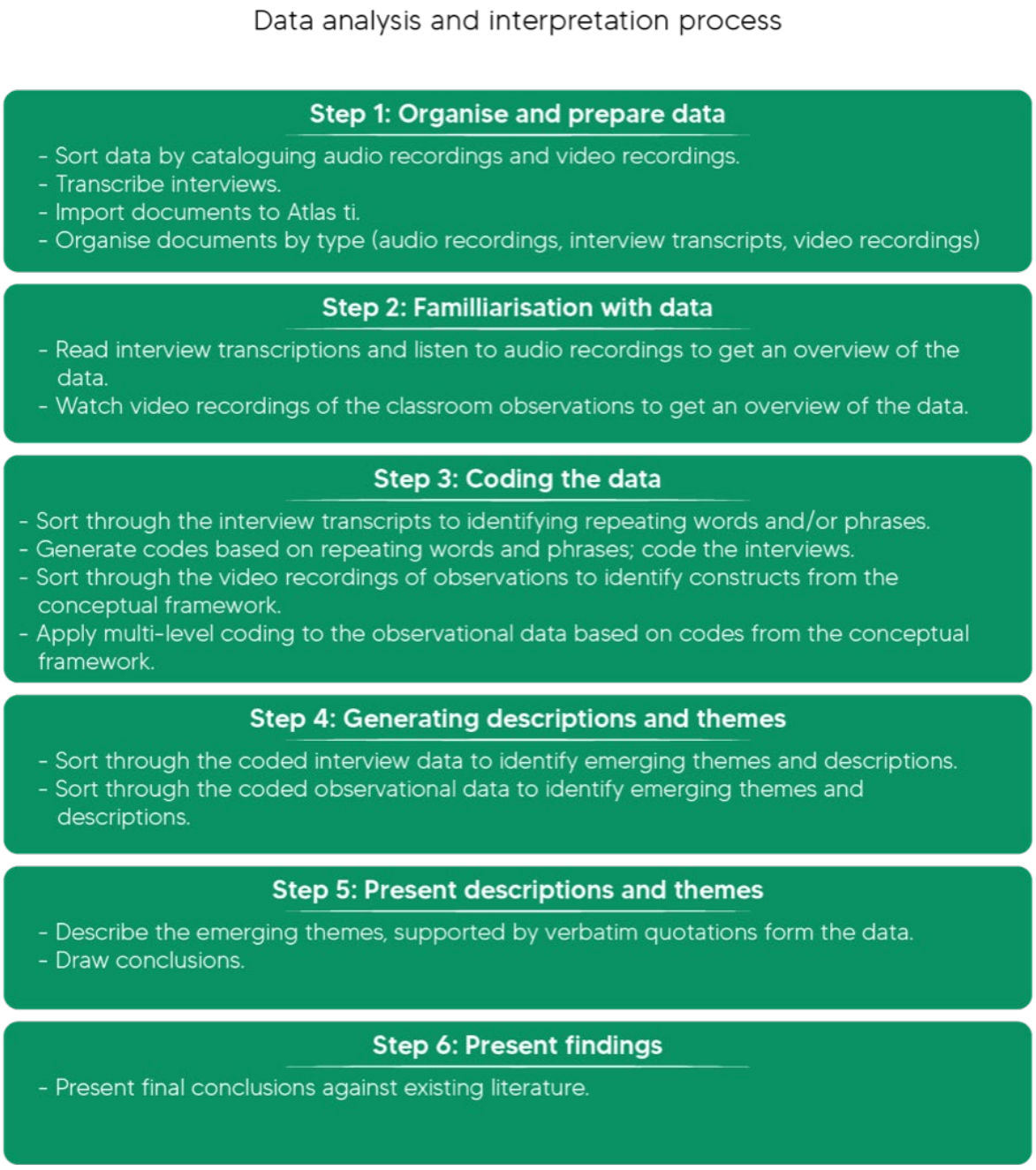


Figure 3.3: Data analysis and interpretation process

The first step was to organise and catalogue the audio and video recordings of the raw data by the method of generation (interviews, observations, follow-up interviews). This was followed by converting the audio recordings of the interviews into verbatim transcriptions. I also highlighted the questions asked in the interviews to gain a clear indication of where one question ended and the next question began. This enabled me to analyse the answers to the same questions across cases and participants (Creswell et al., 2016). I organised the observational data by describing the

participants and the context of this study. The description of the participants includes the number of participants, the relevant background information about their years of experience in teaching technology, and details regarding their education. In terms of the context of the study, I present an overview of the design task that each participant facilitated, and the classroom context where the observations took place. A thorough description of the participants and the research context is necessary as the participants' background and design tasks could potentially influence their perceptions and experiences of formative feedback (Creswell et al., 2016). Next, I imported the interview transcripts and video recordings into a qualitative data analysis program, Atlas ti, to store, organise and label the interview and observational data.

In the second step, I needed to immerse myself in the data. Nieuwenhuis (2016) and Terre Blanche and Durrheim (1999) explain that the quality of data analysis often depends on how well the researcher knows the data. I began by reading and rereading the transcripts and listening to the audio recording several times to get a general idea of what the participants were saying. I then started reflecting on the overall meanings of the data (Creswell & Creswell, 2018). I also watched the video recordings of the observations several times, and reviewed my observation field notes to get an overview of the data.

In the third step, I assigned preliminary codes to the interview data. I used Atlas ti to search for repeating words or phrases in the interview transcripts that could be used to assign codes to the data, and which were relevant to my study. In this way, I utilised inductive coding to organise the interview data into meaningful sections as they appeared in the data. Once I established a set of codes for the interviews, I proceeded to code all of the interviews in Atlas ti.

The use of inductive thematic analysis of the interview meant that I needed to be rigorous and submerged in the analysis process to ensure trustworthy results (Cohen et al., 2018; Creswell, 2007; Creswell et al., 2016). A thematic analysis was considered appropriate as it allowed me to transform the data into findings (Schurink et al., 2011), and to comprehensively explain the data (Cohen et al., 2018). This approach allowed me to establish the patterns, themes, understandings, and descriptions of the participants' formative feedback behaviour without relying on a conceptual framework. Additionally, as Cohen et al. (2018) suggest, the inductive thematic analysis allowed

the me to compare the participants' perceptions of formative feedback across cases, thus contributing to the trustworthiness and transferability of the findings of this study.

Table 3.5 outlines the main data method that I used to analyse the data from each data collection method, as well as a description of the purpose of the data.

Table 3.5: Main data analysis methods and the purpose of the data

Data collection method	Data analysis method	Purpose
Semi-structured interview	Inductive thematic analysis.	To provide: • Context for the research. • Views on formative feedback. • Views on the necessity of formative feedback. • Perceived formative feedback practices.
Structured Observation	Deductive analysis. Inductive analysis.	Deductive analysis of the phases of the design process according to the conceptual framework of this study. Deductive analysis of the feedback level in the EPoDP based on the conceptual framework of this study Deductive analysis of questions and comments according to the conceptual framework of this study Inductive themes emerging from the deductive analysis.
Follow up interview	Inductive thematic analysis.	Member checking. Further exploration of their views and descriptions of formative feedback in the technology classroom.

Next, I utilised a deductive, multi-level coding process to code the observational data based on the constructs of the conceptual framework. Conducting a deductive analysis allowed me to reveal key elements of the participants' implementation of formative

feedback. I was able to present the types of formative feedback questions and comments that the participants used at four distinct levels to support the problem structuring and preliminary problem-solving activities in the design process.

The first level of coding focused on identifying the phases of the design process in which the participants' formative feedback was situated. I worked through the data and identified the phases of the design process based on the design activities, as shown in Table 3.6.

Table 3.6: Identification and coding of EPoDP

Code Name	Description
Problem structuring	Associated with the 'investigate' phase of the design process as prescribed by the DoBE (2012). A process of gathering information on the scope of the design problem. This can include the following activities: • Exploring the scope of and explaining the design problem/need/opportunity. • Gathering information on the context. • Analysing existing solutions. • Practical testing of tools and materials. • Research.
Preliminary problem solving	Relates to the "design" phase of the design process prescribed by the Department of Basic Education (2012) A process of exploring design ideas, specification, and constraints, making preliminary design decisions This can include the following activities: • Write a design brief • Consider the specifications and constraints of possible solutions • Exploring and generating ideas • Making design decisions.

The second level of coding was focused on identifying the level of formative feedback according to Hattie and Timperley's (2007) feedback model. This enabled me to understand the level of participants' formative feedback in the problem structuring and

preliminary problem-solving phases by considering the formative feedback within specific design activities, as shown in Table 3.7.

Table 3.7: Identification and coding of formative feedback levels

Code Name	Description
Task	Feedback about how well a learner performs a task. This includes feedback about acquiring information regarding the problem, context, client, analysis of products, practical testing research, the design brief, design specifications and constraints, and the generation of possible solutions and design decisions.
Process	Feedback about the process related to tasks. This is linked to the methods learners use to gather information about the problem, context, and client. It is also concerned with how the learners analyse existing products, and do research and practical testing. In the design phase, process-level feedback links to how learners write the design brief, identify specifications and constraints, how ideas are collected, and how design decisions are made.
Self-Regulation	The feedback guides the learner to consider what they have done and how well they performed a task in relation to the requirements. This refers to how well the learners were able to gather information about the problem, context, and client. It further concerns how well the learners were able to analyse products and perform practical testing. In the preliminary problem structuring phase, SR formative feedback guides the learner to consider how well they were able to write a design brief, how well the specifications and constraints were considered, and to what extent the collected solutions will solve the problem.
Self	Feedback about the person. This is often referred to as compliments or praise. This type of feedback

	does not place a lot of emphasis on the task, process, or self-regulation.

The third and final level of coding involved identifying and coding the formative feedback questions and comments observed in the EPoDP. The identification and coding of the formative feedback questions and comments were based on Eris' (2004) Inquiry-Driven Design-Based Model, adapted by Schut et al. (2020), as illustrated in Table 3.8.

Table 3.8: The identification and coding of formative feedback question and comments (Eris, 2004; Schut et al., 2020)

Code Name	Description
Request	The questioner does not want to know anything but wants a specific action to be performed.
Verification	The questioner wants to know the truth of an event. Typically yes or no answers.
Disjunctive. Concept completion.	Verification using multiple concepts. The questioner wants to know the missing component in a specified event (e.g. fill in the blanks).
Feature specification	The questioner wants to know some property of the given person or thing.
Quantification	The questioner wants to know an amount.
Definition	The questioner wants to find out what a question concept means.
Example	The questioner invites examples of the question concept.
Comparison	The questioner wants to compare the similarities and/or differences between the question concepts.
Judgemental	The questioner wants to elicit judgement from the responder by requiring a projection of events rather than a strict recall of events.
Compliment	Praise for what the learner did/accomplished.
Critique	The teacher makes an assessment or judgement of the learners' work.
Direct recommendation	The teacher tells the students specifically what to do to improve the design.
Description	A description of a part of the design task that can be observed.

Code Name	Description
Interpretation	The questioner wants to know the meaning of the question concept based on given information.
Procedural	The questioner wants to know the partially or totally missing instrument in the question concepts.
Causal antecedent	The questioner wants to know the states or events that have in some way caused the concept in question (e.g. what lead to…?)
Causal consequence	The questioner wants to know the concept or causal chain that the question concept caused.
Rational/function	The questioner wants to know the motives or goals behind actions (e.g. why?)
Expectational	The questioner wants to know the causal antecedent of an act that presumably did not occur (e.g. why not)
Enablement	The questioner wants to know the act or the state that enabled the question concept.
Future	A question about the future state of the task.
Future description	A description of the future state of the task that can be observed.
Enablement	The questioner wants to construct acts, states, or resources that can enable the question concepts.
Method generation	The questioner wants to generate as many ways as possible of achieving a specific goal.
Proposal/negotiation	The questioner suggests a concept, or negotiates an existing or previously stated concept.
Scenario creation	The questioner constructs a scenario involving the question concepts and wants to investigate the possible outcomes.
Ideation	The questioner wants to generate as many concepts as possible from an instrument without trying to achieve a specific goal.

The identification and coding of the formative feedback questions and comments, as shown in Table 3.8, enabled me to describe the formative feedback questions and comments that the participants used on different levels to guide the learners' problem structuring and preliminary problem-solving activities. A complete qualitative codebook, including coded examples, is presented in Appendix D2.

In the fourth step of the data analysis process, I collected initial themes and descriptions of the interview and observational data by grouping the codes that reflected similar meanings relevant to the research questions. The identification of themes was originally guided by the research questions (Stake, 2006), yet these themes were refined as the analysis progressed.

In the fifth step, I described the emerging themes and supported the results with verbatim quotations from the transcribed interview data. Finally, I interpreted these findings and drew conclusions from the existing literature. My interpretations were based on the thematic analysis since this method is consistent with the case study design within interpretivist assumptions (Braun & Clarke, 2013; Cohen et al., 2018; Creswell & Creswell, 2018a; Yin, 2014).

I concluded the data analysis and interpretation process by answering the main research question of this study. This was done by presenting the findings of this study against the existing literature, and making recommendations for future research.

3.8. MY ROLE AS A RESEARCHER

In this qualitative research study, I was considered the main tool for data collection as, suggested by Creswell (2007, 2014). This meant that I had to remain aware of my own "assumptions, preconceptions and biases about my research topic, purpose, questions and setting" (Durdella, 2019, p. 310). Due to my previous experience as a senior phase technology teacher, I brought certain assumptions and biases to this study (Creswell, 2014; Durdella, 2019) about the perception and implementation of formative feedback. I began this study with the perspective that teachers' perceptions of formative feedback may be diverse, and that their implementation of formative feedback may differ greatly from one another. To avoid these potential challenges, I relied on several data collection methods, member checks, and relied on a conceptual framework embedded in the literature to analyse the results (Durdella, 2019).

Furthermore, I remained aware of the possibility of participant reactivity during the initial interviews and classroom observations (Cohen et al., 2018; Creswell et al., 2016; Durdella, 2019). I attempted to limit these challenges by following Durdella's (2019) guidelines: taking time to explain the participants' role in this study, I utilised open-

ended questions in the interviews, I avoided leading questions, and performed member checks after the observations to reduce misinterpretations. The use of multiple data collection methods, thick and detailed descriptions, and keeping an audit trail (Durdella, 2019) further reduced the effect of these challenges on my study.

3.9. QUALITY ASSURANCE

I strived to enhance the rigour of this study by attending to the five criteria proposed by Guba (1981): credibility, transferability, dependability, confirmability, and authenticity. In this section, I explain the quality criteria and the measures that I undertook to improve the rigour of this study.

3.9.1. Credibility

Credibility is concerned with the accuracy of the research findings (Creswell & Creswell, 2018b; Guba, 1981). The credibility of a case study refers to the degree to which the researcher can describe the participants' perceptions and experiences of a phenomenon (Yin, 2018). In this study, credibility is related to the accuracy of my descriptions of the participants' perceptions and implementation of formative feedback during the early design phases.

Throughout the data collection, analysis, interpretation, and reporting of findings, I relied on several strategies to enhance the credibility of the findings presented in this study. Firstly, Yin (2014) and Creswell (2014) suggest that the use of multiple participants and multiple data collection methods contributes to building credible themes through the use of pattern matching, and cross-checking interpretations. Secondly, I continuously engaged with the interview transcripts of the audio-visual recordings to capture the observations. This allowed me to explore and describe the participants' perceptions of formative feedback and their observed formative feedback practices in the technology classroom. Thirdly, I depended on the conceptual framework to cross-check and confirm my interpretations of the participants' formative feedback questions and comments, the formative feedback level, and the design phase in which the formative feedback was observed. Finally, follow-up interviews not only served as a data collection method, but also as member checking. Member checking allowed me to confirm the accuracy of my interpretations with the participants to ensure that their views are interpreted and presented accurately.

3.9.2. Transferability

Transferability refers to the degree to which readers can transfer the findings of this study to other contexts (Lincoln & Guba, 1985; Patton, 1990). Due to the qualitative nature and boundaries of this study, the findings may not be generalisable to all technology classrooms. Although generalisation was not the aim of this study, I believe that the insight gained from studying the cases in this study may contribute to understanding technology teachers' perceptions and implementation of formative feedback in South African technology classrooms.

I strove to enhance the transferability of the findings of this study by relying on purposive sampling and thick descriptions of the research context (Lincoln & Guba, 1985). The use of purposive sampling techniques allowed me to specify the boundaries of my cases. This specifically referred to only focusing on Grade 8 and 9 technology teachers who were facilitating learners' design activities that required problem solving. Transferability was further enhanced through conducting member checks, reflexive strategies, and continuous comparison of interpretations against the conceptual framework of the study (Creswell, 2007, 2014; Merriam & Tisdell, 2015; Yin, 2015). Since case studies are bound by context (Stake, 2005; Yin, 2014), I paid special attention to providing rich descriptions of the context and participants of the case study. I included a contextual description of the educational setting in which the data was collected, such as the school and the classroom, as well as the participants. I also provide clear descriptions of the themes that emerged from the data, how the data were interpreted, how and what themes emerged, and how I used the themes to construct meaning (Yin, 2014). In addition, I provided descriptions and explanations for decisions regarding which data to include and exclude from this study and the criteria on which these decisions were based. Finally, to attain transferable research findings, I represent the data and the interpretations of the data as truthfully and accurately as possible. I disclose my biases and include descriptions of how my findings could be influenced by my background, culture, and biases (Creswell, 2014).

3.9.3. Dependability

Dependability describes the degree to which the findings of the study are consistent and repeatable (Lincoln & Guba, 1985; Terre Blanche & Durrheim, 1999). Since the

participants' perception and implementation of formative feedback was shaped by their experiences in facilitating design tasks, it is unlikely that the findings of this study can be fully replicated. Therefore, I did not aim to provide findings that could be repeated, but rather findings that could be compared to research in similar contexts. To enhance the consistency and the comparability of the findings, I continued to collect data until data saturation occurred. In addition, I established an audit trail documenting the data collection and analysis. I additionally provided detailed descriptions of the cases, research sites, participants, and the conditions of the study. The original audio and video recordings of the interviews and observations are included for reference. Furthermore, I have chosen to combine existing frameworks from empirical studies to serve as the conceptual framework of this study. I included a description of the conceptual model and the justifications for the appropriateness of the model in this study in Chapter 2.

Finally, I strove to enhance the rigour of this study by comparing the data to the existing literature. This was done by presenting correlations, contradictions, and silences in the data.

3.9.4. Confirmability

Confirmability describes how accurately the findings of this study reflect the opinion, views, beliefs and behaviour of the participants being studied (Creswell et al., 2016; Lincoln & Guba, 1985). In this study, confirmability refers to the degree to which the findings presented on the participants' perceptions and implementation of formative feedback are shaped by the participants rather than my interests, motivations, or bias.

I sought to enhance the confirmability of my study by acknowledging my biases, remaining aware of these throughout the data collection and analysis process. As a junior technology lecturer, I have formed my own opinions, beliefs and perceptions of formative feedback and how formative feedback may be used to support the design process. As a result, I was careful not to place more value on the participants' perceptions and implementation of formative feedback aligned with my notions. Another attempt to increase confirmability includes presenting the data and interpretations as truthfully and accurately as possible and supporting interpretations with evidence (Creswell et al., 2016). To this end, I aimed to provide the reader with evidence of the data collection, documentation, analysis, interpretation, and reporting.

I also include examples and evidence of my data reduction and analysis procedures. Finally, the raw data are also included in the study in the form of audio recordings, interview transcripts, audio and video recordings of the observations, an observation schedule, and field notes.

3.9.5. Authenticity

Authenticity refers to whether or not the results and findings of this study provide a true and balanced description of the participants' views, beliefs, perspectives, context, and events (Lincoln & Guba, 1986).

The authenticity of qualitative studies is raised by continuing data collection until data saturation has occurred (Creswell, 2014; Lincoln & Guba, 1985). Creswell (2014) explains that conducting research in the participants' natural setting rather than experimental conditions further contributes to the authenticity of the findings. Therefore, I continued to collect interview data until no new themes regarding the participants' perceptions of formative feedback occurred. My exposure to the research sites allowed me to provide authentic descriptions of the context and participants of this study. Finally, having access to multiple participants and performing member checks also strengthened the authenticity of this study (Creswell, 2014; Yin, 2014).

3.10. ETHICAL CONSIDERATIONS

The three main principles of research ethics that guided this study were: autonomy, non-maleficence, and beneficence (Rule & John, 2011). These principles shaped the ethical research in terms of asking permission, ensuring voluntary participation, obtaining informed consent, ensuring safety during participation, respecting the participants' privacy, and ensuring trusting relationships (Rule & John, 2011).

3.10.1. Permission to conduct the research

In preparation for the data collection process, I obtained permission from the Ethics Committee of the University of Pretoria, the DoBE in Gauteng schools, and the principals from the different schools where the data were collected. I received informed consent from the principals of the schools where the data were collected and the teacher participants of this study. Informed consent was ensured by discussing the purpose and outline of the study, voluntary participation, the role of the participants,

the benefits of the research, and the dissemination of the findings with the principals and participants.

Creswell and Creswell (2018) cautions researchers against the disruption of research sites caused by data collection. To ensure that the data collection process would not disrupt the research sites, I made appointments with the participants and scheduled the observations in advance at a time that was convenient for the participants. I informed the participants of the purpose and duration of the classroom observations, and set up the recording equipment before the start of the lesson to limit disruptions and interference with teaching time.

3.10.2. Voluntary participation

Throughout the study, I respected the participants' right to voluntary participation. Before the commencement of the study, I told the participants of the purpose of the study and their role if they chose to participate. I informed the participants that their participation was voluntary and that they could withdraw from the study at any time. Although no participants withdrew from the study, the participants did not agree to wear Go-Pros as part of the data collection process, and were not available for stimulated recall interviews. Respecting the participants' voluntary participation meant that the data collection was adapted to account for the limitations without compromising the trustworthiness of this study.

3.10.3. Safety during participation

Although it was unlikely that participants would be harmed in this study, Schurink et al. (2011) note that participants can be harmed physically or emotionally. The authors further note that the harm may likely be emotional (Schurink et al., 2011). Emotional harm might occur when a participant feels uncomfortable with their formative feedback practices being video recorded. To mitigate this, I detailed the data collection process and explained to the participants that the data gathered would not be used to evaluate their performance. The potential risk of emotional harm to the participants was further reduced by conducting the research in the participants' natural settings and not subjecting the participants to any judgement based on their formative feedback practices observed. The research did not include participants who were minors or any sensitive cases.

3.10.4. Confidentially, anonymity and respect for privacy

The participants' privacy was respected through confidentiality and anonymity. The participants' names and any other identifying characteristics were omitted in the dissemination of the findings of this study. To ensure the anonymity of the participants, I used different codes for each data collection method to identify the participants, for example, I9 (initial interview), P2 (observation), FI2 (a follow-up interview). I ensured the confidentiality of the participants by protecting the raw data collected in this study.

3.10.5. Potential benefit

The participants were informed that their participation may benefit the larger body of knowledge on technology teachers' perceptions and the implementation of formative feedback. An additional benefit may include the participants becoming more aware of their formative feedback practices, and growing their knowledge on the use of formative feedback to support learners' design processes.

Finally, in accordance with the Ethics Committee of the University of Pretoria, all of the raw data will be stored in a locked facility at the University of Pretoria. To provide an audit trail, I included copies of the interview transcripts and the analysed data in the appendices.

3.11. SUMMARY

In Chapter 3, I discussed the methodological choices that I made in conducting this study. I explained the interpretivist paradigm, which guided this study. I further justified using a descriptive, single case study design; the use of interviews and observations to collect data; and the use of audio and video recordings to document the data. I further explained and justified the data analysis and interpretations of this study. I concluded this chapter by explaining the quality and ethical measures to which I adhered.

In the next chapter, I present the results of my study. In Chapter 4, I focus on presenting the results on the participants' perceptions of formative feedback, and their formative feedback practices in technology classrooms. This is followed by a discussion of the participants' perceptions of formative feedback and their formative feedback practices in technology classrooms.

CHAPTER 4
RESULTS AND DISCUSSION

4.1. CHAPTER OVERVIEW

In the previous chapter, I explained and justified my methodological choices in accordance with the purpose of the study, the research questions, and the conceptual framework. In this chapter, I present and discuss the results of the interviews that I conducted with 12 senior phase technology teachers regarding their perceptions of formative feedback during the early phases of the design process (EPoDP). Furthermore, I present the results obtained from five Grade 8 and 9 classroom observations related to teachers' implementation of formative feedback during the EPoDP.

4.2. TECHNOLOGY TEACHERS' PERCEPTIONS OF FORMATIVE FEEDBACK DURING THE EARLY PHASES OF THE DESIGN PROCESS

In this section, I discuss the three main themes and sub-themes that emerged from a thematic analysis of the interview data. This discussion is based on the data collection and analysis of the interviews conducted with 12 senior phase technology teachers regarding their perceptions of formative feedback in technology classrooms. Theme 1 relates to teachers' descriptions of formative feedback during the EPoDP. Three sub-themes resulted from the data analysis that indicated that the teachers described formative feedback as providing: 1) Compliments and criticism, 2) Asking questions, 3) Examples of existing work, and 4) Being 'intuitive'. Theme 2 reports on the teachers' perceptions of the rationale for using formative feedback during the design processes. The sub-themes include descriptions of the teachers' perceptions of the necessity of formative feedback and the challenges of giving feedback during the design process. In Theme 3, I present the teachers' perceptions of how formative feedback is implemented in technology classrooms during the EPoDP. This includes accounts of the teachers' use of feedback to: 1) Respond to learners' questions, 2) Provide individual, small group, and whole class feedback, and 3) the frequency and effectiveness of formative feedback.

Figure 4.1 provides an overview of the themes and sub-themes that emerged from the inductive thematic analysis.

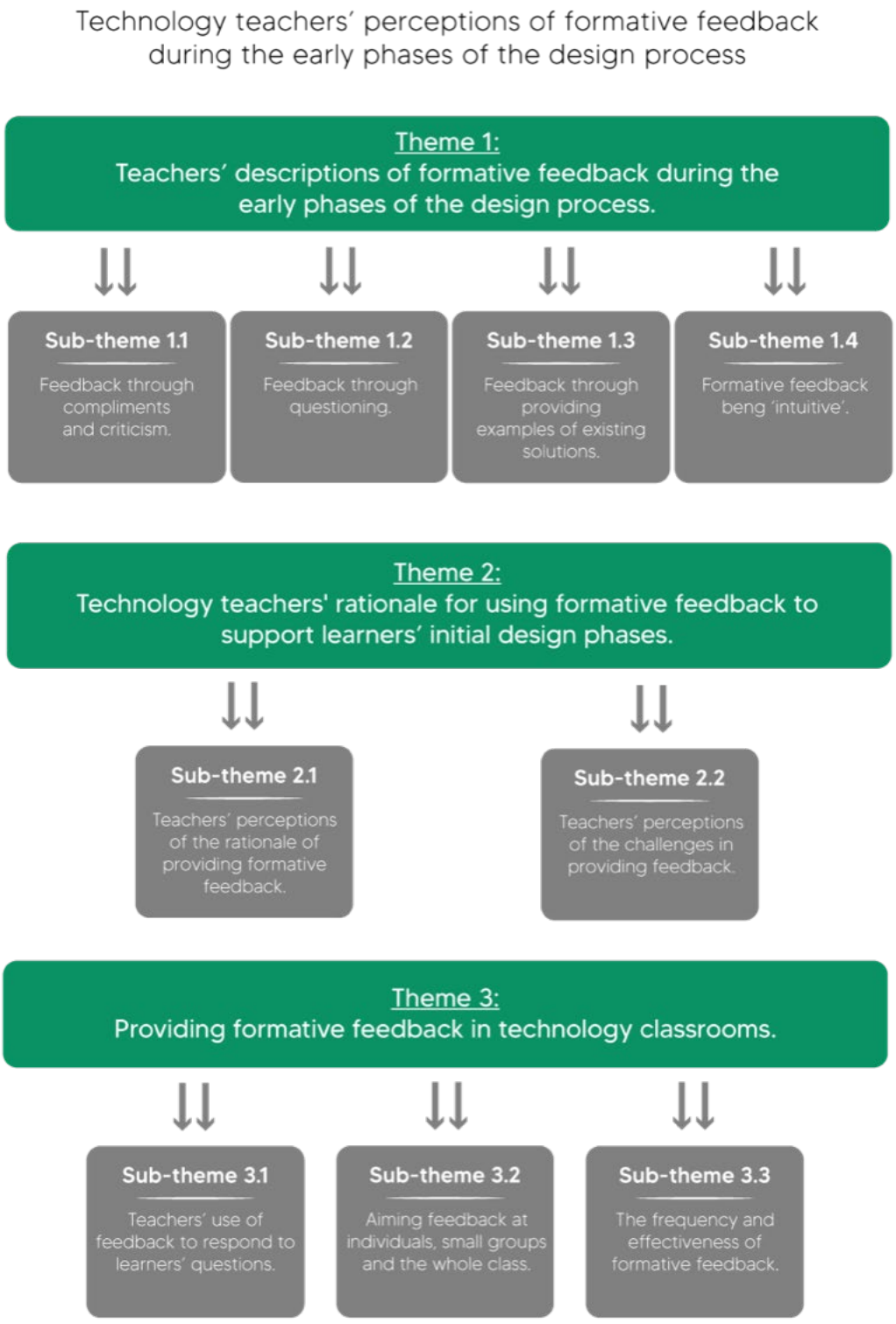


Figure 4.1: Technology teachers' perceptions of formative feedback during the early phases of the design process

In Sections 4.2.1 – 4.2.3, I provide an in-depth discussion of each theme and the related sub-themes that resulted from a thematic analysis of the interview data. As a starting point, I provide an overview of the main theme, and present the inclusion and exclusion criteria for identifying the sub-themes. From here, the result from each sub-theme is presented and interpreted. I support the interpretation of results with verbatim quotes from the interview data collected. These sections are concluded by relating the results to the existing literature (see Chapter 2).

4.2.1 Theme 1: teachers' descriptions of formative feedback during the early phases of the design process

This theme captures the participating technology teachers' descriptions of formative feedback during the EPoDP. The participants described the act of providing formative feedback through: 1) Compliments and criticism, 2) The use of questioning strategies, 3) Examples of existing solutions, and 4) Being 'intuitive'.

In this section, I discuss Theme 1 and the related sub-themes that emerged from the inductive thematic analysis of the interview data. I substantiate my discussion with verbatim quotations from the interviews.

Table 4.1: Inclusion and exclusion criteria used to identify the sub-themes of Theme 1

Theme 1: Teachers' descriptions of formative feedback during the early phases of the design process		
Sub-themes	**Inclusion criteria**	**Exclusion criteria**
Sub-theme 1.1: formative feedback through compliments and criticism.	This sub-theme includes data related to the use of praise or corrective feedback to move learning forward.	This sub-theme excludes data related to the use of direct recommendations and questioning, without elements of complimenting and critiquing.
Sub-theme 1.2: formative feedback through questioning.	This sub-theme includes data related to the use of dialogic questioning about the design task.	This sub-theme excludes data related to the use of questions related to classroom management, or statements related to direct recommendations.

Theme 1: Teachers' descriptions of formative feedback during the early phases of the design process		
Sub-themes	**Inclusion criteria**	**Exclusion criteria**
Sub-theme 1.3: formative feedback through providing examples to existing solutions.	This sub-theme includes data related to the use of examples of existing solutions as formative feedback. These may include samples of student work from previous years.	This sub-theme excludes data related to teachers modelling how to approach design tasks without the aid of existing solutions.
Sub-theme1.4: formative feedback being 'intuitive'.	This sub-theme includes data related to teachers' views of formative feedback as an intuitive process, requiring limited planning.	This sub-theme excludes data related to the teachers' perceptions of formative feedback as a formal practice, requiring planning.

4.2.1.1. Sub-theme 1.1: formative feedback through compliments and criticism

The first way in which the participants characterised formative feedback was by giving learners compliments and constructive criticism during their design processes. Some participants perceived feedback as building learners up through compliments before critiquing or pointing out deficiencies in their designs.

One teacher explained:

> [L]earners want to feel that they have done something right. So, I feel giving them a positive critique is best. You tell them 'you are having a positive influence on the whole class'. So, you first give them that compliment that then you tell them, "but look at this" [I1: initial interview].

Excerpt 4.1: The participants' use of compliments before critique and recommendations

Another teacher explained that feedback means "*[giving] a positive comment, then how they can improve then end with something positive"* [I9: follow up interview]. These characterisations were confirmed by a third teacher, explaining that *"what they already have, you have to be very positive. You just tell them how wonderful they are and that they can do it"* [I4: initial interview].

These quotations indicate that the participants characterised their formative feedback as providing learners with compliments. The participants viewed this approach as beneficial as it encourages learning during the design process. Two types of compliments emerged from their characterisations, namely, compliments directed at the learner doing the designing, and compliments directed at task performance. These two characterisations align with Hattie and Timperley's (2007) notion of praise as formative feedback directed at the level of the self. According to Kluger and DeNisi (1996), when praise is directed at the learner, it may be an effective way of building trusting relationships between teachers and learners. The authors also warn against mixing praise with formative feedback about the learning task, as this might make the feedback ineffective and confusing (Kluger & DeNisi, 1996).

The participants' quotes also seem to indicate that they characterised feedback as a form of critique. For example, one participant explained that:

> [A]s you walk around, you see that the learner does not have this and does not have this, and you see this with every group, then you pull back […] you stand in front and you tell them "it looks great but you are all forgetting your reference list, go back and have a look, and go read design brief/instructions" [I1, initial interview].

Excerpt 4.2: Feedback as a form of critique

Another participant confirmed this by saying: *"so you actually give feedback on [the] gaps that you see. Look at what they do not have yet and give feedback on that"* [I4: initial interview]. Seemingly, the participants considered formative feedback as a way of telling learners how to improve on their work. Participant 2 explained that formative feedback should be *"telling [the learner] or writing on their [the learner's] work how they can improve and how they should think in future"* [I9: follow up interview]. Participant 4 similarly stated that formative feedback requires teachers to *"identify strong and weak points and write down where they have gone wrong or where they can improve"* [I10: initial interview].

These results suggest that the participants viewed their formative feedback as constructive criticism by identifying deficits in the learners' work, and making recommendations for improvement. There are similarities between these results and

Hattie and Timperley's (2007) notion of feedback at task level. This type of feedback is often referred to as corrective feedback and is typically focused on providing information about task accomplishment. Crooks (2001) explains that formative feedback that gives learners information on how they can improve their work, or acknowledgement of improvements that learners have made in their work holds motivational benefits. This implies that formative feedback at task level might motivate learners when they receive acknowledgement of the progress they have made.

The data did not reveal how the participants used compliments or critique to comment on the learners' design processes. Most of the data on the teachers' descriptions focused on feedback in terms of products of learning. However, it appears that the teachers preferred to remain in control when they provided feedback and did not allow learners to take ownership of their tasks. In this way, feedback may be less effective as it does not allow students to become self-regulative (Hattie & Timperley, 2007).

4.2.1.2. Sub-theme 1.2: formative feedback through questioning

The second way in which the participants described their formative feedback practices during the design process was questioning. The participants indicated that they often made use of questions to guide learners through design tasks. Examples of the questions used by the participants to support learners through the problem structuring phase of the design process include: *"who is the customer? Who is the stakeholder? Who are we doing this for? Who is going to buy into this idea afterwards?"* [I3, initial interview]. The use of questioning was supported by a second participant's example: "*What is the target market in the end? Are you going to see it? Or is it personal?"* [I6: initial interview].

A third participant explained that he used questions to guide learners in considering existing solutions to the problem, and how these solutions could contribute to the learners' solutions: *"What do existing clocks look like? How can I use an existing click in the theme of our project to be able to make sure that it adheres to the theme?"* [I1: initial interview].

Some of the participants explained that they assisted learners in making design decisions by asking questions such as: "*What materials do you use? What [materials] is available to you? What is the price range? Will it sustain the pressures it needs to*

uphold? Will it suit the user?" [I3: initial interview]. A second participant supported this notion and provided examples of the questions used to assist learners in making design decisions: *"Is it going to be viable to use that material? Is it going to cost you more? Is it going to cost you less? Is it going to be a better quality if you use one material or another?"* [I6: initial interview].

The participants also indicated that they usually guided their learners to evaluate their design decisions by asking questions such as *"What would you have done differently?"* [I3: the initial interview], *"What does not work on this design?"* [I4: the initial interview], or "*Why does it not work? Is there any improvement that you can think of that you would have made after you have done your project?"* [I6: initial interview].

Furthermore, one participant explained how questions were used to guide learners who were having difficulty navigating the process:

> What is your first step? Where do you start? You identify your material. What is the next step? What is the third step? What is the fourth step? If you are going to pick specific materials what are you going to do with them? How are you going to do it? What kind of tools do you need in order to build that kind of product or design your product? [I6: initial interview].

Excerpt 4.3: Questions used as guidance for struggling learners

From these accounts, it seems that these teachers often used questioning as a strategy to guide learners during their design tasks. These results support the findings of previous studies conducted in professional design settings (Cardoso et al., 2014) and school settings (Schut et al., 2018, 2019, 2020; Stables, 2019) which have shown that design is often supported through dialogic questioning. These results highlight how the technology teachers perceived the use of a questioning as a good strategy to guide learners through the EPoDP. These results build on existing evidence in research conducted by Stables (2016). The author notes that questioning can be used to guide learners' next steps and help teachers to determine what the learner is doing and thinking. However, in their interviews, the teachers' made limited reference to the use of questioning to initiate conversations.

4.2.1.3. Sub-theme 1.3: feedback through providing examples of existing solutions

The third way in which the participants described formative feedback was providing learners with examples of how design tasks should be done, and existing solutions to the design problem. One of the participants explained that "*throughout, I work with previous solutions because it is finished projects that work. Then they can refer back to that instead of having to think of something they have no prior knowledge on"* [I10: initial interview]. This description was echoed by another participant, who stated: *"I have examples from previous assignments that I try to show them what it [the end product] physically looks like. They want to see practically what it should look like at the end"* [I8: initial interview]. A third participant explained that this was done because *"there is no need for my kids to try something that I know is not going to work."* [I5: initial interview].

It appears that the teachers saw formative feedback as a way to give examples of existing solutions to learners, which would support learners in completing their design tasks. In general formative assessment literature, the use of previous students' work might be a good strategy for supporting students in developing success criteria for a particular task (Wiliam, 2019). In the context of technology education, Kimbell (2020) notes the value of using previous samples of student work to support students in developing a construct of quality. However, the use of previous examples should be facilitated with care as the use of previous examples has been reported to lead to design fixation (McLellan & Nicholl, 2011).

Some of the participants also indicated that they had a specific design solution in mind and would guide learners towards these solutions through feedback. One participant clarified: *"I have a specific idea of where I want them to go and then I lead them in that direction"* [I10: initial interview]. The participant further explained that *"Questions are there to guide learners to the ideal solution"* [I10: follow up interview], and that "*you as the teacher have to lead learners in the right direction so that they have an overall idea of the assignment that has to be done"* [I10: follow up interview].

Some scholars attribute the process of guiding learners towards a specific design solution as a design process management technique, which ultimately neglects learner autonomy and decision making (Kimbell & Stables, 2008; McLellan & Nicholl, 2011). Other scholars reject the use of procedural 'recipes' for completing design tasks

when the focus of design tasks is used to develop manufacturing skills at the expense of developing design skills (Kimbell & Stables, 2008). These views are reflected in the interview data as some participants indicated that the design phases were often assigned as homework, not requiring the support of the teacher:

> [T]hey have one period where they can sit and plan as a group in class then it is given for homework. Then they come back for one period where they build and then it is given for homework again. Then they come back to present, so they will have three periods in total. [i1: initial interview].

Excerpt 4.4: Design phases assigned as homework

Another participant affirmed this view by stating, *"I don't see them often, so I usually give them the project and explain it and then tell them that the first phase needs to be completed at home by the next period"* [I8: initial interview].

The participants noted that they were often constrained by time when planning their lessons, and subsequently were unable to provide 'in-the-moment formative feedback' during designing. Time constraints might therefore contribute to teachers' use of 'recipe' like procedures in guiding learners to complete their design tasks, as evidenced in the following statements: *"A step by step procedure, to show them how they can do [build] a crane"* [I8: initial interview]. Often, teachers use resources like YouTube videos to show learners how tasks can be completed, for example, *"We have watched a video in class on how to make an electromagnet"* [I8: initial interview].

Another participant explained that:

> [A]s soon as I see learners that struggle it is always beneficial to take out the textbook or even use the cell phone to show them YouTube videos of how something can be done. As soon as they have seen it, they get a better idea of how they can move forward" [I9: follow up interview].

Excerpt 4.5: Use of examples or 'recipes' to guide learners

From these accounts, it seems that the participating teachers often made use of example solutions, or 'recipe' procedures to guide learners on *how* to complete their design tasks. In this regard, McCormick (2004) has found that teachers often treat

designing as a series of steps or a linear process. The author explains that treating design in this way can result in the design process being viewed as a ritual, and that lessons are often designed around these steps. Looking at learners' design portfolios, McCormick (2004) observed that learners followed this recipe approach to assessment and did not sufficiently demonstrate the development of their own design ideas. Hardy (2015) explains that following a linear design process means starting with and following a series of steps to reach a solution, and that teaching design in this linear fashion limits the potential for exploration and iterations. However, teachers follow linear approaches to designing as it typically makes designing easier to manage (Mawson, 2010). Another factor influencing a linear approach to designing is time constraints (Mettas & Norman, 2011). The effects of time limitations on technology teachers' implementation of formative feedback during the initial phases in the design process are discussed in depth in Section 4.2.2.2

4.2.1.4. Sub-theme 1.4: formative feedback being 'intuitive'

Finally, some of the participants explained that formative feedback is an intuitive process, and that they relied on a *"gut feeling"* [I1: initial interview] when providing feedback.

One participant explained that *"experience is definitely the thing and experience has a greater impact than what you have learned. To realise what works and what does not"* [I9: initial interview]. Another participant agreed by asserting: "I think you learn it in practice, 'work smarter not harder" [I4: initial interview].

The perception that formative feedback is an intuitive process was further confirmed by the participants' responses regarding how formative feedback is planned. The participants explained the process of planning feedback as "*happening on the whim*" [I10: initial interview], "*easy*" [I1: initial interview], as something that "*just happens in the moment*" [I2: initial interview], or that happens "*as we go along*" [I10: initial interview].

The evidence from this section seemingly indicates that these teachers relied on their know-how and pedagogical practice to prepare for formative feedback during the design process. The results suggest that the participants viewed feedback as an intuitive process, and one that does really require planning or practice as it is

something that spontaneously occurs during teaching. Some scholars have speculated that teachers' support during design tasks may be influenced by their own experiences as designers, or their knowledge about the design task presented (Cardoso et al., 2014; Yilmaz & Daly, 2016). Since the participants in this study had been teaching technology for at least one year, I speculate that the participants' experience with teaching technology and pre-service training in technology education may have influenced their perception that formative feedback is intuitive. Furthermore, some of the participants may have taught or facilitated design projects similar to the ones observed in this study. If this is the case, it means that the participants' prior experience with facilitating similar design projects may have influenced their perceptions of the nature of formative feedback in design contexts.

The iterative and co-evolutionary nature of the design process, along with ill-structured design problems means that there is not only one correct solution for a design problem. In the same way, teaching design, and supporting and guiding learners' design processes also do not rely on a singular approach (Strong et al., 2019). Researchers in professional design education explain that teaching is "contingent upon interaction with others and build from moment to moment but drawn upon an existing repertoire of pedagogical practice" (Sawyer, 2004, cited in Strong et al., 2019, p. 13). Therefore, design teachers and instructors need to be adaptive and should be able to draw on a variety of teaching approaches, methods, strategies, content, and pedagogical knowledge from which to draw (Strong et al., 2019).

4.2.2. Theme 2: technology teachers' rationale for using formative feedback to support learners' initial design phases

This theme reports on the participating technology teachers' perceptions of the rationale for formative feedback to support learners during the EPoDP. The challenges that teachers face when providing formative feedback is also covered in this theme. Theme 2 comprises two sub-themes, viz., teachers' perceptions of the necessity of formative feedback, and their perceptions of the barriers to formative feedback. Table 4.2 captures the criteria that I used in identifying the sub-themes for Theme 2.

Table 4.2: Inclusion and exclusion criteria for identifying the sub-themes of Theme 2

Theme 2: technology teachers' perceptions of the necessity of formative feedback during the early phases of the design process		
Sub-themes	**Inclusion criteria**	**Exclusion criteria**
Sub-theme 2.1: teachers' perceptions of the rationale of formative feedback.	This sub-theme included data related to the teachers' perceptions of the rationale and purpose of providing feedback.	This sub-theme excludes data relating to the necessity of feedback to help learners manage their time, tasks, or groups.
Sub-theme 2.2: teachers' perceptions of the challenges of providing formative feedback.	This sub-theme includes data related to the teachers' perceptions of the challenges they face when providing formative feedback.	This sub-theme excludes data related to teachers' general perceptions of the challenges related to teaching technology.

4.2.2.1. Sub-theme 2.1: teachers' perceptions of the rationale of formative feedback

The participants indicated that they considered formative feedback as a necessary part of teaching technology. Some of the participants explained that feedback is necessary to guide learners on where they are going, as well as the next steps required to get there. For example: *"I really have to facilitate that whole [research] process and give them [the learners] feedback now and then and remind them what is expected from that"* [I2: initial interview], and *"Yes, feedback is necessary. It [the design process] goes a lot slower and learners don't work if they don't know what comes next"* [I4: initial interview]. A third participant supported these views, maintaining that *"Constant feedback will give them better ideas to think outside the box, think what is necessary, see what changes can be made to either product strong, better or more successful"* [I6: initial interview].

To further support this view, one of the participants explained that *"If you don't give feedback on the first activity you will have a failure in the end. You have to give feedback and feedback on every activity is necessary"* [I9: initial interview].

These accounts seem to indicate that the participants used feedback to clarify expectations, monitor learners' progress in the task, and explain the possible next steps required. These accounts align with Hattie and Timperley's (2007), and Black

and William's (2010) notion of the three fundamental aims of formative feedback. Effective feedback should guide learners on what the goals of the task are, how they are progressing towards the goal, and what their next steps should be to reduce the gap between their progress and the learning goal (Black & Wiliam, 2010; Hattie & Timperley, 2007). Hattie and Timperley (2007) point out that the power of feedback lies in reducing the gap between where learners are and where they are going.

The results show that the participants were aware of the necessity of providing feedback, and that feedback has different purposes in guiding learners. One participant in particular noted that: *"[learners] can also start to ask themselves questions"* [I5: initial interview]. The participant goes on to clarify that: *"they can start to internalise the knowledge that they get from the book"* [I5: initial interview].

These accounts of the teachers' perceptions of formative feedback support the notion that feedback can be used to increase learners' reflective and meta-cognitive abilities through self-regulative feedback (Kimbell & Stables, 2007; Hattie & Timperley, 2007). Further research is, however, needed to determine teachers' perceptions of the nature of self-regulative questioning in terms of learners' metacognitive processes, and the practical strategies used by teachers to foster self-regulative learning.

4.2.2.2. Sub-theme 2.2: teachers' perceptions of the challenges in providing feedback

Although all of participants indicated that they perceived feedback as an integral part of facilitating designing, some participants indicated that time constraints were barriers to feedback. One participant pointed out that he only received the design briefs from the subject head a few hours before he was meant to distribute the design briefs to the learners: *"You would not believe me, but I am receiving my PAT's now and then I read it now with the learners for the first time"* [I1: initial interview].

The participants also explained that there were only three periods allocated for learners to complete the whole design-and-make activity. The three periods were used to distribute the design tasks, assign team members, and make and present the final products (see Section 4.2.1.2). Another participant explained that group size, together with time restrictions, prevented her from giving feedback in class: *"If each [learner] has to do their own assignment then I don't get to everyone. But if it is a group assignment and they are five or six groups then I get to all of them"* [I4: initial interview].

The participant went on to explain that in order to address the time limitation, she made use of Google Drive as a way for her learners to submit their work for formative feedback. This means that the learners received feedback after a piece of work had been completed, and that feedback was then given in the form of written feedback. A third participant reported that due to time constraints, she was not able to provide learners with sufficient feedback, and that class time was mostly dedicated to the building of their design solutions.

These accounts regarding the challenges that the participants faced in providing formative feedback support the results from the previous theme. In Section 4.2.1.2, it was reported that time constraints are considered a barrier to formative feedback. The results from this section may also serve as a possible explanation for why the teachers used existing examples as feedback (see Section 4.2.1.3) to streamline the design processes. Hardy (2015) and Mettas and Norman (2011) have indicated that time constraints direct the management of design tasks, and that teachers limit their feedback and revert to a linear design process to meet curriculum requirements.

4.2.3. Theme 3: technology teachers' perceptions of how formative feedback is implemented in technology classrooms

This theme describes the participants' perceived implementation of formative feedback during design tasks that require problem solving. In particular, this theme describes how the participants responded to learners' questions; how frequently the participants provided formative feedback on learners' work; and how the participants determined the effectiveness of their formative feedback. In Table 4.3, I present the inclusion and exclusion criteria that I used to identify the sub-themes for Unit 3.

Table 4.3: Inclusion and exclusion criteria used to identify the sub-themes of Theme 3

Theme 3: providing formative feedback in technology classrooms		
Sub-theme	**Inclusion criteria**	**Exclusion criteria**
Sub-theme 3.1: teachers' use of formative feedback to respond to learners' questions	This sub-theme includes data related to the use of formative feedback to respond to learners' questions.	This sub-theme excludes data that refer to student questions that do not relate to the design task.

Theme 3: providing formative feedback in technology classrooms		
Sub-theme	**Inclusion criteria**	**Exclusion criteria**
Sub-theme 3.2: aiming formative feedback at individuals, small groups, and the whole class.	This sub-theme includes data relating to feedback aimed at individuals, small groups, and the whole class.	This sub-theme excludes data that refer to written feedback that is not related to a design task
Sub-theme 3.3: the frequency and effectiveness of formative feedback.	This sub-theme includes data related to the frequency and effectiveness of formative feedback.	This sub-theme excludes data that relate to written feedback after the design task has been completed.

4.2.2.3. Sub-theme 3.1: teachers' use of formative feedback to respond to learners' questions

This sub-theme explores teachers' views of how formative feedback is used to answer learners' questions while they are engaged in design activities. When asked how the participants usually responded to questions from learners, the participants indicated that: *"If I know and I have an answer I will tell them. If not, I will tell them I don't have an answer and I will get back to them"* [I3: initial interview]. Likewise, one of the participants specified that: *"I use my cell phone. So, if they ask me a tough question I will say 'wait let me Google it'. If I don't get an answer, I will YouTube it and show it to them"* [I9: initial interview].

In contrast, some participants indicated that they would rather lead the learners to the answer by creating scenarios or inviting the rest of the class to help learners find solutions. One participant expressed that *"…you do not need to know the answer yourself; you just need to be able to give him a scenario to lead him. You do not need to answer him directly."* [I1: initial interview]. Another participant explained that "I *ask the others [class] what do you think? Help them, give them ideas. In fact, this is your class, you need to make the decisions"* [I6: initial interview]. This view was further supported by another participant:

> I usually give feedback on questions by throwing the question back to the class. Then I get feedback from the learners who are willing to give suggestions and then I will give a summary of what I think they can use as a solution [P5: follow up interview].

Excerpt 4.6: Using a whole-class question strategy to guide learners

These accounts suggest that the participants used formative feedback to answer learners' questions by giving learners similar scenarios to consider, researching the question for the learners, or posing the question to the whole class for input. Eris (2003) suggests that asking scenario-creation questions is necessary during the design process as these questions invite the learners to think of many possible outcomes of the scenario. The author further explains that scenario-creation questions help designers refine their design requirements (Eris, 2003). In a recent study, Royo et al. (2021) report that scenario-creation questions lead to an increase in the amount and quality of design solutions proposed by product design students.

4.2.2.4. Sub-theme 3.2: aiming feedback at individuals, small groups, and the whole class

This sub-theme describes the ways in which the participants provided formative feedback to individuals, small groups, and the whole class during the design process. The results show that the teacher participants would walk around the class while learners were engaged in design activities. They would then give feedback individually and to small groups. The participants further explicated that they would address the entire class when they noticed common errors in individual and group work. One participant specified: *"I will look at everyone's work individually and make recommendations and then I will give a summary to the whole class on what they should focus on and where or what I think they can all improve on"* [P1: follow up interview].

Another participant explained that:

> I usually walk up and down in the class. I look at who can draw and whose measurements are correct. If I get to, say the 4th learner and I see something is wrong, then I will stop the class and say to the class 'let's have a look at your ruler [I9: initial interview].

Excerpt 4.7: Feedback aimed at the whole class to help correct and guide learners

A third participant detailed: *"I walk around from group to group and then I look, and I see, if something does not look right, I help them immediately"* [I10: initial interview].

These accounts seem to indicate that the participants followed different approaches when providing formative feedback. On the one hand, the participants supported individual learners when providing feedback. On the other hand, they also followed a 'whole class' or 'small group' approach in providing learners with feedback during designing. Brookhart (2017) suggests that the audience should determine whether the feedback is given to the individual, a group, or the whole class. The author suggests that providing feedback to the whole class when the feedback only applies to a few learners may be ineffective.

These results regarding the audience for formative feedback seem to align with the descriptions of feedback in professional design studies. In such cases, feedback is described as the process of instructors walking from desk to desk to view students' work, identifying promising and problematic aspects of the design, and considering how well the design specifications were met (Goldschmidt et al., 2010). These results confirm the previous results (see Section 4.2.1.1), which indicated that the participants characterised feedback as the process of identifying deficiencies in learners' designs, and making suggestions for improvement.

4.2.2.5. Sub-theme 3.3: the frequency and effectiveness of formative feedback

This sub-theme conveys the participants' views on how often and how effectively formative feedback is given during the EPoDP. The participants indicated that providing formative feedback is a continuous process. The participants explained: *"I would say they have a week per activity. The first week is their design brief, then they have to submit it. I then mark it and give feedback"* [I9: initial interview]. This was echoed by another participant:

> Feedback is given after every single step. As they finish with the investigation, I will say there is not enough investigation go collaborate more here or go do more research here or I make some suggestions. In other words, in every single step, I give feedback before they go to the next step [I3: initial interview].

Excerpt 4.8: Formative feedback viewed as a continuous process

A third participant supported these views by explaining that:

> I give them a certain amount of time. So when they come back, I go through their investigations, I make comments about what they have to fix. I give them key points on what to look for, what type of information to look for. So each and every part of the design, I have to go through it with them. They give it back to me I check it, I comment, they fix their mistakes we come back. We do the back and forth process [I2: initial interview].

Excerpt 4.9: The use of a back and forth feedback loop

These results seem to indicate that the participants followed a linear approach to feedback, breaking the design task down into sub-tasks to be assessed. At the completion of each sub-task, feedback was provided to support iterations in the design process.

Previous studies on formative feedback have focused on the effectiveness of feedback rather than the frequency thereof (Hattie & Timperley, 2007; Kluger & DeNisi, 1996; Shute, 2008). These studies have shown that process-level feedback and self-regulative feedback are more effective for more advanced learners. Ideally, feedback should progress from the task level to the process level, then to the self-regulative level as learners' knowledge and skills become more advanced (Hattie & Clarke, 2019; Hattie & Timperley, 2007; Wisniewski et al., 2020).

This study shows that the participants viewed their feedback as effective when they observed a change in learners' designs. One of the participants expounded that:

> I know it [feedback] is effective when they actually go and change what I ask them to change and put in more effort where I asked them to put in more effort. If it was not effective, they would just leave things as they are and submit them again. When they change something, it shows that my feedback really did something [I2: initial interview].

Excerpt 4.10: Feedback viewed as effective when changes were seen in learners' designs

This view of effective feedback was echoed by another participant, who explained that he perceived his feedback to be effective when: *"I can see that they applied it. If they don't apply it, it means they didn't take it seriously"* [I3: initial interview]. Other participants indicated that the effectiveness of their feedback was observed at the end of the design task, for example: *"I see it in the results of the project comes to an end if they succeed in what they had to do"* [I3: initial interview]. This was supported by a participant who explained that: *"The design will become better, the final product then should work"* [I5: initial interview].

These perspectives on effective feedback support previous findings that show that teachers will often assess the success of learners' designs based on the end product (Engelbrecht et al., 2007; Nadelson et al., 2015; Neuman, 2003). The results also indicate that success in receiving feedback is measured by adhering to teachers' instructions rather than evidence in developing design capability.

Previous studies on learners' perceptions of effective feedback have indicated that learners perceive feedback as helpful when it is specific, linked to the assessment criteria, and is formative rather than summative (Harris et al., 2014; Hattie & Gan, 2017; Pokorny & Pickford, 2010; Smith & Lipnevich, 2009). In addition, learners have also indicated that for feedback to be effective, they need time to work through and implement the given feedback (Brooks et al., 2019). This means that learners deem formative feedback with time to reflect on and implement feedback more effective than feedback that is given after a task has been completed. Research indicates that learners will abandon feedback that does not require a response, or provide sufficient time for learners to reflect on and implement feedback (Brooks et al., 2019; Hattie & Clarke, 2019).

4.3. IMPLEMENTATION OF FORMATIVE FEEDBACK DURING THE EARLY PHASES OF THE DESIGN PROCESS

In Section 4.3.1, I describe the frequency of formative feedback occurrences in the problem structuring and the preliminary problem-solving phases of the design process. This is followed by Section 4.3.2, in which I present the frequency of feedback occurrences at the four levels of feedback identified by Hattie and Timperley (2007). Subsequently, I provide qualitative examples of these formative feedback occurrences at the task level, process level, self-regulative level, and the self-level (Hattie & Timperley, 2007, 2012), as well as a discussion of the results. Section 4.3.3 concludes this section by providing examples and a discussion of the different types of questions and comments that the participants used to provide feedback to the learners.

4.3.1. Formative feedback and the initial phases of design

The second aim of this study was to explore and describe the nature of formative feedback during the EPoDP. The frequency of formative feedback given by each participant is presented in Figure 4.2.

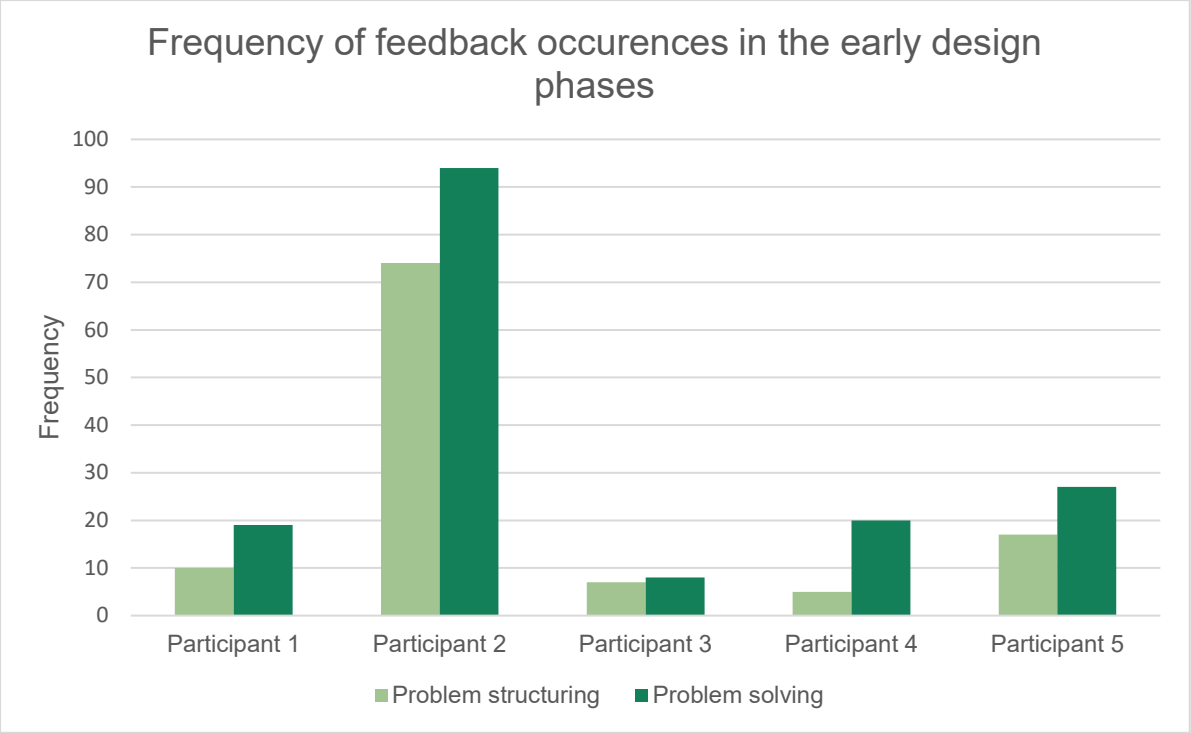


Figure 4.2: Frequency of formative feedback occurrences during the design process' problem-structuring and preliminary problem-solving phases

The data in Figure 4.2 illustrates the frequency of feedback occurrences for each participant directed to support learners' problem-structuring and preliminary problem-solving phases. From Figure 4.2, it can be seen that the frequency of feedback occurrences for Participant 2 was significantly higher than the other participants. Participant 2 spread the problem-structuring and preliminary problem-solving phases over the three lesson period, whereas the other participants completed the early phases in one to two lesson periods. The results suggest that the participants generally provided their learners with feedback that guided them in considering possible solutions to the problem rather than supporting them to define and explore the design problem itself. This result is supported by previous think-aloud protocol studies that indicate that students generally engage more with preliminary design problem solving, rather than problem structuring (Blom et al., 2018; Kelley et al., 2015). One reason for this might be that the participants were constrained by time requirements. Another reason why formative feedback may be predominately observed in the problem-solving phase could be linked to the goal of the design task. Since the goals of a design task are to generate possible solutions, feedback in the problem-solving phase may provide learners with information on how to move their learning forward (Brooks et al., 2019; Hattie & Clarke, 2019). This means that effective formative feedback in the problem-solving phase may significantly reduce the gap between where learners are in their design processes, and the end goals (Hattie & Clarke, 2019) of the design task. This result plays a role in facilitating the problem-structuring and preliminary problem-solving phases.

To further understand the nature of formative feedback in the EPoDP, I investigated the specific feedback occurrences observed within the design process' problem-structuring and preliminary problem-solving phase.

4.3.1.1. Formative feedback in the problem-structuring phase

The design tasks consisted of descriptions of the specific products to be designed, namely, over-water bungalows, an amusement park ride, a water tank structure, a pedestrian bridge, and packaging for a lightbulb. The tasks contained limited information on the end-user and the resources available to design the desired product or artefact (see Appendix C). This means that the design briefs did not completely specify all the requirements, constraints, and context for the given design problems.

In line with Goel and Pirolli's (1992) description of the characteristics of the problem-structuring phase, the results show that the participants' formative feedback was predominately focused on guiding students in identifying what the design problem was, how to gather more information on the design problem, and analysing existing products.

In Excerpt 4.11 - 4.13, I present the examples of formative feedback provided by the participants, which guided the problem-structuring phase.

P2: You have to go and design and make a what?
P2: What is the problem?
P3: What was the problem?
P3: What do we have to do?

Excerpt 4.11: Formative feedback guiding problem identification

Excerpt 4.11 illustrates that the participants guided their learners in identifying the design problem by explicitly asking learners to establish what the design problem was based on the given design task. However, it seems that guidance in exploring the design problem was very limited. In fact, the participants often required learners to complete a sentence by repeating the stated problem outlined in the design task, or they answered their own questions by directing learners to the outlined design problem. This supports previous results in this study (see Section 4.2.1.2). The evidence in Section 4.2.1.2 showed that the participants often provided learners with formative feedback to guide them towards a specific design solution (Engelbrecht et al., 2007; Neuman, 2003).

The examples in Excerpt 4.12 demonstrates how the participants used formative feedback questions to guide learners on how to proceed with researching the problem and existing solutions during the problem-structuring phase of the design process.

P2: How do I do research?
P2: How did you do research?
P1: I showed you my research, was it writing? What was it?
P1: Why wouldn't I put an overwater bungalow in Japan?
P5: What things do you need to go and find out?

Excerpt 4.12: Formative feedback guiding research

The examples of formative feedback in Excerpt 4.12 show that the participants guided learners on how to research a design task. They did this by asking the learners questions to draw their attention to how research should be conducted and presented, and to consider what information is still missing regarding the design problem. Only Participant 5 was observed asking learners to consider what information they still needed to understand the design problem. However, it should be noted that this question was part of the design task activity sheet given to the learners to complete (see Appendix C). It seems that the purpose of the formative feedback presented in Excerpt 4.12 was to guide learners on how to investigate existing design solutions rather than finding information about the design problem, context, clients, or existing products.

After asking formative feedback questions to guide learners on the analysis of existing products, Participant 1 and Participant 2 showed learners videos and images of existing solutions. The results indicate that the participants made use of questions to guide the learners in analysing existing products by drawing their attention to key features of existing designs. Examples of these accounts are presented in Excerpt 4.13.

P2: Can you see the rotary motion?
P2: Here they used what mechanism?
P2: Can you see that it's rotating, and the seats are rotating?
P1: Can you see how it stands out when you fly by it (overwater bungalow in the video)?
P5: Think about the packaging as well. You mentioned that the packaging must be attractive as well.

Excerpt 4.13: Formative feedback guiding the analysis of existing products

Excerpt 4.13 shows how the participants guided their learners through analysing existing products. They also asked questions to draw the learners' attention to key features of existing designs, such as movement in the design, aesthetics, and the mechanisms used in the existing design solutions.

In summary, Excerpts 4.11-4.13 demonstrate how the participants used questions to support their learners' problem-structuring phases. These questions seemed to be directed toward guiding learners to gather information about the design problem that would allow them to explore possible solutions. Some studies have shown that a thorough exploration of the design problem may lead to more innovative and novel design solutions (Creeger et al., 2019; Dorst & Cross, 2001). Initial design ideas that originate from problem identification may lead to obvious or existing solutions (Creeger et al., 2019). Creeger et al. (2019) assert that for learners to generate creative solutions, they should be taught strategies to think critically during the initial design phases. To investigate the impact of problem structuring on learners' exploration of the problem space, Creeger et al. (2012) designed an online tool containing12 problem structuring strategies with question prompts.

The results evidenced by questions in Excerpts 4.11-4.13 align with some of the problem structuring strategies identified by Creeger et al. (2012). The participants in this study were found to have supported learners' problem structuring activities by asking questions relating to the characteristics of the users and their needs, and exploring existing solutions (Creeger et al., 2019). These results furthermore support the notion that the participants were problem-driven in this phase, and guided learners through formative feedback to gather the information needed to understand the problem (Kruger & Cross, 2006). This result further supports the findings of a previous study, which indicate that elementary school teachers emphasise the identification of the problem as part of the problem-structuring phase (Nadelson et al., 2015). The authors also found that the teachers paid limited attention to other problem structuring activities such as exploring the context of the design problem, unique or interesting features of existing designs, and the user for the final design solutions.

4.3.1.2. Formative feedback in the preliminary problem-solving phase

In the preliminary problem-solving phase, the participants' formative feedback appeared to be guided by the design activities that were outlined in the design task.

For this purpose, formative feedback during the preliminary problem-solving phase was mostly focused on supporting learners to write a design brief, identify design specifications and constraints, explore design solutions, and make design decisions about what materials or tools to use in realising their design ideas. Examples of formative feedback during the design phase are captured in Excerpt 4.14 - 4.17.

P1: Your overwater bungalow is for who?
P2: Are you just going to build a structure?
P4: What should it [the design solution] be able to do?

Excerpt 4.14: Formative feedback that guides writing the design brief

From the accounts presented in Excerpt 4.14, it can be seen that the participants guided learners in writing a design brief. They did this by asking them formative feedback questions about how the design problem should be solved, and how their design solutions could be realised. As prescribed in the CAPS document for technology, the design brief should be a short statement that outlines the design problem to be solved and the purpose of the solution (DoBE, 2012b). As part of the design brief, the participants asked learners to consider the design problem, who the client was, and the purpose of the design solution.

Next, the participants supported learners in identifying the design specifications. In Excerpt 4.15, I present examples of the formative feedback questions that the teachers asked to support learners' identification of design specifications.

P2: What are those specs?
P2: How wide are your poles that you are using?
P4: What are your specifications?
P1: What are the overall dimensions?
P1: What extra detail has your client asked you to add to the product you are going to design?

Excerpt 4.15: Formative feedback that guides learners in identifying design specifications

The accounts in Excerpt 4.15 show that the participants supported the learners in identifying design specifications. This was carried out by asking the learners to consider what design specification is, what the dimensions of their design solutions are, the types of material they can use, and what additional features their designs would have. The results further showed that the participants used formative feedback to guide learners in exploring possible solutions. Examples of these accounts are presented in Excerpt 4.16.

P5: What is your idea?
P3: What ideas do I have?
P2: How are you going to solve the problem?
P2: What are you going to make?
P1: Most overwater bungalows are made of what?
P2: What's going to make your ride turn?

Excerpt 4.16: Formative feedback that guides idea generation

The examples presented in Excerpt 4.16 show that the participants guided the learners in exploring possible design solutions. They did this by asking the learners to consider what ideas they have, how they are going to solve the problem, and what materials and mechanisms can be used in their design solutions. The participants also used formative feedback to guide learners' design decisions in the preliminary problem-solving phase. Examples of the formative feedback used to guide learners in making design decisions are illustrated in Excerpt 4.17.

P2: Are you going to use a gear system? Are you going to use a hydraulic system? A pneumatic system? What are you going to use to make this ride move?
P2: What materials are you going to use?
P2: what are you going to use to make the mechanism?
P1: Most overwater bungalows are made of what?
P3: Which techniques do you think will strengthen it [the design solution]?

Excerpt 4.17: Formative feedback that guides design decisions

Excerpts 4.14 - 4.17 demonstrate that the formative feedback provided by the participants in the preliminary problem-solving phase was directed mainly at guiding learners in completing the design activities as set out in the design task. The teachers seldomly encouraged learners to consider the design brief or design specifications once the learners had decided on a particular solution.

This result supports previous results in this study that showed that the participants characterised formative feedback as a process of providing examples of existing solutions, and guiding learners towards specific design solutions (see Section 4.2.1.2). A previous study by McLellan and Nicholl (2011) shows that teachers' feedback during the design process might be biased and lead learners to specific design solutions that could hamper their creativity when designing. It seems possible that these results are due to the nature of the design briefs presented to the learners. The design briefs all included a statement or a brief description of the desired design solution.

The results in this section have implications for supporting learners to develop diverse, creative and novel design solutions (Daly et al., 2019). Some authors assert that generating multiple and diverse solutions during the preliminary problem-structuring phase has the potential to promote innovative and novel design solutions (Daly et al., 2019). Although this study did not investigate the creativity of learners' design solutions, it seems that supporting learners through formative feedback in the preliminary problem-structuring phase may influence the quality and novelty of their design solutions.

Furthermore, the formative feedback given during the preliminary problem-solving phase of the design process was primarily directed at the whole class and, in most cases, the learners were not required to answer the questions asked by the participants. This contradicts previous results in this study where participants indicated that feedback was mainly provided to small groups or individuals (see Section 4.2.3.2).

This section provided an overview of the formative feedback given to support learners' design activities within the EPoDP. In the following section, I further explore the nature of technology teachers' formative feedback by looking at the level at which formative feedback was provided. Understanding the level at which they provided feedback has important implications for designing a framework to plan and implement formative feedback in technology classrooms. Such a framework could support teachers to plan

and implement feedback that helps learners move their learning from surface knowledge (task level) to conceptual understanding (self-regulative) (Hattie, 2012).

4.3.2. Levels of formative feedback during the early phases of the design process

This section presents the four levels of formative feedback given during the design process' problem structuring and preliminary problem solving. The results are based on a model for feedback created by Hattie and Timperley (2007). This model demonstrates how formative feedback occurs at the task level, the process level, the self-regulation level, and the level of the self (Hattie & Timperley, 2007).

Figure 4.3 shows the frequency of formative feedback occurrences at each formative feedback level

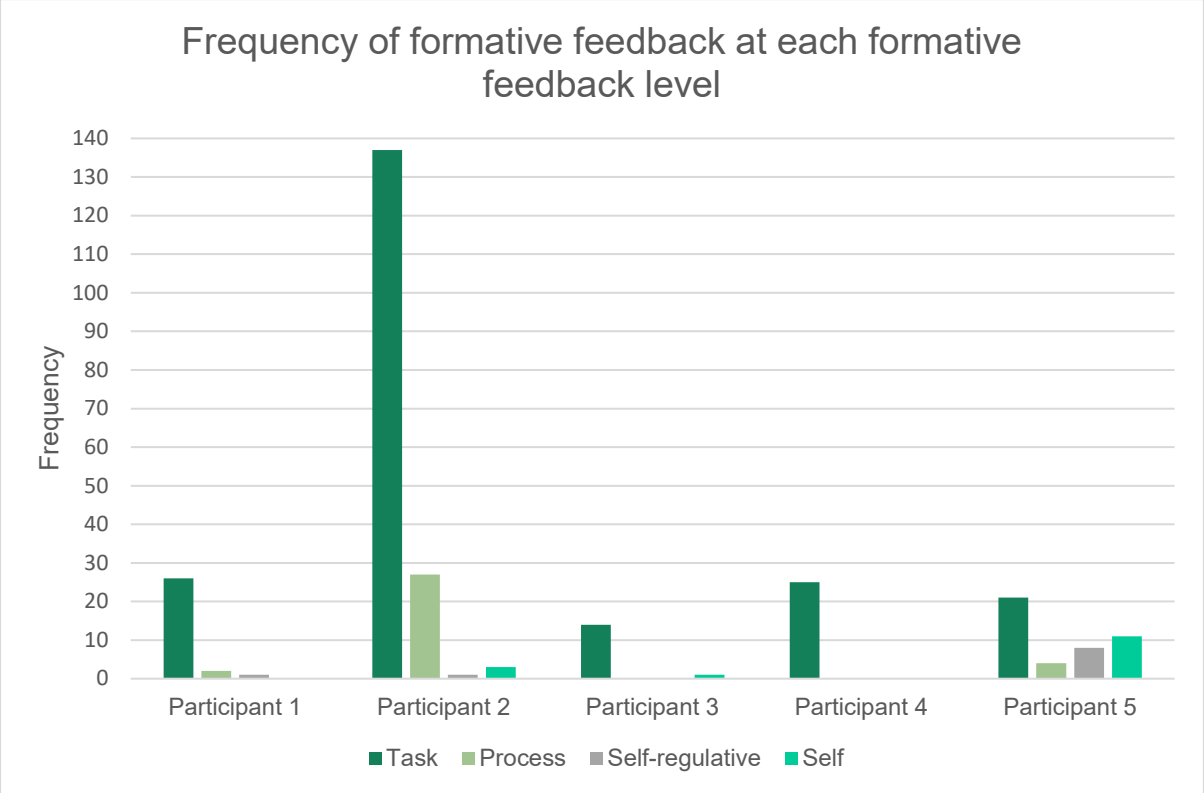


Figure 4.3: Frequency of formative feedback at each formative feedback level

The results presented in Figure 4.3 show that the most formative feedback was aimed at task level. This implies that the majority of the formative feedback provided to the learners was aimed at supporting them to understand and complete the design task. This result supports Hattie and Timperley's (2007, 2012) findings, which indicated that

feedback at the task level is the most common in classrooms. Often, task-related feedback is focused on the correctness of a response (Hattie & Gan, 2017). The effectiveness of task-related feedback may be increased when the feedback is information seeking and builds on surface knowledge (Hattie & Gan, 2017). In contrast, very few instances of feedback occurred at the self-regulation and self-level. The results of a study on school learners' perceptions of feedback (Brooks et al., 2019) indicated that learners perceive self-regulative feedback as a distinct level of feedback but not as helpful feedback. The authors speculate that the lack of self-regulative feedback and the perceived ineffectiveness of self-regulative feedback may be due to self-regulative feedback being underused in the classroom (Brooks et al., 2019). Lawson et al. (2019) report that teachers believe that self-regulative feedback is necessary to promote academic achievement, but that teachers are not sure how to teach self-regulation in the classroom. Furthermore, the authors report that time constraints and large class sizes may be a limiting factor in providing self-regulative feedback.

4.3.3. Task-level formative feedback

The majority of formative feedback observed in the EPoDP were found to be focused on supporting learners to understand and complete the given design task. During the problem structuring phase, this meant that the formative feedback was aimed at guiding learners in identifying and exploring the scope of the design problem, investigating existing solutions, and considering where and by whom the design solution would be used. Examples of the task-related formative feedback occurrences are presented in Excerpts 4.18 - 4.19:

P2: What mechanism will you use to make this Ferris wheel rotate or move?
P2: Can you remember what was the reinforcements used to make the structure stronger?
P1: I've already done my research. Was it writing? Can you design something from words?
P5: So your idea, in other words, is to use it where? With cell phones?
P5: Who will be the clients? Who is this light intended for?
P3: I have already done [discussed] two types of structures with you, which two were they?
P4: What is the best type of structure for this bridge?

Excerpt 4.18: Task-level feedback in the problem structuring phase

The accounts presented in Excerpt 4.18 demonstrate how the participants used formative feedback to clarify the task goals and expectations. The questions in the excerpt above also illustrate how the teachers used formative feedback to support learners' surface understanding about the content on which the design task was based.

These accounts presented in Excerpt 4.18 also seem to support the results from Section 2.1 that showed that formative feedback in the problem-structuring phase is structured around the design task documents. This meant that participants often used task-related feedback to guide learners in answering the questions in the design task documents. To support my observation, in Excerpt 4.19 I present the corresponding instructions from the design tasks related to the task-level feedback identified.

Design document, P2: Identify a frame structure and a mechanism that will be suitable for the ride that your class will design and make.
Design document, P1: Research overwater bungalows in order to gain a better understanding of overwater bungalows. Your research must include pictures and information answering the question you are researching.
Design document, P3: Do research on structures. Name and identify the two types of structures that we discussed in class and provide two advantages and disadvantages of each.
Design document, P4: Research three possible bridge designs that will be suitable for the scenario.
Design document, P5: Where will the design be used? Who are your intended clients?

Excerpt 4.19: Task-related questions in the design documents

The results from the data analysis of the task-level feedback observed in the preliminary problem-solving phase further supported the notion that the formative feedback was structured around the design task documents. During the preliminary solution phase, the formative feedback was focused on helping learners to write a design brief, identify the specifications of potential design solutions. The teachers further supported learners' idea generation and selection. Examples of task-level feedback occurrences during preliminary problem-solving phases are presented in Excerpt 4.20.

P1: What are you going to design and make?
P3: What ideas do I have?
P1: What are the overall dimensions?
P4: What are the specification it [design solution] should have?
P5: This light has to come in a vacuum-sealed package.
P5: What [materials] are you going to use?

Excerpt 4.20: Task-level formative feedback in the preliminary problem-solving phase

These accounts seem to indicate that the majority of task-level feedback in the preliminary problem-solving phase was solution-focused and structured around the

design task. The questions presented in Excerpt 4.20 were asked after the participants read the questions or design statements from the design tasks in Excerpt 4.19. This meant that most of the feedback the participants provided guided learners towards completing a design brief, identifying design specifications and constraints, exploring possible solutions, and making design decisions. Although it seems that the participants' feedback guided the learners to explore various design solutions, the participants often directed learners towards the design brief in finding the correct information to complete the design brief, specification, and constraints. The participants further used videos and images during the lesson to show learners existing examples, and draw learners' attention to the desired aspects of existing solutions. I speculate that the participants engaged in task-level feedback in the preliminary problem-solving phase to reduce the "discrepancies between learners' current understanding and the learning intention or goal" (Hattie & Timperley, 2007, p. 7). The answers to the questions in Excerpt 4.20 were often met with confirmation if the answer was correct or learners were prompted to elaborate if their answer was incorrect. This feedback process aligns with Hattie and Gan's (2017) graphic organiser to support a dialogic and visible feedback process. The authors propose that when a question is asked, the teacher evaluates whether the learners' answer meets the success criteria. If the learners' answer is correct, the teacher can then proceed to process-level feedback (Hattie & Gan, 2017). If the learner has answered incorrectly, the teacher can prompt them to elaborate on their answers (Hattie & Gan, 2017).

As can be seen in Excerpt 4.21, some participants were observed telling learners what they expected the design solutions to be.

P3: Use that triangulation because it will strengthen your model much faster.
P1: I showed you my research, was it writing? What was it? Pictures!
P2: You have to design and make a what? An amusements park? No! A park ride!
P4: You are confronted with a bridge that you have to build…

Excerpt 4.21: Task-level feedback guiding learners towards a specific solution

In general, the results of this study confirm the findings of previous studies that show that task-level feedback is the most common feedback level in classrooms (Hattie & Timperley, 2007). The results of this study further indicate that feedback about the

task was mainly structured around the design tasks, implying that the participants remained in control of learning rather than acting as facilitators (van den Bergh et al., 2013). A possible explanation for this result might be that the participants might not have clarified the learning intentions and success criteria. One study reported that teachers did not explicitly set learning goals for their students. This resulted in only 5% feedback at the task level being related to learning goals (van den Bergh et al., 2013). Setting explicit learning goals and communicating these learning goals with learners can be useful in directing feedback about the task (Hattie & Timperley, 2007; van den Bergh et al., 2013). Hattie and Gan (2017) maintain that feedback is most effective when learners' current status, learning goals, challenges, and success criteria are transparent to the teacher and the learner. Hattie and Timperley (2007) suggests that the use of examples, models, and explicit communication of success criteria are key to providing feedback that helps learners answer the question 'where am I going?' Therefore, communicating the success criteria to learners at the beginning of the design task may promote learners' self-regulation, and increase the effectiveness of task-related feedback.

4.3.4. Process level formative feedback

Feedback at the process level was found to be considerably less than feedback at the task level. Process-level feedback relates to the processes needed to perform or understand a task (Hattie & Timperley, 2007). The result in this section confirms the results of previous studies, which show that process-level feedback is less common in a classroom setting than task-related feedback (Brooks et al., 2019; Hattie & Timperley 2007).

An analysis of process level formative feedback showed that this type of feedback mainly occurred during the preliminary solution phase. Process level formative feedback during the problem structuring phase was mostly focused on *how* something should be done.

Examples of process level formative feedback during the problem structuring phase are presented in Excerpt 4.22.

P2: How do you design a ride?
P2: How do you do research?
P1: What can you do with a hundred thousand Rands?
P5: What things do you need to go and find out?

Excerpt 4.22: Process level formative feedback in the problem-structuring phase

The feedback accounts presented in Excerpt 4.22 require the learners to speculate and explore processes to complete their tasks. Stables (2017a) notes that asking questions that call for speculation can be effective in helping learners to determine what their next steps could be in completing the design task.

The process-level feedback that was observed during the preliminary problem-solving phase is illustrated in Excerpt 4.23. The accounts indicate that process-level feedback was used to support learners in identifying methods and processes that would allow them to complete the design task.

P2: …how are you going to make this thing turn?
P2: How are you going to make your ride stable?
P1: How do we go about writing a design brief?

Excerpt 4.23: Process-level formative feedback in the preliminary problem-solving phase

The formative feedback accounts presented in Excerpt 4.23 might be useful in helping learners to determine what their next steps could be and how to improve their work. The process-level feedback illustrated in Excerpt 4.23 may support learners to identify aspects of their conceptual designs that can be improved upon. Learners may also be able to use the formative feedback to further consider methods and procedures to achieve specific design goals.

Overall, the process-level feedback that was observed in the preliminary problem-structuring phase was directed at the whole class. In contrast, the participants directed the majority of their feedback at individuals in the preliminary problem-solving phase. These results align with those of a previous study where the process-level feedback

was focused on acquiring specific skills, and was predominantly aimed at individuals (Brooks et al., 2019).

Process-level feedback has the ability to increase motivation and self-regulation by guiding learners to detect errors in their work and consider ways to improve their work (Hattie & Timperley, 2007). In this study, only a few instances of process feedback could be observed during the lessons. I speculate that an increase in process-level feedback might be observed in the later stages of the design process as learners are required to have some level of proficiency in order for process-level feedback to be effective (Hattie & Timperley, 2007).

4.3.5. Self-regulative formative feedback

Looking at formative feedback on the self-regulative level, the data analysis showed that very few formative feedback statements were focused on self-regulation. Brooks et al. (2019) describe self-regulative feedback as prompts and questions to "engage, think, reflect and self-monitor and act upon feedback" (p. 9). Even though formative feedback at the process and self-regulation levels are considered to be most effective, several scholars have noted the scarcity of self-regulative feedback in classrooms (Brooks et al., 2019)

During the problem-structuring phase, there were only two instances where self-regulative formative feedback was observed. During the preliminary problem-solving phase, the self-regulative formative feedback provided was focused on how the design idea would be presented to the client. These instances are presented in Excerpt 4.24.

P5: How would you give it to the customer to buy?
P5: How are you going to ensure that the quality is safe for hospitals?
P5: Is it going to be separate, assembled? What's the idea?
P1: If you design an overwater bungalow that is not very attractive and appealing, do you think will attract any people to go and stay there?

Excerpt 4.24: Self-regulative formative feedback in the problem-structuring and preliminary problem-solving phase

The examples in Excerpt 4.24 show self-regulative formative feedback questions that aim to support learners' self-monitoring and self-assessment of their design ideas.

More specifically, the feedback questions seemed to support learners to evaluate whether their final designs would be appealing to customers, to consider how their design solutions would be presented to customers, and finally, the overall quality of their design solutions.

Self-regulation can be achieved by developing learners' ability to consider where they are going with a task, how they are going to get there in relation to success criteria, and planning what to do next to move closer to the intended learning goal (Hattie, 2019; Hattie & Timperley, 2007). Therefore, a key element of providing effective formative feedback is the communication of success criteria (Black, 2015; Black & Williams, 2009; Hattie & Timperly, 2007, 2019). I speculate that one reason for observing few formative instances at the self-regulation level may be due to the success criteria not being communicated to learners at the start of the design task. Another reason may be that the participants were unsure of how to provide self-regulative feedback. Researchers have found that although many teachers would like to foster self-regulated learning in the classroom, they are not sure how to support self-regulation in learners (Lawson et al., 2019).

4.3.6. Formative feedback about the self

Formative feedback on the self-level in both the problem-structuring and preliminary problem-solving phases was focused on praising learners for their ideas or confirming that learners were heading in the right direction. Excerpts 4.25 and 4.26 illustrate the formative feedback on the self-level that the participants gave in the EPoDP.

P5: That's a good idea.
P5: That's a good scenario.
P3: That is 100% correct.

Excerpt 4.25: Self-level formative feedback during the problem-structuring phase

The examples in Excerpt 4.25 demonstrate the formative feedback the participants gave learners during the problem-structuring phase of the design process. Here, the participants gave learners self-level feedback confirming that the contexts of the design problem and the design needs they identified were correct. The participants were further observed giving the learners self-level formative feedback in the problem-

solving phase by complimenting and confirming that the learners were on the 'right path' considering their proposed design solutions. Examples of self-level feedback during the problem-solving phase of the design process is presented in Excerpt 4.26.

P2: Yes, that's a very good answer. Well done.
P2: You are on the right path.
P5: That is actually a really good idea.
P5: I like that idea.

Excerpt 4.26: Self-level formative feedback during the preliminary problem-solving phase

The examples in Excerpt 4.26 show that the participants used formative feedback to compliment learners on their preliminary ideas for design solutions, as well as to confirm that learners' ideas were in line with the participants' idea of an ideal solution. The participants seldomly elaborated on the formative feedback to explain to the learners what was correct about their answers or ideas. They would then usually proceed to the next group for formative feedback, or pose the next question to the class. This implies that self-level formative feedback served as confirmation that the learners were proceeding well with their tasks and could continue.

Overall, the results show that self-level formative feedback was scarce in the EPoDP. This means that the participants gave affective feedback about the learners and remained focused on the design tasks and processes needed to complete the task. This is a positive result as research suggests that self-level feedback often distracts learners from the task, and can decrease learners' motivation for engaging in more challenging tasks. (Hattie & Timperley, 2007, 2019). From a psychology perspective, Eskreis-Winkler and Fishbach (2020) explain that the effectiveness of praise and criticism as feedback depends on the receivers' mental frame. The authors explain that when people are in a commitment frame of mind, praise is more effective than criticism, and they are more focused on the goal and how to reach it. In contrast, criticism was observed to be more effective with people who are focused on their progress. People that are in a progress frame of mind continuously evaluate whether they have made sufficient progress towards a goal, and adapt their goals accordingly (Eskreis-Winkler & Fishbach, 2020). The authors further explain that novices in a field

are more likely to adopt a commitment frame of mind, while experts are likely to adopt a progress frame of mind (Eskreis-Winkler & Fishbach, 2020). Therefore, some learners in this study may have been motivated by praise and self-level feedback rather than criticism. The authors caution against the overuse of praise as it may lead to a deficiency in feedback about missed opportunities, improvements or discrepancies (Eskreis-Winkler & Fishbach, 2020). This statement aligns with Hattie and Gan (2017) and Hattie and Timperley's (2007) notion that feedback at the self-level may dilute feedback at the task, process and self-regulative levels. The use of compliments as a formative feedback strategy is discussed in more detail in Section 4.2.3.2.

This section showed how the teachers used formative feedback at the task level, process level, self-regulation level, and self-level to guide learners through the initial phases in the design process. From Section 4.2.1 and Section 4.2.2, it was observed that the teachers guided learners through the EPoDP by focusing their formative feedback at different levels. Furthermore, it can also be seen that this formative feedback was given by using various questions and comments. This raises questions about what types of questions and comments teachers ask to guide learners through their design processes. In the section that follows, I present the results obtained from the data analysis of the types of formative feedback questions and comments that the teachers used to guide learners through the problem-structuring and preliminary problem-solving phases of the design process.

4.3.7. Types of formative feedback

In this section, I present the results of the types of formative feedback questions and comments observed during the EPoDP. Studies in professional design practice and school-based design settings have shown that formative feedback may be observed as low-level questions, low-level comments, Deep Reasoning Questions (RDQs) and Generative Design Questions (GDQs) (Eris, 2004; Schut et al., 2020). The results summarised in Figure 4.4 show the frequency of the formative feedback questions and comments observed in the EPoDP of this study.

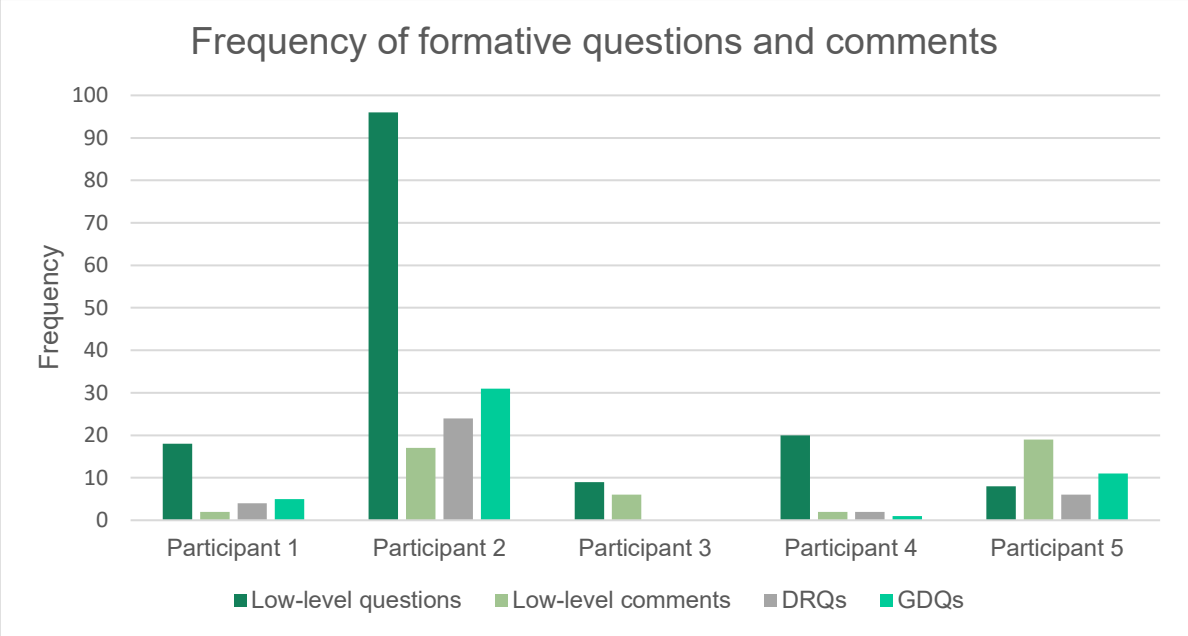


Figure 4.4: The frequency of formative feedback questions and comments in the early phases of the design process

From Figure 4.4, it can be seen that the participants' formative feedback included low-level questions and comments, as well as high-level questions. Overall, low-level questions made up the majority of the participants' formative feedback, while low-level comments were found to be the least common form of formative feedback. It seems that the use of low-level questions was twofold. First, the participants utilised low-level questions to promote a shared understanding with the learners about the design problem that should be solved. Secondly, it seems that the participants used low-level questions to communicate the success criteria for the design task. These results seem to align with the findings of previous studies where teachers and instructors engaged more in formative feedback by posing low-level questions and comments rather than high-level questions (Schut et al., 2019). Schut et al.'s (2019) study showed that low-level questions were effective in creating a shared understanding of the design between clients, peers, and the teacher.

Schut et al. (2019) suggest that DRQs and GDQs be used to promote learners' reflective, evaluative, and generative thinking processes. High-level questions, in the form of Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs), were found to be less common than low-level questions in this study. In Section 4.3.3, the results show that self-regulative feedback was underused. I

speculate that the limited use of GDQs may be linked to the infrequent use of self-regulative feedback. Since the purpose of self-regulative feedback is to promote learners' self-assessment, self-monitoring and improvement strategies, the limited use of DRQs and GDQs may be related to the infrequent use of self-regulative feedback.

In the sections that follow, I present and discuss the types of low-level questions and comments, and high-level questions observed in the EPoDP. I also discuss the pedagogical implications of the use of various types of questions and comments to guide learners through the design process by referring to the existing literature on the topic.

4.3.7.1. Low-level questions

The previous section demonstrated that low-level formative feedback questions were the most frequent type of feedback used during the EPoDP. More specifically, Figure 4.5 shows that the participants used verification, concept completion and example questions when supporting students during their design task.

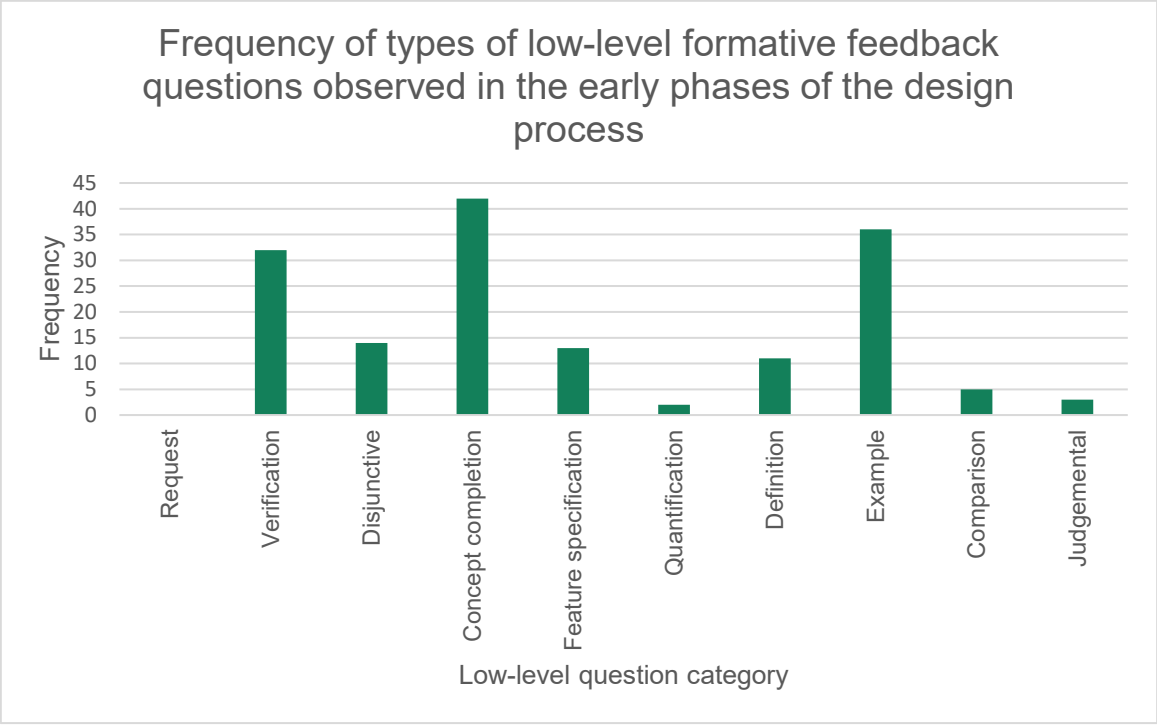


Figure 4.5: The frequency of types of low-level formative feedback questions observed in the early phases of the design process

Figure 4.5 shows that verification, concept completion, and example questions were the most frequently observed questions during the EPoDP.

The results imply that the participants mostly asked clarifying questions to promote a shared understanding of the design task, design problem, and learning goals. These included questions that required yes or no answers, or for learners to complete the sentence and/or give examples of concepts (Eris, 2004; Graesser et al., 2008; Tawfik et al., 2020). The use of verification, concept completion, and example questions in this study could support learners in answering the feedback question '*Where am I going?'* (Hattie & Clarke, 2019; Hattie & Gan, 2017).

The results indicate that quantification, definition, comparison, and judgement related questions were the least common low-level formative feedback questions posed during the EPoDP. The limited use of quantification, definition, comparison, and judgement related questions may be attributed to the information seeking nature of the questions, and the audience for these questions. In a previous section of this study, I reported that the participants aimed their feedback at individuals or the class depending on the learners' needs. I speculate that since quantification, definition, comparison, and judgement related questions aim to seek information about specific concepts, and that the low-level questions observed were mostly aimed at the whole class, these questions were not asked as frequently as they did not pertain to the whole class. The data further indicated that no request questions were asked. Requests are not information-seeking questions, and require an action to be performed (e.g. a tool to be handed to the questioner) (Eris, 2004). I did not observe any request questions as the focus of my study was on teacher feedback. The framework I used to analyse the low-level questions was based on the conversations between collaborating professional designers (Eris, 2004).

In Excerpt 4.27 below, I present examples of the formative feedback questions that I observed the participants using to verify and clarify aspects of the learners' design tasks

P2: Can you identify the material?
P2: Can you see this corrugated iron?
P2: Can you see the motion?
P2: Are you just going to build a structure?
P1: Can you see how it stands out when you fly by it?
P4: Do they specify that it [the bridge] should be able to hold 20 people?
P4: Will your hanging bridges look the same?

Excerpt 4.27: Verification questions in the EPoDP

The examples in Excerpt 4.27 illustrate how the participants used verification questions to support a shared understanding about aspects of existing solutions and the goal of the design task. During the lesson, Participant 1 and Participant 2 showed the learners videos and images of existing solutions to the design problem. From the accounts presented in Excerpt 4.27, it can be seen that the participants used verification questions to direct learners' attention to the key features of existing designs. The questions were often followed by the participant pausing or pointing to the key feature in the existing product. This implies that the participants used verification questions to direct learners' attention to key features, which presumably should be included in the learners' final designs.

It should be noted that verification questions also served a management purpose during the lesson. The participants often used verification questions to confirm that the learners were on track, and that the participants could proceed to the next point.

The second type of low-level formative feedback questions observed were disjunctive questions. Similar to verification questions, disjunctive questions may be answered with a yes or no. Disjunctive questions, however, include more than one concept that can be confirmed. *"Is your ride going to move?"* [P2] is an example of a verification question as it simply requires a yes or no answer. *"Is a soft seat safe or comfortable"* [P2] is an example of a disjunctive question as the learner can answer "yes, it is safe" or "yes, it is comfortable". In this study, the results showed that only Participant 2 asked disjunctive questions. The purpose of these questions was to guide learners in considering what mechanisms they could use in their designs of an amusement park ride. The participants also used this type of question to guide the learners during the

product analysis phase to consider the key features of the designs. These accounts are presented in Excerpt. 4.28.

P2: Are you going to use a pulley system? Are you going to use a gear system? Are you going to use a hydraulic system?
P2: Is it strong enough? Is it waterproof? Will it protect me from tics?
P2: Is your ride going to move? Will it be stronger if it didn't move?

Excerpt 4.28: Examples of disjunctive questions in the EPoDP

The examples in Excerpt 4.28 show that although the participant did not provide learners with direction as to how to complete the analysis of existing products, the participant used disjunctive questions to guide learners in considering the different features of the existing designs. In doing this, the participant maintained a level of ambiguity in the activity, which allowed learners to further explore the possibilities of the design task (McLellan & Nicholl, 2011).

Concept completion questions, often referred to as 'fill in the blank' questions, were the most frequently used low-level question type that I observed. The results showed that the participants used task-related concept completion questions to explore the problem and define the scope of the problem. This was done by considering what the design problem is, who the solution is for, where it could be used, and what mechanism could be considered as part of the design solution(s). Examples of concept completion questions in the EPoDP are presented in Excerpt 4.29.

P3: What do we have to do?
P1: For who?
P2: You have to go and design and make a what?
P1: In your case, you are going to say what?
P4: What technique can you use to strengthen it [frame structure}?
P4: What should you be able to do over the river?
P5: So your idea, in other words, is to use it where?

Excerpt 4.29: Concept completion question in the EPoDP

Some instances of verification, disjunctive, and concept completion questions were observed in the problem-solving phase. However, the majority of the questions presented in Excerpt 4.28 - 4.29 were found in the problem-structuring phase. Furthermore, these were focused on supporting students to interpret and understand the design task. From the examples provided in Excerpt 4.29, it seems that the participants used concept completion questions to build learners' surface knowledge about the design problem (Black, 2015; Hattie & Timperley, 2007). They also served a formative purpose by helping learners to determine what they know about the design task (Where am I?) (Black, 2015; Hattie & Timperley, 2007).

These results align with the work of Tawfik et al. (2020) in which the authors suggest that verification, disjunctive, and concept completion questions are asked by novice problem solvers throughout the problem-solving process. The authors add that these questions are most common in the phase where the focus is on defining the scope of the design problem.

Hattie and Timperley (2007) suggest that feedback is most effective when it moves learners forward from the task level to the process level, and from the process level to the self-regulation level. Similarly, Tawfik et al. (2020) contend that asking simple or shallow questions (verification, disjunctive, and concept completion) forms the foundation for asking more complex questions. Therefore, it can be argued that task-level feedback can become increasingly effective in moving learners from task level to process level. However, this may only be the case if the questions asked at the task level are focused on defining the scope of the design task and then building on this knowledge with more complex task-related questions.

Tawfik et al. (2020) suggest that, on the one hand, verification, disjunctive, and concept completions questions might be helpful in defining an open-ended problem. On the other hand, the authors explain that feature specification, quantification, definition, example, and comparison questions build prior knowledge and can help learners to make connections between the concepts needed to find a design solution. Feature specification questions require the properties of a concept to be listed (Graesser et al., 2008). Feature specification questions may be used to clarify aspects of the form and function of the design (Schut et al., 2020). In this study, feature specification questions were used to link to learners' prior knowledge of the design

problem with existing solutions. These questions were also used to clarify the form and function of the learners' designs. Examples of these questions are illustrated in excerpt 4.30.

P2: What material, what fabric did they use?
P1: What are the overall dimensions?
P4: If you think of a bridge, what should it be able to do?

Excerpt 4.30: Feature specification questions in the EPoDP

The examples from Excerpt 4.30 indicate that the feature specification questions that the participants asked were based on learners' prior knowledge and experiences of fabrics, dimensions of their prototypes, and the purpose of structures. The results also show that feature specification questions were mostly task related. This implies that this type of question was used to build learners' surface knowledge about their intended design solution (Hattie & Timperley, 2007). In Section 4.3.1, I reported that the teachers seemed to omit success criteria for the completion of the design task. However, by asking feature specification questions, it is possible for learners to construct their own success criteria for their intended design solution (Hattie, 2019). In this way, feature specification questions can serve to guide learners in constructing success criteria for their designs. The use of feature specification questions as a way of constructing success criteria (Hattie & Timperley, 2007) during the design process should be researched further. This is necessary as the learners' construction of success criteria during designing has the potential to guide them to be more self-regulative

The second most common question type observed in the EPoDP was questions that required learners to list examples of concepts. The teacher participants asked their learners to give examples of a variety of concepts, including the tools and materials needed to make their designs, what their design ideas were, and the learners' thought restrictions or limitations of designs. Examples of these accounts are presented in Excerpt 4.31.

P1: What are you going to use to make the gear?
P5: What type of lights?
P2: What are the materials you are going to use?
P3: What ideas do I have?
P3: I have already discussed two types of structures with you, which two were they?

Excerpt 4.31: Questions eliciting examples of concepts during the EPoDP

The accounts of questions requiring learners to list the examples as presented in Excerpt 4.31 suggest that the participants used these questions to determine the level of learners' prior knowledge about the concept. This has important pedagogical implications as example questions can guide learners to determine their current levels of understanding (where am I?) (Hattie & Timperley, 2007, 2012), and provide them with a range of options to make design decisions. Information on learners' current levels of understanding can in turn help teachers to guide learners in determining where they are heading and how to plan their next steps (Hattie & Timperley, 2007, 2012).

Overall, the results provided important insights into how the participating teachers used low-level questions to guide learners through the initial phases in the design process. More specifically, the results show that the participants used verification, disjunctive, and concept completion questions to help learners in exploring the scope of the design task. These results contribute to the current understanding of how different question types are used during the EPoDP. The results further seem to point to the potential of exploring feature specification questions as a way of moving learners towards becoming more self-regulative by constructing the success criteria of their design solution in this way.

In the section that follows, I provide an overview of low-level comments as formative feedback. I specifically focus on the pedagogical implications of how low-level comments are used to guide learners through the EPoDP.

4.3.7.2. Low-level comments

In this section, I present the results of the frequency of low-level formative feedback comments during the problem-structuring and preliminary problem-solving phases of the design process.

The results indicate that the participants commented on learners' design tasks throughout the EPoDP. They did this by complimenting and critiquing learners' work, and making direct recommendations for changes and improvements. The frequency of the low-level comments provided to learners during the EPoDP is summarised in Figure 4.6.

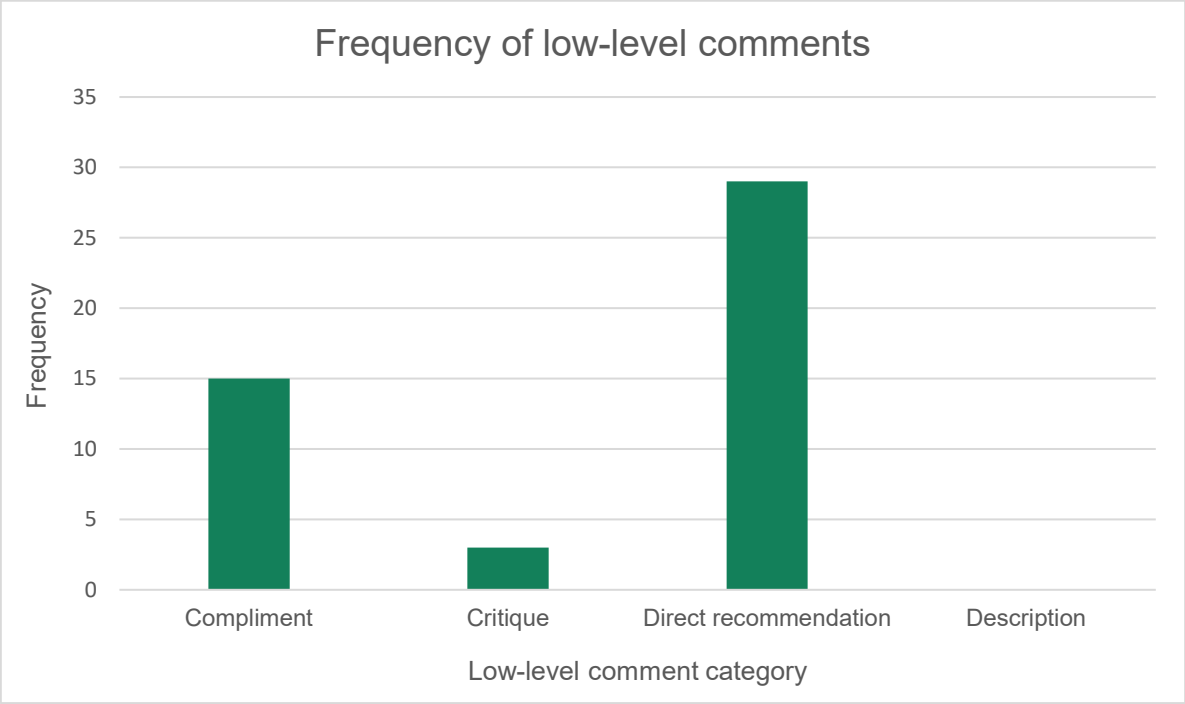


Figure 4.6: The frequency of low-level formative feedback comments during the early phases of the design process

Figure 4.6 shows that the participants frequently complimented learners on their design tasks, and made several direct recommendations on what learners could do to improve their work, while only two instances of critique were observed. In this study, no description-related comments were observed. These results confirm the results from Section 4.2.1.1 in which the participants characterised feedback as the process of providing learners with compliments and criticism. Specific examples of compliments are shown in Excerpt 4.32.

P5 That's actually a really good idea?
P5: That's a good idea, it's creative! So it's for small kids who do not like the dark.
P5: That's a good scenario [context]!
P3: That is 100% correct.
P2: You are on the right path.

Excerpt 4.32: Compliments as formative feedback in the EPoDP

The examples in Excerpt 4.32 indicate that the participants gave learners compliments on their design ideas, their problem context, and the client. It should be noted here that none of the participants elaborated once they had given compliments. This meant that the participants did not explain why they gave learners a compliment regarding the learners' ideas. In all of the instances presented in Excerpt 4.32, the participants complimented the learners and design teams and then proceeded to the next learner or team. Some researchers suggest that providing learners with compliments on their design tasks has the ability to decrease uncertainty, and increase learners' self-esteem (Hattie & Timperley, 2007; Shute, 2008). In this way, students are reassured that they are on the right path in the design problem-solving process.

In contrast, only two instances of critique were observed during the EPoDP. These accounts are presented in Excerpt 4.33.

P5: That's a really boring design for a roll (critique). Or what you can do is, what I was thinking you can do is, that roll is loose right, imagine you put a box around it and then there is a pin at the bottom (Proposal/Negotiation).

P2: No, a dimension line is a measuring line.

Excerpt 4.33: Critique as formative feedback in the EPoDP

The examples in Excerpt 4.33 show that Participant 5 critiqued the design solutions for one team by calling it "*boring*". The participant followed the critique with a recommendation that the learners should reconsider the design by looking at the purpose and aesthetics of the design solution. Participant 5 then continued to give the learners a recommendation of how *he* thought the design solution should look. Alternatively, Participant 2 followed the critique with an explanation of dimension lines,

and what information is indicated by dimension lines. This implies that although the participants followed the critique with discussions, they did not provide learners with sufficient information on what did not work in their designs, nor did they offer additional formative feedback to guide learners in considering their next steps. Some researchers suggest that providing learners with information on what worked and what did not work in their design tasks is essential when giving compliments and criticisms. This is because formative feedback becomes more effective when it guides learners in making improvements to their designs (Kluger & DeNisi, 1996; Shute, 2008).

The delivery of compliments and criticism as formative feedback observed during the EPoDP contradicts the results from Section 4.2.1.1. In Section 4.2.1.1, some participants explained that they would move around the class and consider learners' work and then provide compliments and criticism based on their work. This was not observed with all of the participants in the classroom observations. Participant 5 was the only participant that walked from desk to desk and discussed learners' design ideas with them before complimenting or critiquing them. In contrast, Participant 2 discouraged the learners from discussing their design tasks with one another or asking the participant questions while completing sections of the design task documents. The participant moved between the learners but did not look at what the learners were doing and, as such, the bulk of this participant's formative feedback was combined with instruction.

Direct recommendations we the most frequent low-level formative feedback comment observed in the EPoDP. Direct recommendations included "specific advice about particular aspects of the design" (Cummings et al., 2016, p. 400). The participants mostly gave the learners direct recommendations on what their design solutions should be. Occurrences of direct recommendations are presented in Excerpt 4.34.

P3: You are going to design a frame structure that can hold a reservoir or water tank.
P4: You just have to build a bridge.
P1: You have to design an overwater bungalow that consists of two bedrooms.
P2: You can say a park ride.
P5: This light has to come in a vacuum-sealed package.
P5: So I would say like a puzzle format.

Excerpt 4.34: Direct recommendations in the EPoDP

The accounts in Excerpt 4.34 show that the participants gave learners specific advice about what their design solutions should be, and how the solutions should be presented. The results align with previous studies in professional design settings that show that novice designers are often exposed to more directive feedback (Dannels & Martin, 2008). Directive feedback is less conducive to autonomous thought (Dannels & Martin, 2008) and therefore does not always promote self-regulative learning (Hattie & Timperley, 2007).

Overall, the results of the low-level formative feedback comments in Excerpt 4.32 - 4.34 align with the results from previous sections that indicate that the participants often used formative feedback to direct learning and remain in control of the design process. The results from this section reveal that the participants often gave the learners direct recommendations on what the design solutions should be. The results further highlighted that the participants provided information on promising and problematic aspects of learners' designs. Here, compliments and criticism were used to comment on learners' work. When teachers highlight promising and problematic aspects of learners' designs, they support learners in answering the feedback question *'How am I going to get there?'* (Hattie & Gan, 2017). This in turn supports learners to plan their next steps and move closer to the learning goal of generating possible solutions to the design problem.

The results indicate that none of the participants gave descriptions of learners' design tasks. It is speculated that one of the factors that may have contributed to the lack of descriptions and low-level comments could be that the participants mostly provided whole-class formative feedback from the front of the classroom. Participant 5

interacted with groups of learners more frequently and did not spend a lot of time considering the group's drawings and sketches, but rather focused on asking the learners questions to clarify their ideas. Another factor that could have contributed to this result is that in most cases, the learners were not involved in activities in groups or individually during the observation. The lessons were directed by the teachers and consisted of whole-class discussions.

In the following section, I present the results regarding instances of high-level formative feedback observed in the problem-structuring and problem-solving phases of the design process. More specifically, I present and discuss the occurrence of Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs) as formative feedback.

4.3.7.3. High-level questions

This section demonstrates the occurrence of high-level formative feedback questions in the form of Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). DRQs and GDQs are differentiated based on the types of answers they elicit. DRQs have a single correct answer or set of answers, whereas GDQs invite various possible correct answers to the question (Eris, 2004; Cardoso et al., 2014; Schut, 2008). Although low-level questions and DRQs both have a single correct answer or set of answers, low-level questions are information-seeking questions. Low-level questions aim to confirm and communicate facts (Cardoso et al., 2014). In contrast DRQs support reflection and evaluation (Schut et al., 2018, 2020). DRQs aim to explore the causal explanation of facts (Cardoso et al., 2014). This means that DRQs could, for example, be used to explain why an object is made from a specific type of material.

Figure 4.7 provides an overview of the frequency of the DRQs and GDQs in the EPoDP. The results presented here indicate that GDQs were the most frequently observed high-level formative feedback question category observed.

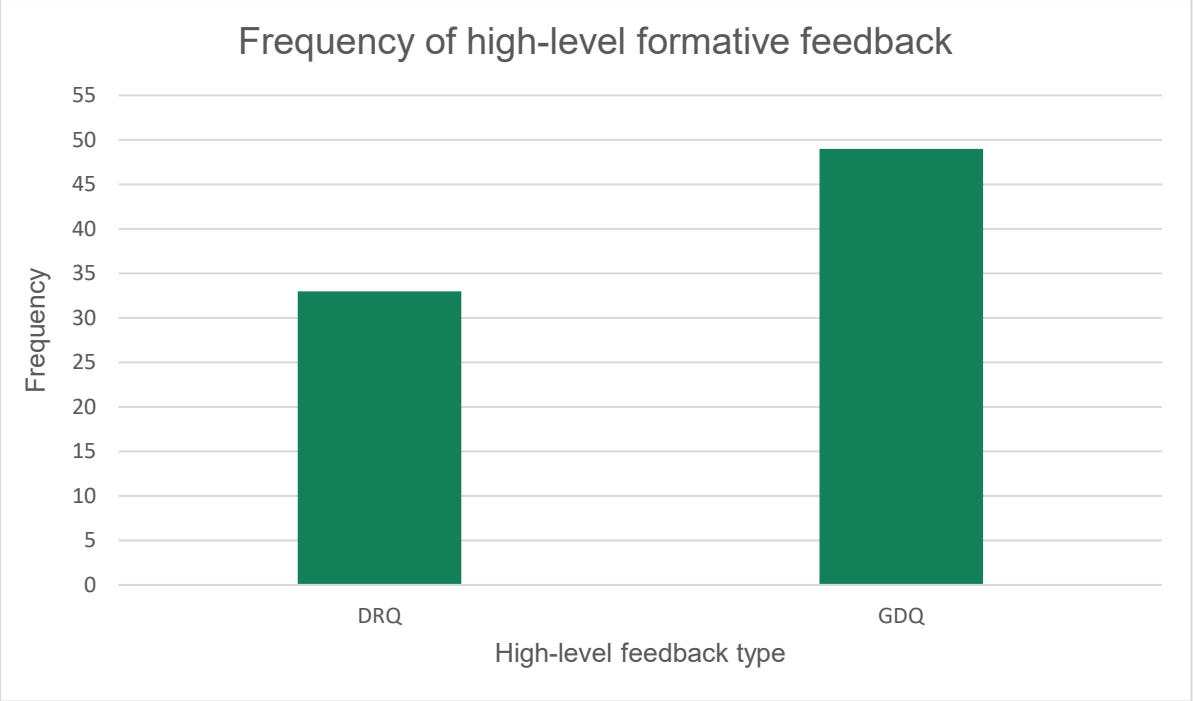


Figure 4.7: Frequency of high-level formative feedback questions during the early phases of the design process

Through GDQs, the participants were observed to encourage learners to explore possible design solutions and methods for building, strengthening, and supporting features of the design. In contrast, the participants were observed to use DRQs to elicit learners' understanding of how existing designs worked, who would benefit from solving the design problem, how the design could be realised, and why the design problem should be solved.

In the following sections, I present accounts of the DRQs and GDQs observed in the EPoDP. This is followed by a discussion of the pedagogical implications of these questions for guiding learners' design processes, as supported by the relevant literature in the field of design and technology education.

Deep Reasoning Questions (DRQs)

The deep reasoning questions posed by the participants mainly consisted of interpretations, and procedural and causal antecedent questions. Figure 4.8 presents an overview of the types of DRQs observed in the EPoDP.

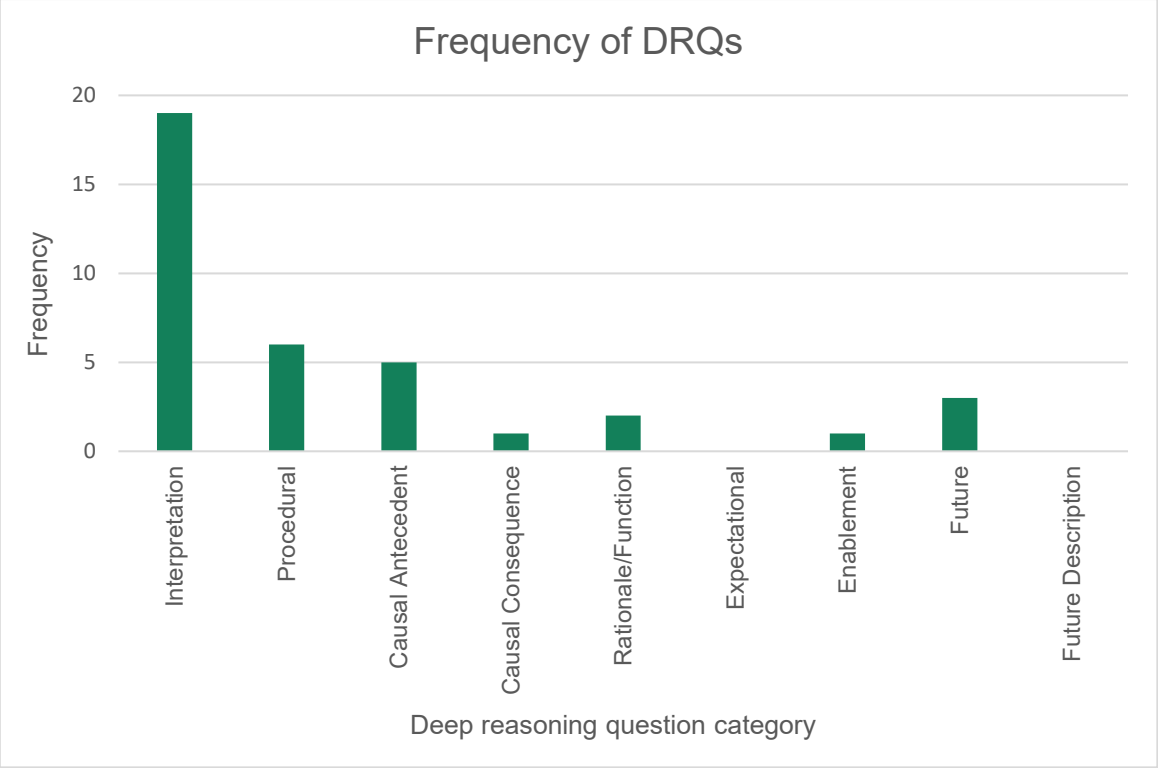


Figure 4.8: Frequency of types of DRQs observed in the early phases of the design process

The results presented in Figure 4.8 show that interpretation questions were the most frequent type of question posed by the participants. Furthermore, only one instance of causal consequence and enablement questions were observed while no future description or expectational questions were observed. Interpretation questions require learners to make meaning of a specific concept. In this study, the participants read the design brief in class, and then proceeded to ask learners interpretation questions. It seems that the purpose of these questions was to elicit learners' interpretation of the design problem, context, client, and client needs. The high frequency of interpretation questions implies that the participants mainly required learners to reflect on their understanding of the design problem. The learners further had to consider who would benefit from solving the design problem based on the description of the design task given to them. Examples of interpretation questions are presented in Excerpt 4.35.

P2: What is the problem and describe who will benefit from it?
P5: Who is this light intended for?
P1: What are you going to design and make?
P1: For who?

Excerpt 4.35: Examples of interpretation questions posed in the EPoDP

The examples in Excerpt 4.35 show how the participants guided the learners to keep considering what the design problem was and who the design solution would be for as they progressed to the preliminary problem-solving phase. This meant that although the learners were moving towards activities that would enable them to explore various solutions to the design problem, the participants used interpretation questions to remind the learners of what the problem was and who the client was after reading the design brief. Further to this, the participants also made use of procedural questions to guide learners in considering how certain features of their designs could be realised and the processes required to proceed with generating possible solutions. Examples of procedural questions are presented in Excerpt 4.36.

P2: Where do I start measuring her? From her knees to her nose?
P1: How do we go about writing a design brief?
P2: What's going to make your ride turn?
P2: What do they use to make the rides safe?

Excerpt 4.36: Examples of procedural questions posed in the EPoDP

The procedural questions illustrated in Excerpt 4.36 show how the participants used questions to guide learners on what plans can be made to achieve design goals and to consider how design goals were reached in existing designs as the learners started to explore and formulate preliminary design solutions. In this study, the participants used procedural questions to prompt the learners to consider the status of their designs and to consider their actions in the design process. Cardoso et al. (2014) suggest that procedural questions, along with other DRQs, should be used to support learners in reflecting on the status of their designs and to justify their actions and decisions as designers.

Causal antecedent questions aim to support learners to consider what happened when made certain design decisions or took certain actions, why it happened and how it happened. The results further indicate that the teacher participants used causal antecedent questions to guide learners in evaluating how learners have presented their designs and why and how their design goals were realised. This is illustrated in Excerpt 4.27.

P2: Why are we designing this?
P2: Why do you think people will annotate a sketch?
P2: Why do you think people used fibreglass?
P2: What makes the wheels turn?

Excerpt 4.37: Examples of causal antecedent questions in the EPoDP

Excerpt 4.37 seems to indicate that the participants used causal antecedent questions to guide learners in considering what lead them to specific designing solutions, and what allowed design ideas to be realised. More specifically, the causal antecedent questions that the participants posed prompted the learners to consider why they were designing a solution to a problem, as well as why and how designers take specific actions.

Finally, similar to the results obtained by Schut et al. (2020), the results of this study indicate that DRQs categorised as ‘future’ were mainly focused on how learners’ ideas would impact future states of designs. Examples of future questions are demonstrated in Excerpt 4.38.

P5: How would you give it to the customer to buy?
P5: How would the customers receive it and get it?
P5: If you need to replace them [light bulbs], how would you do it?

Excerpt 4.38: Examples of future questions in the EPoDP

As can be seen from Excerpt 4.38, only Participant 5 asked questions related to the future states of learners’ designs. These questions were specifically related to the clients and how they would receive the designs and how they would use or interact

with the designs. By asking future questions, the participant supported learners in identifying the future strengths and shortcomings of their designs.

Taken together, Excerpt 4.35 - 4.38 seem to indicate that the use of DRQs served an evaluative purpose in the EPoDP. This meant that the participants used interpretation, procedural, causal antecedent, and future questions to guide learners to evaluate and reflect on their tasks and processes as they started to consider preliminary design solutions. These results align with previous studies that have also shown that the use of DRQs often serves an evaluative and reflective purpose during the design process (Cardella et al., 2014; Cardoso et al., 2014; Cummings et al., 2015; Schut, 2019; Yilmaz & Daly, 2014, 2016). DRQs are significant and could help learners gain a causal understanding of the effects that design actions and decisions have on the outcome of the design solution (Cardoso et al., 2014).

The results indicated that no expectational or future description questions were asked during the observations of the EPoDP. I speculate that this might have been due to the limited time learners were engaged in independent solution generation activities. As a result, the learners may not have required feedback from their teachers to reflect on or consider the future state of their design and design goals. Furthermore, only two instances of rationale/function and one causal consequence question were observed; this does not present sufficient evidence on which to comment.

Generative Design Questions (GDQs)

The participants in this study were observed to pose GDQs throughout the EPoDP. GDQs support learners to consider the possibilities for a question concept. Cardoso et al. (2014) report that GDQs could support learners to analyse their progress and consider how to continue or improve on their design task. Therefore, GDQs may provide support in answering the feedback questions '*How am I going to get there?'* and *'Where to next?'.* This result aligns with those of previous studies that indicate that GDQs are frequently observed in the preliminary problem-solving phase of the design process (Goldschmidt, 2016). Figure 4.9 illustrates the types of GDQs observed in the EPoDP.

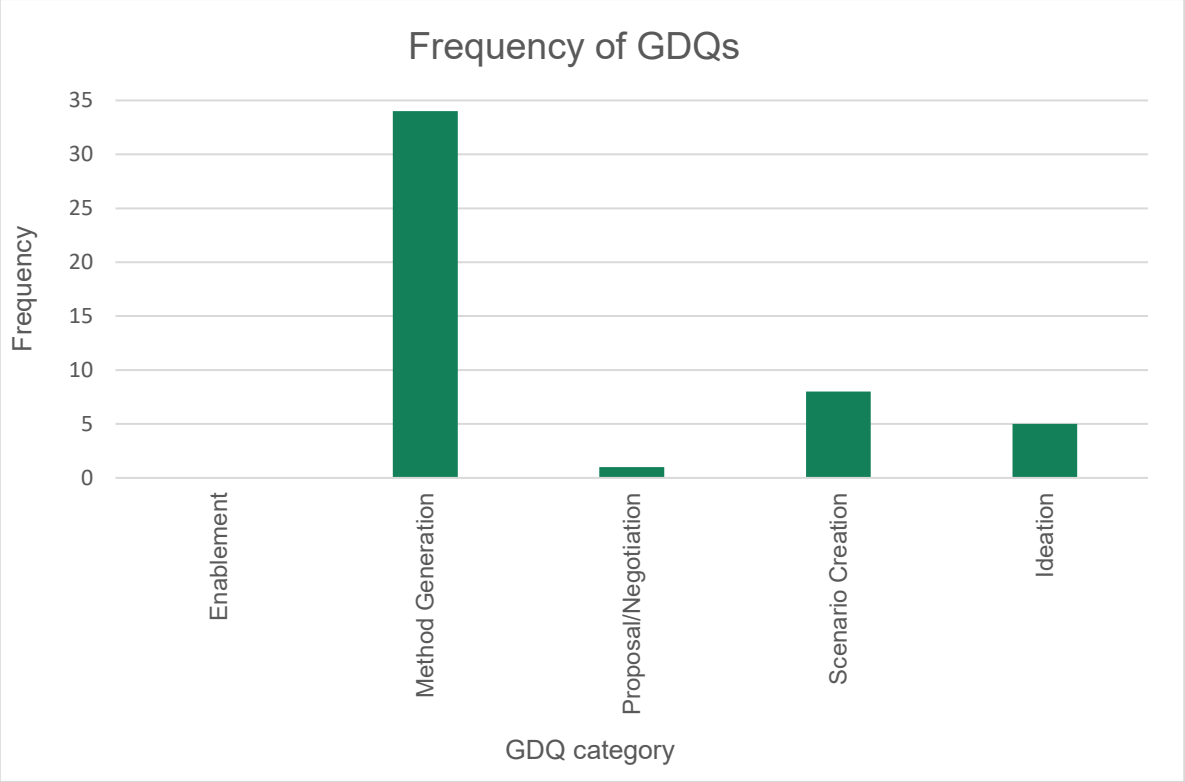


Figure 4.9: Frequency of GDQs observed in the early phases of the design process

The results in Figure 4.9 show that the participants used GDQs to guide the learners in exploring various methods to realise their designs. They further used these to create scenarios for learners to consider and explore their preliminary design ideas. The results also show that no enablement questions were asked to explore methods that would enable the realisation of design goals. Enablement questions invite the use of multiple resources for achieving a specific goal (Eris, 2003). Eris (2003) explains that the question context plays an important role in distinguishing between Deep Reasoning Enablement, and Generative Design Enablement questions if the participant believes or suggests that there is one correct method that enables the concept (Eris, 2003). The only enablement question observed in the study was *"What makes this thing go round?" P2*. Based on the context of the question, the participant implied that the correct answer would be related to gears. Therefore, the question can be described as Deep Reasoning Enablement. The lack of enablement questions may be attributed to the participants only being observed during the problem-structuring and preliminary problem-solving phases of the design process. I speculate that Generative Enablement Questions might be observed in the later stages of the design process as learners start to prototype and make the solutions. This would then guide

learners in choosing methods and procedures that would enable them to realise their design goals.

The results show that the participants predominately posed method generation questions. This means that the participants asked learners questions to guide them in considering various ways of achieving their design goals. Method generation and procedural questions are closely related as they both support learners' consideration of how to reach design goals. Eris (2003) explains that method generation questions support the generation of several possibilities to establish a goal. In contrast, procedural questions assume that there is one or several specific methods to reach a design goal. In Excerpt 4.39 I present examples of the method generation questions posed in the EPoDP.

P2: What are you going to use to keep it in the air?
P5: How could the customers receive it and get it?
P2: How do you anchor pylons?

Excerpt 4.39: Examples of method generation questions in the EPoDP

The accounts presented in Excerpt 4.39 show that method generation questions were posed by the participants to guide learners' exploration of methods for realising specific design features. The results show that only two instances of proposal/negotiations were observed in this study. These accounts are presented in Excerpt 4.40:

P5: Or what you can do is, what I was thinking you can do is, that roll is loose right, imagine you put a box around it and then there is a pin at the bottom.

P5: I want to add something here, it is something you can research. If this light is going to be used for medical purposes what if you can get a light that kills most of the bacteria

Excerpt 4.40: Examples of proposal/negotiation questions in the EPoDP

From Excerpt 4.40 it can be seen that only Participant 5 was observed to make proposals regarding learners' design tasks. The proposals observed were related to

the function of the design solution, and were often observed to be followed up with method generation questions.

The participants further supported learners' exploration of design ideas by creating scenarios for learners to consider where, why and how design features would be useful.

> P1: Why wouldn't I put an overwater bungalow in Japan?
> P2: Do you think if we had webs between our fingers we would be able to swim faster?

Excerpt 4.41: Scenario creation questions in the EPoDP

The results in Excerpt 4.41 show how the participants used scenarios to guide learners' exploration of the problem context, unique features of the design, and usability of the proposed design solution. Ideation questions were predominately observed in the problem-solving phase where the participants guided learners in considering their preliminary design ideas. This is illustrated in Excerpt 4.42.

> P1: What can you do for a hundred thousand rands?
> P5: How can you make a product that can be adjusted according to room size?

Excerpt 4.42: Ideation questions in the EPoDP

The ideation questions presented in Excerpt 4.42 required learners to explore how a budget of R100 000 may influence their designs, and explore how the design can be adjusted based on changes in the context and user needs. The participants did not require the learners to answer these questions, but rather used them to motivate learners to explore more possibilities for their design ideas. The use of ideation questions aligns with Stables' (2016) notion of 'left field' questions, which encourage learners to think differently about their designs.

Taken together Excerpt 4.39 - 4.42 indicate that method generation was the most frequent type of GDQ asked by the participants followed by scenario creation, ideation, and proposal/negotiation. The high frequency of method generation questions observed align with the findings of Schut et al. (2020), which found that method

generation and proposal/negotiation questions were the most frequently posed GDQs by clients and peers in the primary technology classroom. The low frequency of proposal/negotiation questions also seems to contradict Schut et al.'s (2020) findings. I speculate that this contradiction might be a result of formative feedback being posed from the front of the classroom toward the whole class; whereas the participants in Schut et al.'s (2020) study moved from group to group to provide formative feedback.

4.4. SUMMARY

In this chapter, I presented the results of this study. As a starting point, I discussed technology teachers' perceptions of formative feedback by presenting supporting evidence of the themes and related sub-themes that emerged. I also presented the results of the implementation of formative feedback in technology classrooms. To this end, I presented evidence of occurrences of formative feedback observed in the EPoDP, and discussed how the results related to existing knowledge on formative feedback.

The results indicate that these technology teachers viewed formative feedback as giving learners compliments and criticism, questioning, providing examples to existing solutions, and intuition. They also saw it as necessary, yet constrained by time. In addition, the results show that the teachers used formative feedback to respond to learners' questions individually, in groups, and as a class. It was further found that the learners' commitment to acting on formative feedback determined the effectiveness of the feedback. Finally, the results indicate that formative feedback was predominantly implemented through low-level questions aimed at the task level in the problem-solving phase of the design process.

In Chapter 5, I interpret the results of the study and relate these results to the existing literature. I present the findings of the study and revisit the research questions posed in Chapter 1. Following this, I discuss the limitations of the study and conclude the chapter with recommendations for training, practice, and future research.

CHAPTER 5
SUMMARY, LIMITATIONS AND RECOMMENDATIONS

5.1. CHAPTER OVERVIEW

This chapter presents a synopsis of the preceding chapters, a summarised discussion of how the research questions were addressed, and the conclusions that I reached in this study. I also contextualise these conclusions in terms of what has already been found in studies on formative feedback in design and technology education. After stating the conclusions that I reached in this study, I list the potential theoretical, methodological, and practical contributions that the study attempted to make. I specifically emphasise a framework for technology teachers to plan and implement formative feedback, which was one of the aims of this study (see Section 1.5). I conclude this chapter by reflecting on the possible limitations of this study and how I addressed these. Thereafter, I provide recommendations for further research.

5.2. OVERVIEW OF THE STUDY

It has been widely recognised that formative feedback has the potential to enhance student learning in professional design and technology education (Black, 2008; Cardoso et al., 2016, 2014; Hattie & Timperley, 2007; Schut et al., 2018; Stables et al., 2016). However, the CAPS document prescribed by the DoBE (2011) for technology seemingly lacks instructional guidelines to support design activities in the problem-structuring and preliminary problem-solving phases of the design process through formative feedback. Therefore, the purpose of this study was to develop a framework to support technology teachers to plan formative feedback questions and comments. I did this by empirically studying how the technology teachers perceived and implemented formative feedback to guide learners through the design process. Figure 5.1 provides a brief overview of this study.

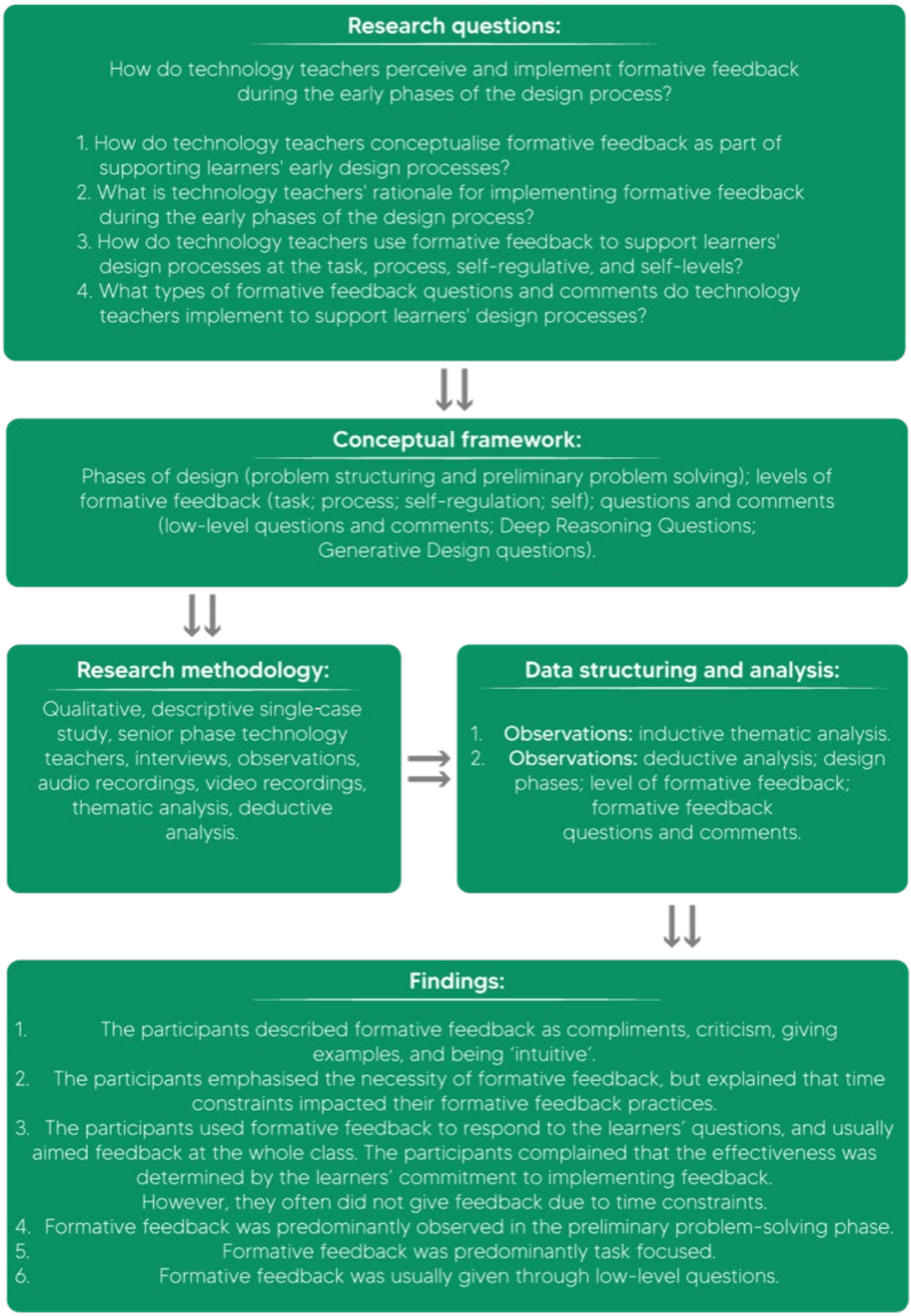


Figure 5.1: Overview of the study

In **Chapter 1**, I provided an overview of, and background to this study. I introduced and justified my focus on technology teachers' perceptions of formative feedback questions and comments at different levels in the early phases of the design process (EPoDP). I formulated the following primary research question that guided the planning and implementation of this study:

How do technology teachers perceive and implement formative feedback during the early phases of the design process?

After declaring my working assumptions, I explained the theoretical, methodological, and practical contributions this study aimed to make. I provided a brief overview of the paradigmatic and methodological choices I made, and the ethical principles that guided the research process. I referred to the quality criteria that I considered to ensure a rigorous and trustworthy study. I defined EPoDP, formative feedback, and technology education as key terms in this study. Finally, the chapter was concluded with a brief overview of the integrated conceptual framework of this study, and an overview of the structure of this dissertation.

In **Chapter 2**, I gave a historical overview of the development of technology as a subject in the South African curriculum. This was followed by a review of the existing literature on design as a complex problem-solving activity; formative assessments in technology classrooms; formative feedback embedded in formative assessment; formative feedback in design settings; and formative feedback questions and comments in design activities. I concluded Chapter 2 by explaining the integrated conceptual framework that I created to explore the implementation of formative feedback questions and comments on four distinct levels during the EPoDP.

In **Chapter 3**, I outlined the research methodology of this study. I described and justified my choice to use an interpretive, qualitative, descriptive single-case study research design in the context of design problem-solving in technology classrooms. I discussed how I combined convenience and purposive sampling to select 12 senior phase technology teachers to participate in semi-structured interviews, and five Grade 8 and 9 technology teachers to participate in classroom observations. Next, I described how I planned and executed the data collection, documentation, and analysis employing semi-structured interviews and non-participant observations. I further described the inductive thematic analysis process that I followed, and how the

results were presented. I conclude the chapter by comprehensively discussing my role as a researcher, the quality assurance measures taken, and the ethical guidelines to which I adhered in completing a rigorous and ethical study.

In **Chapter 4**, I presented and discussed the results of the technology teachers' perceptions and implementation of formative feedback in the EPoDP. I presented the technology teachers' perceptions of formative feedback in three themes: how the technology teachers described formative feedback; the rationale for implementing formative feedback; and their perceptions of how formative feedback is implemented in technology classrooms. The technology teachers' implementation of formative feedback was presented based on the phases of the design process, the formative feedback level, and the formative feedback questions and comments that I observed in the EPoDP. Throughout this chapter, I present extracts from the interview transcripts, and observational data to support my discussions.

5.3. FINDINGS OF THE STUDY

In this section, I present the finding of this study by positioning the results in conjunction with the existing literature on formative feedback in design settings. In Table 5.1 and Table 5.2, I present the findings of this study structured according to the themes discussed in Chapter 4. I conclude this chapter with a discussion of the findings and the conclusions drawn in terms of the secondary research questions presented in Chapter 1.

Table 5.1: Technology teachers' perceptions of formative feedback in conjunction with the existing literature

Technology teachers' perceptions of formative feedback during the early phases of the design process		
Theme 1: Teachers' descriptions of formative feedback during the early phases of the design process		
Sub-Theme	**Explanations in the literature alongside the researcher's observations**	**Findings**
Sub-theme 1.1: formative feedback through compliments and criticism. The participants indicated that compliments hold motivational value and should precede corrective feedback or critique. The participants viewed critique as an opportunity to support learners to identify areas for improvement, correct work, and decide on the next steps.	Compliments may be associated with formative feedback on the level of the self, as described by Hattie and Timperley (2007). Compliments and praise are expected by learners, but do not guarantee increased task motivation (Hattie & Gan, 2017). Studies have indicated that when self-level feedback is mixed with other levels of feedback, that feedback about the task, process, and self-regulation becomes diluted and ineffective (Hattie & Gan, 2017). Mixing praise and compliments with feedback about the task is often premature, confuses learners, and discourages revisions of their work (Hattie & Gan, 2017). The teachers engaged in 'desk crits' during problem-solving activities (Caldwell et al., 2016; McLain, 2021). Feedback about the accomplishment or performance of a task was task-level feedback (Hattie & Timperley, 2007). Corrective feedback at the task level may hold motivational value, and support learners' development of self-regulation skills (Hattie & Gan, 2017).	The teachers deemed it necessary to give learners formative feedback on what they had done well, and pointed out what learners could improve on during the design process. Even though previous studies consider the motivational effects of compliments and criticism as formative feedback strategies, I did not investigate these effects.
Sub-theme 1.2: formative feedback through questioning. Participants can provide formative feedback using questions about the potential users and existing solutions to support learners' problem structuring activities. The participants indicated that they often used questions to support learners' design decisions about materials, budget, user needs and quality of the design	The use of questions as a pedagogical tool has been well established in design-based education (Cardoso et al., 2014; Cummings et al., 2016; Schut & Blom, 2019; Schut et al., 2018, 2020; Stables et al., 2016). Studies have shown that formative feedback through questioning may facilitate the interaction between instructors and students, stimulate learners' creative, convergent, and divergent thinking (Cardoso et al., 2016, 2014; Schut & Blom, 2019; Schut et al., 2018, 2020, 2021; Stables, 2016; Stables et al., 2016). Formative feedback often serves to support learners'	The teachers perceived questioning to be an effective method to support learners' design processes. Although questioning is an effective formative feedback method and holds potential benefits in supporting learners' design processes, they did not always utilise feedback. This study

solutions. The results also showed that the participants described using questions to guide learners' reflection and evaluation of their design processes and outcomes.	task management through completing a series of steps (Kimbell & Stables, 2008; McLellan & Nicholl, 2011).	did not explore how the learners responded to questions.
Sub-theme 1.3: formative feedback through providing examples to existing solutions. The participants of this study indicated that they showed learners examples of existing solutions during the design process. The participants indicated that this reduces the time spent on trial-and-error in exploring design solutions.	Showing learners examples of existing design solutions may be a way to communicate success criteria for the task, and develop an understanding of the desired quality of the design solution (Black & Wiliam, 2010; Kimbell, 2020). The aim of formative feedback should be to reduce the gap between learners' current level of performance and the learning goal (Black & Wiliam, 2010; Hattie & Clarke, 2019; Hattie & Timperley, 2007). Studies show that teachers sometimes teach design as a series of linear steps to mitigate the time constraints associated with design projects (Mettas & Norman, 2011). Teaching design in a linear fashion has been shown to contribute to teacher autonomy and the management of design projects (Mawson, 2010). Using examples of existing products during design activities may reduce the exploration of ideas, and iterations between design phases (Hardy, 2015). Showcasing existing solutions may also lead to fixation and reduce learner autonomy in the design process (Kimbell & Stables, 2008; McLellan & Nicholl, 2011).	Formative feedback includes showing learners examples of existing solutions to communicate quality and success criteria. The present study only focused on the problem-structuring and preliminary problem-solving phases of the design process; I did not evaluate the learners' design outcomes against success criteria.
Sub-theme 1.4: Formative feedback being 'intuitive'. The results from this study show that formative feedback is based on the interaction between the teachers and	The design process supports learners in solving open-ended, ill-structured design problems that do not single correct solutions of problem-solving pathways (Jonassen, 2010; Strong et al., 2019). As such, there is no singular approach to supporting learners during the design process (Strong et al., 2019). To meet the needs of learners' in design settings is challenging and requires teachers' to be prepared to support learners, through their experiences and teaching methods (Strong et al., 2019).	The findings of this study indicated that the technology teachers viewed formative feedback as 'intuitive'. Teaching experience plays an important role in teachers' abilities to give feedback. These teachers were

learners is not planed and happens at the moment.		prepared to give feedback, but feedback was not planned. Although previous studies have indicated that teaching by improvision requires teachers to rely on a variety of methods, strategies and know-how, this study only focused on the implementation of formative feedback to support learners' design processes.
Theme 2: Technology teachers' perceptions of the rationale for formative feedback during the early phases of the design process.		
Sub-Theme	**Explanations in the literature alongside the researcher's observations**	**Findings**
Sub-theme 2.1: the teachers' perceptions of the rationale of formative feedback. The results that emerged from this study indicated that the participants viewed formative feedback as necessary to support learners design processes.	The fundamental aim of feedback is to reduce the discrepancy between learners' current level of understanding/performance and the learning goal (Black & Wiliam, 2010; Hattie & Timperley, 2007). To reduce the gap, teachers should support learners in identifying the learning goals, how learners are progressing towards these goals, and what their next steps should be towards achieving the learning goal (Black & Wiliam, 2010; Hattie & Timperley, 2007).	Formative feedback is necessary to communicate their expectations, monitor learners' progress and guide learners on possible next steps. This study did not investigate the influence that formative feedback had on the learners' next steps.
Sub-theme 2.2: Technology teachers' perceptions of the challenges of providing formative feedback.	Time constraints and curriculum requirements mean that teaching the design process is often reduced to a series of steps using existing examples to guide learners towards developing a solution (Mettas & Norman, 2011; Yilmaz & Daly, 2016)	Time constraints and curriculum requirements negatively impacted the teachers' implementation of formative feedback during the design process.

Participants have limited interaction time with learners and have limited time to complete the design tasks each term. The participants often reverted to written and summative feedback on design tasks due to time constrictions.		
Theme 3: Providing formative feedback in technology classrooms		
Sub-Theme	**Explanations in the literature alongside the researcher's observations**	**Findings**
Sub-theme 3.1: technology teachers' use of formative feedback to answer learners' questions. When the participants did not have the answers to learners' questions during the design process, they would research the answer using textbooks and YouTube, or ask the class for their input.	Strong et al. (2019) suggest that teaching design using improvisation may be ideal for teachers who "tolerate the uncertainty of not having all the answers for every question" (p. 14).	The teachers encouraged learners to work collaboratively to answer questions and find solutions during the design process.
Sub-theme 3.2: aiming formative feedback at individuals, small groups, and the whole class. The participants' direct feedback to individuals, groups, and the whole class depended on the aim of the feedback. If the feedback applied to the whole class, the participants	The use of formative feedback was dependent on whether it wa required by individuals, groups, or the whole class (Brookhart, 2017). Giving feedback to the whole class when the feedback only applies to an individual may be ineffective and confuse learners (Brookhart, 2017).	The formative feedback audience depends on individual, group, or whole class feedback needs. This study did not investigate how the teachers determined when individual, small group, or whole class feedback would support learners' design processes.

provided feedback to the whole class. As the participants walked from desk to desk, they provided feedback to individuals and groups, and pointed out aspects of the designs that needed to be improved.		
Sub-theme 3.3: the frequency and effectiveness of formative feedback. The participants often determined the success of learners' design processes based on the end products. The participants deemed feedback to be effective when they could see that the learners had applied it to their designs.	Feedback is effective when it supports learners to move from their current level of understanding or performance towards the learning goal. (Hattie & Clarke, 2019; Hattie & Timperley, 2007). Learners have indicated that feedback is helpful when it is formative and linked to assessment criteria (Harris et al., 2014; Hattie & Gan, 2017; Pokorny & Pickford, 2010; Smith & Lipnevich, 2009). Learners deem formative feedback as effective when they receive sufficient time to process and apply the feedback rather than receiving summative feedback (Brooks et al., 2019; Hattie & Clarke, 2019).	The teachers deemed formative feedback to be effective when the design solution met the assessment criteria. This study did not investigate learners' design outcomes. Therefore, I could not comment on the effectiveness of the teachers' formative feedback to support learners' design processes.

Table 5.2: Technology teachers' implementation of formative feedback positioned in conjunction with the existing literature

Technology teachers' implementation of formative feedback during the early phases of the design process		
Formative feedback and the design process		
Formative feedback per phase	**Findings in the literature**	**Findings of this study**
Formative feedback in the problem-structuring phase The participants in this study supported learners in identifying the design problem, conducting research, and exploring existing solutions. The participants guided learners' exploration of existing products through videos and images during the lesson, while drawing their attention to certain aspects of the solutions.	The problem-structuring phase of the design process (Goel, 2014; Goel & Pirolli, 1992) is associated with the investigation phase in the design process described by the South African Department of Basic Education (DoBE, 2012). For learners to explore and generate feasible and innovative design solutions, they need to explore the design problem (Daly et al., 2019). Teachers may often need to support learners' exploration of less obvious sub-problems in the design space to support novel solutions to design problems (Daly et al., 2019). A study on the effects of problem exploration on design students' design solutions indicates that when several problem-structuring strategies are used, designers can generate more and more creative design solutions (Creeger et al., 2019; Dorst, 2019a; Dorst & Cross, 2001).	Technology teachers use formative feedback to support learners' problem structuring activities. The findings of this study suggest that the participating teachers did not support learners in identifying sub-problems to the design problem. Even though I did not investigate the quality and creativity of the learners' design solutions, further research may be needed to explore the effects of problem-structuring activities on school-based design learners' design solutions.
Formative feedback in the preliminary problem-solving phase The participants were observed to support learners' problem-solving activities using formative feedback questions. The participants supported learners in writing a design brief, identifying design specifications, generating preliminary solutions, and making design decisions.	The preliminary problems-structuring phase of the design process (Goel, 2014; Goel & Pirolli, 1992) is associated with the design phase in the design process described by the South African Department of Education (DoBE 2012). Supporting learners' preliminary problem-solving activities may lead to increased creativity and novelty of design solutions (Daly et al., 2019). Strategies like the use of questioning and design heuristics may support learners to overcome fixation, and explore a wider range of possible design solutions (Daly et al., 2019; McLellan & Nicholl, 2011).	This finding supports those of a previous study that indicates that without guidance on how to assess, technology teachers prioritise product-based summative assessment over the assessment of learners' design processes. This study only explored the implementation of formative feedback during the EPoDP. I cannot comment on

		how the teachers' supported iteration between the design phases in the later phases of the design process.
Levels of formative feedback during the early phases of the design process		
Formative feedback per phase	**Findings in the literature**	**Findings of this study**
Task-level feedback The formative feedback was predominantly task related. In this study, the results showed that task-level feedback was observed in the problem-structuring and preliminary problem-solving phases of the design process. The results also showed that task-level feedback was used to verify and clarify the learners' understanding of the design problem and the goals of the design task.	Feedback at the task level is the most frequently observed feedback level in classrooms (Hattie & Clarke, 2019; Hattie & Timperley, 2007). Formative feedback at this level provides the learners with information about their performance of a task in relation to the learning goal (Hattie & Clarke, 2019; Hattie & Timperley, 2007). Task-level feedback becomes more effective when the learning goals and expectations are communicated to learners at the beginning of a task (Hattie & Gan, 2017). Task-level feedback should ideally lead to process-level and self-regulative feedback as learners become more proficient in a task (Hattie & Gan, 2017).	The findings of this study show that task-level feedback was frequently observed as a range of low-level and high-level questions, as well as low-level comments. In addition, task-level feedback was guided by the activities in the design tasks. This study did not investigate the correlation between task-level feedback and learners' task proficiency.
Process-level feedback Process-level formative feedback was observed in the problem structuring and preliminary problem structuring phases. Participants used formative feedback to support learners in exploring the design problem and how to achieve design goals.	Process-level feedback provides information about the process, skills, strategies and thinking required to complete a task (Brooks et al., 2019; Hattie & Timperley, 2007). In a study conducted by Brooks et al., (2019) the authors found that process-level feedback was predominately observed through the use of question prompts.	Process level formative feedback was observed as deep reasoning and generative design question prompts.
Self-regulative feedback The results show that the participants in this study provided limited self-regulative formative feedback.	Self-regulative feedback supports learners' development of self-monitoring, self-assessment, and self-management skills (Brooks et al., 2019). Teachers are often unsure of how to promote self-regulation in the classroom.	The findings show that self-regulative formative feedback was aimed at supporting learners' consideration of

		users' needs and the fitness for purpose of their design solutions.
Self-level feedback The participants in this study gave learners self-level feedback by confirming that their problem identification was correct, and that they were progressing towards a 'correct' solution.	Self-level feedback can be described as positive affective statements about the learner (Hattie & Timperley, 2007). Feedback on the self-level usually does not contribute to defining learning goals, reflecting on progress, or planning the next steps (Hattie & Timperley, 2007). Feedback at the task level, process level, and self-regulative level becomes diluted and ineffective when mixed with self-level feedback (Hattie & Timperley, 2007; Kluger & DeNisi, 1996).	The findings showed that the self-level was limited, observed as low-level compliments combined with the task level and process level. Although studies have shown that self-level formative feedback may decrease learners' task motivation, I did not investigate the learners' task motivation in this study.
Types of formative feedback questions and comments		
Formative feedback per phase	**Findings in the literature**	**Findings of this study**
Low-level questions The results showed that the participants utilised verification, disjunctive, concept completion, feature specification, quantification, examples, comparison, and judgement related questions to support learners' design processes. Verification, concept completion, and example questions were most frequently observed. These questions were observed in the problem-structuring and preliminary problem-solving phases. Request questions were not observed.	Verification, disjunctive, and concept completion questions and task level lay the foundation for more complex questions on a higher level of feedback (Hattie & Timperley, 2007; Tawfik et al., 2020). Verification, disjunctive, and concept completion questions are more frequently observed in the problem exploration phase of the design process of novice designers (Tawfik et al., 2020). Feature specification, quantification, definition, example, and comparison questions build the surface knowledge that is required to explore and generate design solutions (Tawfik et al., 2020). Feature specification questions are used to communicate information about the form and function of a design solution (Schut et al., 2021). Therefore, feature specifications may be utilised as success criteria in the later phases of the design process.	Verification, concept completion, and disjunctive question prompts are utilised to support task-level feedback during the initial design phases. This study did not explore whether feature specifications were utilised as success criteria in the later phases of the design process.

Low-level comments The results in this section align with previous results indicating that participants utilise compliments and critique to manage learners' design processes. Additionally, the participants were also observed giving learners direct recommendations on what their design solutions should be.	Directive feedback decreases learner autonomy in design settings (Dannels & Martin, 2008). Learners will require time to work through and apply critique and direct recommendations (Brooks et al., 2019).	Compliments, critique, and direct recommendations were utilised to support task-level and self-level formative feedback during the initial design phases.
High-level questions Generative Design Questions were observed more frequently than Deep Reasoning Questions. DRQs observed in the EPoDP included interpretation, procedural, causal antecedent, causal consequence, rationale/function, enablement, and future questions. GDQs were observed in the initial design phases and included method generation, proposal/negotiation, scenario creation, and ideation questions.	Deep Reasoning Questions serve a reflective and evaluative purpose (Cardoso et al., 2014; Schut & Blom, 2019; Yilmaz & Daly, 2014b, 2016). In a design context, DRQs may support learners' development of a causal understanding of their design decisions or their design solutions (Cardoso et al., 2014). GDQs allow learners to explore various possibilities of how to achieve their design goals (Dym et al., 2005).	Procedural, causal antecedent, and method generation question prompts were utilised to support process-level and self-regulative formative feedback during the initial design phases.

5.3.1. Secondary Research Question 1: How do technology teachers conceptualise formative feedback as part of supporting learners' early design processes?

The main findings regarding this research question were that these technology teachers provided formative feedback through compliments, critique, questioning, and presenting examples of existing solutions. The teachers participating in this study described formative feedback as a necessary aspect of teaching design, but noted that time constraints and curriculum requirements limited the frequency and effectiveness of their formative feedback. The findings also showed that the participants used formative feedback to encourage collaborative problem solving during design activities. Overall, the sampled technology teachers viewed formative feedback as intuitive and supported by teaching experience.

These findings highlight technology teachers' perceptions of the value and purpose of formative feedback in the EPoDP. As such, these findings contribute to the existing body of knowledge on the perception of formative feedback in school-based design settings. These findings may also contribute to professional practice by developing technology teachers' understanding of the benefits and shortcomings of feedback practices in technology classrooms.

Further research may be necessary to consider the effects of compliments and criticism on learners' design outcomes. A further study on the planning and implementation of desk-crits as a formative feedback strategy may further contribute to developing pedagogical guidelines for teaching design in school-based settings.

5.3.2. What is technology teachers' rationale for implementing formative feedback during the early phases of the design process?

The five technology teachers observed in this study implemented formative feedback in the problem-structuring and preliminary problem-solving phases of the design process. In contrast to the findings supporting the co-evolution of design problems and solutions, the participants were not observed to support iterations between the phases of the design process. In addition, the teachers were observed to support linear steps in completing the design tasks according to the activities in the design. Finally, the

findings showed limited evidence of the teachers supporting iterations between the problem structuring and the preliminary problem-solving phases.

The findings of this study may contribute towards the professional practice of in-service technology teachers, as well as the training of pre-service technology teachers by highlighting the value of iteration in supporting learners' generation of novel design solutions. Additional research may be necessary to determine how this teaching methodology impacts the generation of design solutions in a school-based design setting. Further research is also needed to investigate how learners utilise feedback to change and improve their design activities.

5.3.3. How do technology teachers use formative feedback to support learners' design processes at the task, process, self-regulative, and self-levels?

Based on the formative feedback levels identified by Hattie and Timperley (2007), the results of this study indicate that the majority of formative feedback was observed at the task level. Self-regulative feedback was the least observed level of formative feedback in this study. Overall, the findings in this study suggest that task-related formative feedback was frequently guided by the activities of the design task. Task-level feedback was observed through a range of low-level questions, low-level comments, and high-level questions to support learners' problem-structuring and preliminary problem-solving activities. The findings further indicate that process-level formative feedback was observed as Deep Reasoning Questions (DRQs) and Generative Design Questions (GDQs). These supported learners in considering processes and methods that may be utilised to achieve their design goals. Formative feedback at the self-regulative level was observed through high-level questions aimed at supporting learners' consideration of users' needs and the purpose of the design solution. Finally, formative feedback at the level of the self was observed as compliments and confirmation of learners' progress; this was mixed with task and process-level feedback.

The findings of this study may make a theoretical contribution to how technology teachers use formative feedback to support learners' initial design phases through low-level questions, low-level comments, and high-level questions. Further research is required to determine how technology teachers' structure formative feedback at the task and process level to support learners' self-regulation during design tasks.

5.3.4. What types of formative feedback questions and comments do technology teachers implement to support learners' design processes?

In analysing the types of formative feedback questions and comments observed, I found that the technology teachers predominately asked verification, concept completion, and disjunctive questions to support learners at the task level. Compliments, critique, and direct recommendations were observed at the task and self-level. Finally, procedural, causal antecedent, and method generation questions were observed at the process and self-regulation levels during the initial design phases. This study also revealed that the majority of high-level formative feedback questions were GDQs, while DRQs were asked less frequently. This meant that the teachers predominately asked questions that required learners to explore multiple possibilities. This ultimately meant that the high-level formative feedback questions were focused on finding and developing a design solution rather than generating methods for understanding the design problem or gathering information about the context, client, and purpose of the design solution. The DRQs observed in this study were mainly found to be interpretation questions that were structured around the design task activities. Here, the interpretation questions were most frequently asked and used to remind the learners of the design problem that they needed to solve. Procedural and causal antecedent questions were found to be focused on how and why the design task should be completed. More specifically, the questions focused on how the design task activities should be completed for assessment purposes.

These findings may contribute to the professional practice of pre-service and in-service teachers' use of formative feedback questions and comments to support learners on four distinct levels during the initial design phases. The findings from this study may also contribute to future research to develop pedagogical guidelines to support technology teachers' implementation of formative feedback. Further research may be necessary to explore how formative feedback through low-level questions, low-level comments, and high-level questions influence learners' design outcomes.

Taken together, the findings of this study suggest that the teachers used a range of low-level and high-level questions, and low-level comments. They did this to guide learners towards exploring, finding, and developing design solutions while keeping in mind how their design ideas could be realised in the making phase.

5.4. CONTRIBUTIONS OF THE STUDY

In this section, I present the contributions of this study. I address the primary research question formulated in Chapter 1 by outlining the theoretical contribution. I also discuss the professional and practical contributions that this study may make to technology education.

5.4.1. Theoretical contribution

The findings of this study add to the existing body of knowledge on technology teachers' formative feedback practices. More specifically, this study contributes to our understanding of technology teachers' perceptions and implementation of formative feedback during the EPoDP. Theoretically, this study contributes to the existing literature by providing an alternative conceptual framework (see Section 2.8). This framework can be used to understand how technology teachers implement formative feedback. I created this framework by integrating the frameworks of Goel and Pirolli (1992, 2014), Hattie and Timperley (2007) and Schut et al. (2020). In addition, the conceptual framework that I compiled for this study allowed me to observe how the teachers implemented formative feedback questions and comments at different levels in the EPoDP. In contrast, previous studies have only focused on the types of formative feedback questions and comments that designers and design learners make during the design process.

Based on the findings of this study, and drawing on my conceptual framework and existing frameworks for planning for formative feedback (Brooks et al., 2019; Schut et al., 2020; Swathi et al., 2020), I propose the framework captured in Figure 5.2 for planning for formative feedback in the early phases of the design process in technology education.

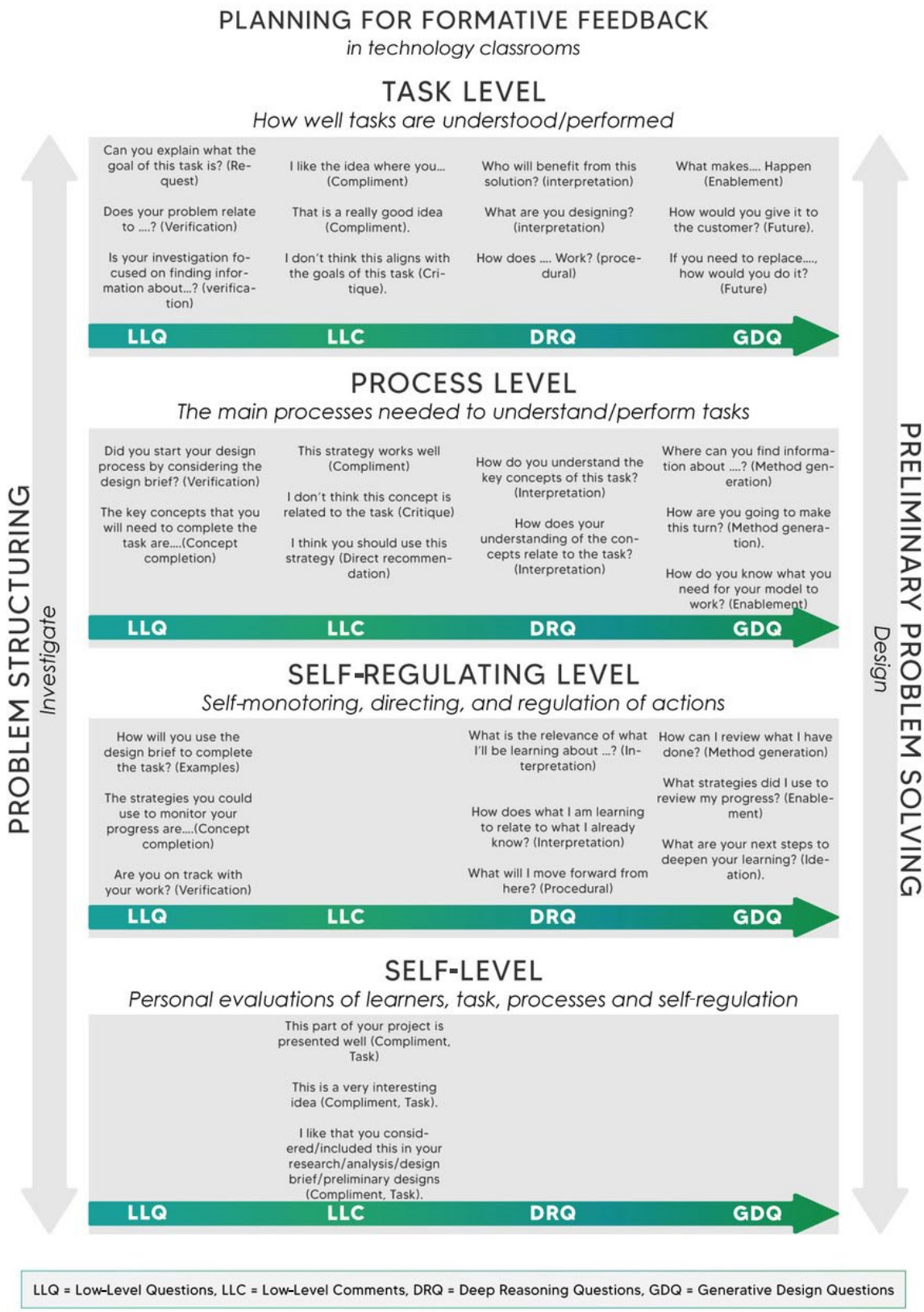


Figure 5.2: Proposed framework for planning for formative feedback in technology classrooms (adapted from Brooks et al., 2019; Schut et al., 2020; Swathi et al., 2020)

The proposed formative feedback framework presented in Figure 5.2 may be used to translate theory into practice by providing practical examples of questions and comments at each formative feedback level, as well as in the EPoDP. Technology teachers could use Figure 5.2 to plan formative feedback during problem structuring and preliminary problem solving. The framework might also support pre-service and in-service technology teachers' planning of formative feedback questions and comments, progressing from low-level questions and high-level questions from the task level to the self-regulative level. Although self-level feedback is not regarded as effective in supporting learners to reach the learning goals, it was included in the framework since studies have shown that learners expect self-level feedback from their teachers (Brooks et al., 2019).

The formative feedback questions were designed based on the existing literature on formative feedback in professional design practice and technology education, as well as the evidence and results from the present study. In terms of implementation, it is important to emphasise the interaction between the phases of the design process, formative feedback levels, and the types of questions and comment rather than viewing them linearly. In the same way, the progression of formative feedback levels, and question and commenting levels is also iterative and should be used to continuously move learning forward. To this end, the framework for planning for formative feedback is a model of formative feedback in the EPoDP. Further research is required to establish the feasibility of the framework as a tool to support technology teachers' planning and implementation of formative feedback to support learners' design processes.

5.4.2. Contribution of this study to technology education practice

The findings of this study provide insights into technology teachers' perceptions of formative feedback, and their formative feedback practices during the EPoDP. This may benefit technology teachers and other education stakeholders. Various education stakeholders may benefit from an understanding of how technology teachers perceive and practice formative feedback during the EPoDP, applying what they gain from the findings of this study to their daily classroom activities.

The findings of this study suggested that the technology teachers mainly gave learners formative feedback in the preliminary problem-solving phase of the design process.

Therefore, the findings of this study and the proposed formative feedback framework suggested in Section 5.4.1 could assist teachers in planning for formative feedback in the problem-structuring and preliminary problem-solving phases.

Based on the findings of this study, technology teachers are encouraged to ask a range of low- and high-order questions about the design context, client needs, purpose, and potential of design solutions to guide learners at the task level (Blom, 2016, Brooks et al., 2019). This means that teachers can use questions to focus learners' attention on the missing information in the design problem, and draw learners' attention to possible sources of information. Questions at the task level could also support learners' access to prior knowledge of design tasks. Building on this, process-level questions can be used to support learners' information-seeking activities. This can be done by asking questions related to identifying the key concepts in the task, the design goals that should be met, and the key strategies learners will need to complete the task (Brooks et al., 2019). This may include questions relating to how further information can be gathered on the design context, client needs, purpose, and potential of the design solutions. This will assist teachers to discover how the learners' understanding of these concepts might improve their preliminary problem solving. Finally, technology teachers should encourage learners' self-regulative learning by asking questions in which learners should consider how the learning goals will be met, how they are keeping track of their progress, and what the next steps in their design processes should be (Brooks et al., 2019).

In addition, teachers can also use questions to support the preliminary problem-solving phase of the design process by asking a range of lower and higher-order questions. These questions should relate to writing a design brief, identifying design specifications and constraints, making design decisions, and exploring possible solutions. To this end, questions at the task level may focus on the learning goals and what successful completion of the design activities would look like, whether learning intentions are being met, how learning criteria can be addressed, or what elements should be improved. At the process level, questions and comments should be aimed at the strategies needed to complete the design activities, and methods or strategies that can be used to increase understanding of the task and improve the design ideas. Finally, self-regulative questions should aim to move learning forward by focusing questions and comments on what the next steps should be in realising design ideas,

considering the progress learners have made, and how they plan to achieve their design goals by using the design and assessment criteria. The problem-structuring and preliminary problem-solving processes should be supported at the beginning and throughout the design process to ensure that novel solutions are explored and developed to realise design goals.

5.5. LIMITATIONS OF THE STUDY

In this section, I discuss the potential limitations typically associated with qualitative studies. This discussion is focused on addressing the challenges relating to transferability, selected participants, data collection, and data capturing.

5.5.1. Level of transferability of the study

The interviews and observations in this study were conducted only in Grade 8 and Grade 9 technology classrooms in Pretoria and Johannesburg, Gauteng. Therefore, the findings of this study may not be transferred to all technology classrooms in South Africa or globally. The aim of this study was not to generalise the findings, but rather to provide insight into the perceptions of, and formative feedback practices of technology teachers. This study can thus merely inform technology practitioners on the perceptions of, and formative feedback practices of Grade 8 and Grade 9 technology teachers. Even though the lack of generalisability may imply a potential limitation to this study, it is up to the reader to decide the level of transferability of this study based on the detailed descriptions and the evidence that I have included.

5.5.2. Sampling and participants

This study was limited to 12 interview participants and five observation participants. The challenge was to identify a sampling method and criteria that allowed to me select participants who were representative of Grade 8 and Grade 9 technology teachers experienced in facilitating the design process. I experienced distinct challenges in gaining enough participants to take part in this study. Despite my efforts to invite technology teachers to participate in this study, I was not able to get enough participants who were representative of experienced technology teachers. In addition, I had to adapt my sampling method and intended methodological strategies by relying on interviews and whole class observations only. This was due to the fact that I could

not use stimulated recall interviews and Go-Pro cameras for micro observations as initially planned due to the participants not being supportive of these data collection methods. Even though I experienced challenges with identifying suitable participants, and with the data collection methods, I followed all possible guidelines to enhance the trustworthiness and rigour of this study.

5.5.3. Data collection and capturing

Another potential limitation of this study relates to the time lapse between the observations and the follow-up interviews. This was partly due to the Department of Basic Education limiting research in the first and fourth terms of the school year. This meant that I had to complete some of the observations during the third term of 2020. With special permission, I was able to complete some of the observations in the first term of 2021. In addition, a national state of disaster was declared, resulting in a nationwide lockdown due to the COVID-19 pandemic. This limited my access to the participants for follow-up interviews in person and online, thus the responses from the participants were delayed.

In terms of data capturing, I experienced technical difficulties using camera equipment to capture the data. The challenge I faced using a stationary SWIVL action camera with a microphone worn by the participant was that the camera would occasionally focus on other areas of the room instead of the teacher. This typically occurred where the teachers did not keep the mic and receiver still while being recorded. This resulted in some gestures that the teachers made not being recorded. Additional factors such as noise levels, interruptions, and interactions between the teachers and learners might have affected the richness of the data. Furthermore, one of the observations was not captured on video due to software updates being downloaded during the observation. I was able to address these limitations by relying on the audio recordings of the lessons to refer back to in instances where the audio was unclear on the video recordings.

5.6. RECOMMENDATIONS OF THIS STUDY

In light of the findings of this study, I make recommendations for teacher development and practices, possible policy implementation, and future research. This may support improved formative feedback practices in technology education.

5.6.1. Recommendations for development and practice

Based on the outcomes of this study, it seems clear that pre-service technology teachers may gain valuable knowledge on formative feedback practices in technology classrooms if they are trained in this field. More specifically, I assert that pre-service technology teachers need to be trained to plan and implement formative feedback to support the design process.

I also recommend that in-service training and workshops for technology teachers be developed and implemented, providing clear guidelines to develop and support their facilitation of the design process through formative feedback.

In terms of practice, I recommend that pre-service and in-service technology teachers practically apply the findings of this study to support learners' design processes. In doing so, the quality of the current facilitation of the design process may be enhanced. This may equip teachers with guidelines to help them to plan and implement formative feedback strategies that guide learners to become more self-regulated in their design problem-solving activities.

5.6.2. Recommendations for future research

Based on the findings of this study, the following areas have been highlighted as recommendations for further research:

- Case studies replicating this study in the context of various technology classrooms allowing for generalisability.
- An exploratory case study on using suitable data collection strategies when involving teachers in a study, specifically in terms of their preferences.
- An exploratory study on the effects of teachers' experience in teaching technology and facilitating specific design tasks on formative feedback practices
- A follow-up study on the use and effectiveness of a formative feedback model for improving technology teachers' planning and implementation of formative feedback in the EPoDP.

- An exploratory study on the challenges of providing formative feedback during the EPoDP.
- A case study of learners' responses to formative feedback in the EPoDP.
- An exploratory study on the effect of formative feedback on learners' design outcomes.

5.7. CONCLUSION

In this chapter, I presented a summary of the research conducted on teachers' perceptions and implementation of formative feedback in technology classrooms. As a starting point, I provided discussions from previous chapters. This was followed by a discussion of the findings that answered my research questions. I provided an overview of the possible theoretical, methodological, and practical contributions derived from this study's findings. I concluded this chapter with a discussion of the study's potential limitations, and recommendations for future research.

The findings of this study highlight that these technology teachers perceived formative feedback as providing compliments and critique on learners' designs, providing learners with examples of existing solutions, questioning, and being 'intuitive'. In addition, the findings show that these technology teachers viewed formative feedback as a necessary part of facilitating the design process, but that time constraints impacted the frequency and effectiveness of their formative feedback practices. Finally, the findings indicate that the teachers used formative feedback to respond to learners' questions, however, this was usually aimed at the whole class. In terms of the implementation of formative feedback, the findings show that these technology teachers predominately used low-level formative feedback questions related to the task to guide learners' preliminary problem-solving activities. If we want learners to develop their abilities, we should encourage current and future teachers to plan and implement effective formative feedback to support learners' design processes. Failure to support learners' design processes may inhibit the development of the design skills recommended in the technology CAPS document.

REFERENCE LIST

Adams, R., Forin, T., Chua, M., & Radcliffe, D. (2016). Charterizing the work of coaching during design reviews. *Design Studies*, *45*, 30–67. https://doi.org/https://doi.org/10.1016/j.destud.2015.12.007

Adams, R., Forin, T., & Joslyn, C. (2017). Approaches to Coaching Students in Design Reviews. In *American Society for Engineering Education*. Purdue University.

Adams, R. S., & Siddiqui, J. (Eds.). (2016). *Analyzing Design Review Conversations*. Purdue University Press.

Ahmed, S., Wallace, K., & Blessing, L. T. (2003). Understanding the differences between how novice and experienced designers approach design tasks. *Research in Engineering Design*, *14*, 1–11. https://doi.org/https://doi-org.uplib.idm.oclc.org/10.1007/s00163-002-0023-z

Ankiewicz, P. (2020). Technology education in South Africa since the new dispensation in 1994: An analysis of curriculum documents and a meta-synthesis of scholarly work. *International Journal of Technology and Design Education* (2020). https://doi.org/10.1007/s10798-020-09589-8

Ary, D., Jacobs, L. C., Razavieh, A., & Sorensen, C. (2006). *Introduction to Research in Education* (7th edition). Thomson Wadsworth.

Aurisicchio, M., & Bracewell, R. (2009). Guiding Engineering Design Activities Through a Question Based Approach. *ASME International Design Engineering Technical Conference & Computers and Information in Engineering Conference* (pp. 1–11). https://www.doi.org/10.1115/DETC2009-87590.

Mouton, J. (2001). *How to succeed in your master's and doctoral studies : a south african guide and resource book.* Van Schaik.

Barak, M. (2010). Motivating self-regulated learning in technology education. *International Journal of Design Education*, *20*, 381–401. https://doi.org/10.1007/s10798-009-9092-x

Barlex, D. (2008). Assessing Capability in Design and Technology: The case for a minimally invasive approach. *Design and Technology Education: An International Journal*, *12*(2), 43–56.

Black, P. (2008). Formative assessment in the learning and teaching of design and technology. *Design and Technology Education: An International Journal*, *13*(3), 19–26.

Black, P. (2015). Formative Assessment in the learning and teaching of design and technology. *Design and Technology Education: An International Journalcation: An International Journal*, *13*(3), 19–26.

Black, P., & Wiliam, D. (1998). Inside the Black Box: Raising Standards Through Classroom Assessment. *Phi Delta Kappan*, *80*(2), 139–144.

Black, P., & Williams, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, *21*(1), 5–31.

Black, P., & Wiliam, D. (2010). Inside the Black Box: Raising Standards through Classroom Assessment. *Phi Delta Kappan Magazine*, *92*(1), 81–90. https://doi.org/10.1177/003172171009200119

Blom, N. (2019). *Using linkography to understand the cognitive mechanisms of technology learners during the design process*. University of Pretoria.

Blom, N., Haupt, G., & Fraser, W. (2018). Naive Designers' Information Use during the Design Process in a Low-Resource Classroom. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(6), 2563–2586. https://doi.org/https://doi.org/10.29333/ejmste/90091

Braun, V., & Clarke, V. (2013). *Successful qualitative research : a practical guide for beginners*. SAGE publications.

Brookhart, S. M. (2017). *How to give effective feedback to your students.* ASCD.

Brooks, C., Carroll, A., Gillies, R. M., & Hattie, J. (2019). A matrix of Feedback for Learning. *Australian Journal of Teacher Education*, *44*(4), 14–32. https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=4007&context=ajte

Brooks, C., Huang, Y., Hattie, J., Carroll, A., & Burton, R. (2019). What's my next step? School Students' Perceptions of Feedback. *Frontiers in Education*, *4*(96). https://doi.org/10.3389/feduc.2019.00096

Caldwell, G. A., Osborne, L., Mewburn, I., & Nottingham, A. (2016). Connecting the Space between Design and Research: Explorations in participatory research supervision. *Educational Philosophy and Theory*, *48*(13), 1352–1367. https://doi.org/10.1080/00131857.2015.1111129

Cardella, M., Buzzanell, P., Cummings, A., Tolbert, D., & Zoltowski, C. (2014). A Tale of Two Design Contexts: Quantitative and Qualitative Explorations of Student-Instructor Interactions Admist Ambiguity. *DTRS 10: Design Thinking Research Symposium, 2014.* Perdue University.

Cardoso, C., Badke-Schaub, P., & Eris, O. (2016). Inflection moments in design discourse: How questions drive problem framing during idea generation. *Design Studies*, *46*(C), 59–78.

Cardoso, C., Eris, O., Badke-Schaub, P., & Aurisicchio, M. (2014). Question asking in design reviews: how does inquiry facilitate the learning interaction? *Design thinking research symposium* (pp. 1–18).

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed). Routledge.

Creeger, S., McKilligan, S., & Seifert, C. (2019). Exploring the problem space with Problem Exploration Strategies. *International Association of Societies of Design Research Conference 2019.*

Creswell, J. W. (2007). Designing a Qualitative Study. In L. G. Shaw (Ed.), *Qualitative Inquiry and Research Design: Choosing Among Five Approaches* (2nd ed., p. 39). Sage.

Creswell, J. W. (2014). *Research Design: Qualitative, Quantitative and Mixed Methods Approaches2* (4th ed). Sage.

Creswell, J., & Creswell, J. W. (2018). Writing strategies and ethical considerations.

In A. Marks (Ed.), *Research Design: Qualitative, Quantitative and Mixed Methods Approaches* (5th ed., pp. 88–98). Sage.

Creswell, J. W., Ebersohn, L., Eloff, I., Ferreira, R., Ivankova, N. V., Jansen, J. D., Nieuwenhuis, J., Pietersen, J., Plano Clark, V., & van der Westhuizen, C. (2016). *First steps in research*. (K. Maree, Ed.) (2nd ed.). Van Schaik Publishers.

Creswell, J., & Poth, C. N. (2018). *Qualitative inquiry & research design: choosing among five approaches* (4th ed). Sage.

Crooks, T. (2001). The validity of formative assessments. *Paper presented to the British Educational Research Association Annual Conference, University of Leeds, 13–15 September.*

Cross, N. (2004). Expertise in design: an overview. *Design Studies*, *25*(5), 427–441. https://doi.org/https://doi.org/10.1016/j.destud.2004.06.002

Cummings, A., Tolbert, D., Zoltowski, C., Cardella, M., & Buzzanell, P. (2016). A Quantitative Exploration of Student-Instructor Interactions Amidst Ambiguity. In R. S. Adams & J. A. Siddiqui (Eds.), *Analyzing design review conversations.* (pp. 395–412). Purdue University Press. https://search.ebscohost.com/login.aspx?direct=true&scope=site&db=nlebk&db=nlabk&AN=1259105

Daly, S. R., Yilmaz, S., Christian, J. L., Seifert, C. M., & Gonzalez, R. (2019). Design Heuristics in Engineering Concept Generation. In D. Schaefer, G. Coates & C. Eckert (Eds.), *Design education today : Technical contexts, programs and best practices.* (Vol. 101, pp. 601–629). https://doi.org/10.1002/j.2168-9830.2012.tb01121.x

Dannels, D. P., & Martin, K. N. (2008). Critiquing critiques: A genre analysis of feedback across novice to expert design studios. *Journal of Business and Technical Communication*, *22*(2), 135–159.

de Jager, R. (2011). Latest changes in the Technology Education curriculum in South Africa. In K. Stables, C. Benson & M. J. De Vries (Eds.), *PATT 25: Perspectives on Learning in Design and Technology Education* (pp. 144–150). Goldsmiths

University of London.

de Vries, M. J. (Ed.). (2018). *Handbook of Technology Education*. Spinger. https://doi.org/https://doi.org/10.1007/978-3-319-44687-5

Denzin, N. K., & Lincoln, Y. S. (2018). *The SAGE handbook of qualitative research* (5th ed). Sage.

Department of Basic Education. (2012). *Curriculum and Assessment - Policy Statement Grades 7-9: Technology* (1st ed.). Goverment Printing Works.

Doppelt, Y., Mehalik, M. M., Schunn, C. D., Silk, E., & Krysinski, D. (2008). Engagement and Achievements: A Case Study Design-Based Learning in a Science Context. *Journal of Technology Education*, *19*(2), 22–39.

Dorst, K. (2019a). Co-evolution and emergence in design. *Design Studies*, *65*, 60–77.

Dorst, K. (2019b). Design beyond Design. *She Ji: The Journal of Design, Economics, and Innovation*, *5*(2), 117–127.

Dorst, K., & Cross, N. (2001). Creativity in the design process. *Design Studies*, *22*, 425–437.

Durdella, N. (2019). *Qualitative Dissertation Methodology: A Guide for Research Design and Methods.* SAGE Publications, Inc.

Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., & Leifer, L. J. (2005). Engineering design thinking, teaching and learning. *Journal of Engineering Education*, *94*(1), 103–120.

Dym, C. L., Little, P., & Orwin, E. J. (2014). *Engineering Design: A Project based approach* (4th ed.). John Wiley & Sons.

Engelbrecht, W., Ankiewicz, P., & de Swart, E. (2007). An industry-sponsored, school focused model for continuing professional development of technology teachers. *South African Journal of Education 2*(*27*), 579–595.

Eris, O. (2003). Asking generative design questions: a fundamental cognitive mechanism in design thinking. *Conference: Proceedings of the international*

conference on engineering design.

Eris, O. (2004). *Effective Inquiry for Innovative Engineering Design* (First). New York: Springer Science and Business Media. In A. Folkeson, K. Gralen, M. Norell & U. Sellgren (Eds.), *DS 31: Proceedings of ICED 03, the 14th International Conference on Engineering Design, Stockholm*. The Design Society.

Eris, O., Sheppard, S., & Kwan, A. (2007). Learning to question: A longitudional analysis of question asking behavior and engagement in project-based learning. *International Conference on Engineering Design* (pp. 1–6).

Eskreis-Winkler, L., & Fishbach, A. (2020). When praise—versus criticism—-motivates goal pursuit. In E. Brummelman (Ed.), *Psychological Perspectives on Praise*. Routledge.

Flick, U. (Ed.) (2018). *The SAGE Handbook of Qualitative Data Collection*. SAGE Publication.

Fogler, H. S., & LeBlanc, S. (2008). *Strategies for creative problem solving*. Pearson Education.

Foster, P. (2006). Observational Research. In R. S. & V. Jupp (Ed.), *Data collection and analysis* (pp. 58–92). SAGE Publications Ltd.

Fox-Turnbull, W. (2009). Stimulated recall using autophotography - A method for investigating technology education. *Strengthening the Position of Technology Education in the Curriculum. Delft, The Netherlands: International Technology and Engineering Educators Association*.

Fox-Turnbull, W. (2019). Assisting teachers' understanding of student learning in technology. *International Journal of Technology and Design Education*, *29*(5), 1133–1152. https://doi.org/10.1007/s10798-018-9484-x

Fox-Turnbull, W. H. (2017). Enhancing teachers' understanding of young students' learning in technology. *PATT 34 Technology and Engineering Education*. ITEEA. https://hdl.handle.net/10289/12341

Fox-Turnbull, W. H. (2018). Assisting teachers' understanding of student learning in

technology. *International Journal of Technology and Design Education*, *29*(5), 1133–1152. https://doi.org/https://doi.org/10.1007/s10798-018-9484-x

Frey, B. B. (2018). *The SAGE Encyclopedia of Educational Research, Measurement and Evaluation*. SAGE Publication. https://doi.org/https://dx.doi.org/10.4135/9781506326139

Gan, M. (2011). *The effects of prompts and explicit coaching on peer feedback quality*. The University of Auckland. https://researchspace.auckland.ac.nz/bitstream/handle/2292/6630/whole.pdf?sequence=5&isAllowed=y

Given, L. M. (2012). *The SAGE Encyclopedia of Qualitative Research Methods.* SAGE Publications.

Goel, V. (1992). Comparison of Well-Structured & Ill-Structured Task Environments and Problem Spaces. *Proceedings of the Fourteenth Annual Conference of the Cognitive Science Society*.

Goel, V. (1995). *Sketches of Thought* (1st ed.). The MIT Press.

Goel, V. (2014). *Creative brains: designing in the real world*. https://www.frontiersin.org/articles/10.3389/fnhum.2014.00241/full

Goel, V., & Pirolli, P. (1992). The Structure of Design Problem Spaces. *Cognitive Science*, *16*, 395–429.

Goldschmidt, G. (2016). Linkographic Evidence for Concurrent Divergent and Convergent Thinking in Creative Desgin. *Creativity Research Journal*, *28*(2), 15–122. https://www.tandfonline.com/doi/full/10.1080/10400419.2016.1162497

Goldschmidt, G., Casakin, H., Avidan, Y., & Ronen, O. (2014). Three studio critiquing cultures: Fun follows function or function follows fun? *Design Thinking Research Symposium*. *West Lafayette,* Indiana.

Goldschmidt, G., Hochman, H., & Dafni, I. (2010). The design studio crit: Teacher student communication. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *24*(3), 285–302.

Gomez Punte, S. M., van Eijck, M., & Jochems, W. (2013). A sampled literature review of design-based laerning approaches: a search for key characteristics. *International Journal of Technology and Design Education*, *23*(3), 717–732. https://doi.org/10.1007/s10798-012-9212-x

Graesser, A., Rus, V., & Cai, Z. (2008). Question classification schemes. *Proceedings of the workshop on Question Generatio* (pp. 10–17).

Guba, E. G. (1981). Criteria for assessing the trustworthiness of naturalistic inquiries. *Educational Communation and Technology*, *29*(2), 75–91.

Gumbo, M. T. (2016). The question of Technology Education: A pertinent issue/interviewer. *Inaugural Lecure*. University of South Africa.

Gumbo, M. T. (2020). Professional Development of Technology Teachers: Does their training meet their needs? *Perspectives in Education*, *38*(1), 58–71. https://doi.org/http://dx.doi. org/10.18820/2519593X/pie. v38i1.5

Hancock, D., & Algozzine, B. (2011). *Doing Case Study Research* (2nd ed.). Teachers College Press.

Hardy, A. (Ed.). (2020). *Learning to Teach Design and Technology in the Secondary School: A Companion to School Experience*. Routledge.

Harris, L. R., Brown, G. T., & Harnett, J. A. (2014). Understanding classroom feedback practices: A study of New Zealand student experiences, perceptions, and emotional responses. *Educational Assessment, Evaluation and Accountability*, *26*(2), 107–133.

Hattie, J. (2009). *Visible learning: A synthesis of over 800 metaanalyses relating to achievement.* Routledge.

Hattie, J., & Clarke, S. (2019). *Visible Learning Feedback*. Routledge.

Hattie, J., & Gan, M. (2017). Instruction based on feedback. In R. E. Mayer, P. A. Alexander (Eds.), *Handbook of research on learning and instruction* (2nd ed., pp. 249–271). Routledge, Taylor & Francis Group.

Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 81–112.

Haupt, G. (2015). Learning from expers: forstering extended thinking in the early phases of the design process. *International Journal of Technology and Design Education*, *25*, 483–520. https://doi.org/https://doi-org.uplib.idm.oclc.org/10.1007/s10798-014-9295-7

Jonassen, D. H. (2010). *Learning to Solve Problems: A Handbook for Designing Problem-Solving Learning Environments* (1st ed.). Taylor & Francis Group. https://ebookcentral-proquest-com.uplib.idm.oclc.org/lib/pretoria-ebooks/detail.action?docID=574578.

Jonassen, D. H. (2011). *Learning to solve problems: A handbook for designing problemsolving learning environments*. Routledge.

Kelley, T. R., Capobianco, B. M., & Kaluf, K. J. (2015). Concurrent think-aloud protocols to assess elementary design students. *International Journal of Technology Design Education, 25*, 521–540. https://doi.org/10.1007/s10798-014-9291-y

Kimbell, R. (2007). Assessing Design Innovation. In L. Lindstrom (Ed.), *Technology Education in New Perspectives: Research, assessment and curriculum development* (14th ed., pp. 17–36). Stockholm Institute of Education Press (HLS Förlag).

Kimbell, R. (2012). Evolving project e-scape for national assessment. *International Journal of Technology and Design Education*, *22*(2), 135–155. https://doi.org/10.1007/s10798-011-9190-4

Kimbell, R. (2020). Capability, Quality and Judgement: Learners' Experiences of Assessment. In P. J. Williams & D. Barlex (Eds.), *Pedagogy for Technology Education in Secondary Schools: Research Informed Perspectives for Classroom Teachers* (pp. 201–217). Springer International Publishing.

Kimbell, R., & Stables, K. (2007). *Researching Design Learning: Issues and findings from two decades of research and development*. Springer.

Kimbell, R., & Stables, K. (2008). Designerly thinking beyond design. Designerly Thinking Beyond Design. In K. Borg & V. Lindberg (Eds.), *Kunskap, lärande och bedömning i estetiska och praktiska ämnen* [Knowledge, learning and assessment in aesthetical and manual school subjects] (pp. 188-198). Stockholm University Press.

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: A historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin*, *119*(2), 254.

Kruger, C., & Cross, N. (2006). Solution driven versus problem driven design: strategies and outcomes. *Design Studies*, *27*(5), 527–548.

Lawson, M. J., Vosniadou, S., Van Deur, P., Wyra, M., & Jeffries, D. (2019). Teachers' and Students' Belief Systems About the Self-Regulation of Learning. *Educational Psychology Review*, *31*(1), 223–251. https://doi.org/10.1007/s10648-018-9453-7

Liikkanen, L., & Pertulla, M. (2009). Exploring problem decomposition in conceptual design among novice designers. *Design Studies*, *30*(1), 38–59.

Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic Inquiry*. Sage.

Lincoln, Y. S., & Guba, E. G. (1986). But is it rigorous? Trustworthiness and authenticity in naturalistic evaluation. *New Directions for Program Evaluation*, *30*, 73–84.

Lyle, J. (2003). Stimulated Recall: a report on its use in naturalistic research. *British Educational Research Journal*, *29*(6), 861–878.

Mack, L. (2010). The philosophical underpinnings of educational research. *Polyglossia, 19*, 5-11.

Maree, K. (2020). *First steps in research* (3rd edition). Van Schaik.

Mawson, B. (2010). Children's Developing Understanding of Technology LK - https://UnivofPretoria.on.worldcat.org/oclc/503324747. *International Journal of Technology and Design Education*, *20*(1), 1–13.

McCormick, R. 2004. Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education, 14*, 21-44.

McLain, M. (2021). Towards a signature pedagogy for design and technology education: a literature review. *International Journal of Technology & Design Education* (2021). https://univofpretoria.on.worldcat.org/oclc/8990307963

McLellan, R., & Nicholl, B. (2011). If I was going to design a chair, the last thing I would look at is a chair. Product analysis and the causes of fixation in students' design work 11-16 years. *International Journal of Technology and Design Education*, *21*(1), 71–921.

Mentzer, N. (2014). Team Based Engineering Design Thinking. *Journal of Technology Education*, *25*(2), 52–72.

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation.* ProQuest Ebook Central. https://ebookcentral-proquest-com.uplib.idm.oclc.org

Mettas, A., & Norman, E. (2011). A grounded theory approach to the development of a framework for researching children's decision-making skills within design and technology education. *Design and Technology Education: An International Journal*, *16*(2), 3–19.

Mettenfelner, C. N., & Ravitch, S. (2018). Naturalistic Inquiry. In B. B. Frey (Ed.), *The SAGE Encyclopedia of Educational Research, Measurement and Evaluation* (pp. 1135–1137). SAGE Publication.

Mills, A., Eurepos, G., & Wiebe, E. (2010). *Encyclopedia of Case Study Research*. Sage.

Mills, A. J., Eurepos, G., & Wiebe, E. (Eds.) (2012). *Encyclopedia of Case Study Research* (pp. 100–102). SAGE Publications.

Moreland, J., & Jones, A. (2000). Emerging assessment practices in the emergent curriculum: Implications for technology. *International Journal of Technology and Design Education*, *10*(3), 283–395.

Murray, J., McKilligan, S., Daly, S., Seifert, C., & Studer, J. (2018). Innovative Solutions through innovated Problems. *International Journal of Engineering Education*, *34*, 695–707.

Murray J. K., Studer J. A., Daly S. R., & McKilligan S. S. C. (2018). Design by taking perspectives: How engineers explore problems. *Journal of English Education*, *108*, 248–275. https://doi.org/https://doi.org/10.1002/jee.20263

Nadelson, L. S., Pfiester, J., Callan, J., & Pyke, P. (2015). Who is doing the Engineering, the Student or the Teacher? The development and use of a rubric to categorize level of design for the elementary classroom. *Journal of Technology Education*, *26*(2), 22–45.

National Professional Teachers' Organisation of South Africa. (2018). *CAPS Review: Technology*. https://www.naptosa.org.za/professional/professional-archived

Neuman, K. E. 2003. The importance of redesign. *Technology Teacher, 63*(3), 7-9.

Nieuwenhuis, J. (2016). Analysing qualitative data. In K. Maree (Ed.), *First Steps in Research* (2nd ed., pp. 104–131). Van Schaik.

Patton, M. Q. (1990). *Qualitative Evaluation and Research Methods* (2nd ed., p. 169). SAGE Publications.

Patton M. Q. (2002). *Qualitative research and evaluation methods*. 3rd edition. Sage Publications.

Patton, M. Q. (2015). *Qualitative Research and Evaluation Methods* (4th ed.). SAGE Publication.

Pokorny, H., & Pickford, P. (2010). Complexity, cues and relationships: Student perceptions of feedback. *Active Learning in Higher Education*, *11*(1), 21–30.

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.

Rauscher, W. (2016). A Philosophical Framework for Enhancing the Understanding of Artefacts in the Technology Classroom. *African Journal of Research in Mathematics, Science and Technology Education*, *20*(3), 214–224. https://doi.org/https://doi.org/10.1080/18117295.2016.1215959

Reitzma, G., & Mentz, E. (2009). In-service training for technology teachers: A needs assessment. *African Journal of Research in Mathematics, Science and Technology Education*, *13*(2), 15–29.

Ritchie, J., Lewis, J., Elam, G., Tennant, R., & Rahim, N. Qualitative Research Practice: A guide for social science students and researchers. In J. Ritchie, J. Lewis, C. McNaughton Nicolls & R. Ormston (Eds.), *Qualitative Research Practice* (2014). SAGE Publication.

Royo, M., Mulet, E., Chulvi, V., & Felip, F. (2021). Guiding questions for increasing the generation of product ideas to meet changing needs (QuChaNe). *Research in Engineering Design*. https://doi.org/10.1007/s00163-021-00364-x

Rule, P., & John, V. (2011). *Your guide to case study research*. (I. Holtzhausen de Beer, Ed.) (1st ed.). Van Schaik Publishers.

Sanders, M. (2008). The nature of Technology Education in the U.S. In *American Society for Engineering Education Annual Conference and Exposition* (pp. 16845–16869). American Society for Engineering Education.

Sawyer, R. K. (2004). Improvised lessons: Collaborative discussion in the constructivist classroom. *Teaching Education*, *15*(2), 189–201.

Schurink, W., Fouché, C., & De Vos, A. (2011). Research at Grass roots: For the Social Sciences and Human Service Professionals. In J. Read (Ed.), *Research at grass roots* (4th ed.). Van Schaik Publishers.

Schut, A., & Blom, N. (2019). Exploring the nature of young learners' convergent thinking during designing. *Conference: PATT 37- Developing a knowledge economy through technology and engineering education*. Malta.

Schut, A., Klapwijk, R., & Gielen, M. (2018). Effects of Convergent and Divergent

Feedback on Creative Thinking During Children's Design Processes. In N. Seery, J. Buckley, D. Canty & J. Phelan (Eds.), *2018 PATT36 International Conference: Research and Practice in Technology Education: Perspectives on Human Capacity and Development* (pp. 506–512). Delft University of Technology.

Schut, A., Van Mechelen, M., Gielen, M., & de Vries, M. J. (2020). Towards constructive design feedback dialogues: guiding peer and client feedback to simulate children's creative thinking. *International Journal of Technology and Design Education* (2020). https://doi.org/https://doi.org/10.1007/s10798-020-09612-y

Schut, A., Van Mechelen, M., Klapwijk, R., Gielen, M., & De Vries, M. J. (2021). Design Feedback that Stimulates Children's Creative Thinking: A Feedback Intervention. *Techne Serien-Forskning i Slöjdpedagogik Och Slöjdvetenskap*, *28*(2), 128–139. https://doi.org/https://orcid.org/0000-0002-1802-7135

Shah, J.J, Klukarni, S., & Vargas-Hernandez, N. (2000). Evaluation of idea generation mthods for conceptua design: effectiveness metrics and design of experiments. *Journal of Mechanical Design*, *122*(4), 377–384.

Shah, J. J, Smith, S., & Vargas-Hernandez, N. (2003). Metrics for measuring ideation effectiveness. *Design Studies*, *24*(2), 111–134.

Shute, V. J. (2008). Focus on formative feedback. *Review of Educational Research*, *78*(1), 153–189.

Smith, J. K., & Lipnevich, A. A. (2009). Formative assessment in higher education: frequency and consequence." In G. A. D. L. D. M. McInerney & G. T. L. Brown (Ed.), *Student Perspectives on Assessment: What Students Can Tell Us About Assessment for Learning* (pp. 279–295). Information Age Publishing.

Stables, K. (2017a). Talking with Avatars: The potential and impact of design dialogue with an on-screen avator on the developent of learner's design and technology project work. In S. Warner & L. Litowitz (Eds.), *PATT2017: Technology & Engineering Education- Fostering the creativity of youth around the globe* (pp. 1–13). Philadelphia PATT.

Stables, K. (2017b). Use of Portfolio for Assessment in Design and Technology Education. In M. J. de Vries (Ed.), *Handbook of Technology Eduction* (pp. 749–763). Springer.

Stables, K., Kimble, R., Wheeler, T., & Derrick, K. (2016). Lighting the blue touch paper: Design talk that provokes learners to thinkin more deeply and broadly about their project work. In *PATT 32: Technology Education for 21st Century Skills* (pp. 1–13). Utrecht, Netherlands.

Stake, R. E. (1995). *The Art of Case Study Research*. SAGE Publication.

Stake, R. E. (2006). *Multiple Case Study Analysis* (EPUB). The Guilford Press.

Strong, A. C., Lande, M., & Adams, R. (2019). Teaching Without a Net: Mindful Design Education. In D. Schafer, G. Coates & C. Eckert (Eds.), *Design Education today: Technical contexts, programs and best practices* (pp. 1–22). Springer.

Studer J. A., Daly, S. D., & McKilligan S., & Seifert, C. M. (2018). Evidence of problem exploration in creative designs. *Artificial Intelligence for Engineering Design, Analysis and Manufacturing*, *32*(special issue 4), 415–430. https://doi.org/https://doi.org/10.1017/S0890060418000124

Swathi, R., Fox-Turnbull, W. H., Earl-Rinehart, K., & Clader, N. (2020). Development of formative assessment tool for a primary, technology classroom. *Design And Technology Education: An International Journal*, *25*(2), 101–116. https://ojs.lboro.ac.uk/DATE/article/view/2763

Tawfik, A. A., Graesser, A., Gatewood, J., & Gishbaugher, J. (2020). Role of questions in inquiry-based instruction: towards a design taxonomy for question-asking and implications for design. *Educational Technology Research Development*, *68*(April 2020), 653–678.

Terre Blanche, M., & Durrheim, K. (Eds.) (1999). *Research in Practice: Applied Methods for the Social Studies*. The University of Cape Town.

Terry, G., Hayfield, N., Clarke, V., & Braun, V. (2017). *The SAGE Handbook of Qualitative Research in Psychology*. SAGE Publications Ltd.

Thompson, M., & Wiliam, D. (2008). Tight but loose: scaling up teacher professional development in diverse contexts. In *ETS Research Report Series* (Vol. 2008, pp. i–141). https://doi.org/10.1002/j.2333-8504.2008.tb02115.x

van den Bergh, L., Ros, A., & Beijaard, D. (2013). Teacher feedback during active learning: Current practices in primary schools. *British Journal of Educational Pshychology*, *83*, 341–362. http://web.b.ebscohost.com.uplib.idm.oclc.org/ehost/pdfviewer/pdfviewer?vid=1&sid=738b917e-6f7c-4f2c-89f7-782d16a789bc%40pdc-v-sessmgr05

van Niekerk, E., Ankiewics, P., & de Swart, E. (2010). A process-based assessment framework for technology education: a case study. *International Journal of Technology and Design Education*, *20*, 191–215. https://doi.org/10.1007/s10798-008-9070-8

Visser, W. (2009). Design: one, but in different forms. *Design Studies*, *30*(2009), 187–223.

Wiliam, D., & Thompson, M. (2007). Tight but Loose: A Conceptual Framework for Scaling Up School Reforms. In E. C. Wylie (ed.), *Tight but Loose: Scaling Up Teacher Professional Development in Diverse Contexts*. Educational Testing Service (ETS).

Wiliam, D. (2019). *Embedded formative assessment: (strategies for classroom assessment that drives student engagement and learning).* Solution Tree.

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The Power of Feedback Revisited: A Meta-Analysis of Educational Feedback Research. *Frontiers in Psychology*, *10*, 3087. https://doi.org/10.3389/fpsyg.2019.03087

Yazan, B. (2015). Three approaches to case study methods in Education: Yin, Merriam and Stake. *The Qualitative Report*, *20*(2), 134–152. http://www.nova.edu/ssss/QR/QR20/2/yazan1.pdf

Yilmaz, S., & Daly, S. R. (2014a). Influences of feedback interventions on student concept generation and development practices. *Design Thinking Research Symposium 2014* (pp. 1–23). Purdue University.

Yilmaz, S., & Daly, S. R. (2014b). Influences of feedback interventions on student concept generation and development practices. *DTRS 10: Design Thinking Research Symposium*. Perdue University Press.

Yilmaz, S., & Daly, S. R. (2016). Directing Convergent and Divergent Activity Through Design Feedback. In R. Adams & J. Saddiqui (Eds.), *Analyzing Design Review Conversations* (pp. 413–429). Perdue University Press.

Yin, R. K. (2014). *Case Study Research*. (V. Knight, Ed.) (5th ed.). Sage.

Yin, R. K. (2015). *Qualitative research from start to finish, second edition.* ProQuest Ebook Central. https://ebookcentral-proquest-com.uplib.idm.oclc.org

Yin, R. K. (2018). *Case study research: design and Methods* (6th ed.). Sage.

APPENDIX A-PERMISSION TO CONDUCT RESEARCH

A1-GDE permission

A2- Permission from District director

A3- Permission from School principal

A4-Permission from School Governing Body

A1 - GAUTENG DEPARTMENT OF EDUCATION PERMISSION

GAUTENG PROVINCE
Department: Education
REPUBLIC OF SOUTH AFRICA

8/4/4/1/2

GDE AMENDED RESEARCH APPROVAL LETTER

Date:	30 October 2019
Validity of Research Approval:	10 February 2020 – 30 September 2020 2019/202A
Name of Researcher:	Loubser N
Address of Researcher:	326 Starling Road
	Eldoraigne
	Centurion, 0157
Telephone Number:	074 619 3003
Email address:	nele.loubser@up.ac.za
Research Topic:	The effect of teacher feedback during the design process.
Type of qualification	Masters' in Education
Number and type of schools:	One Primary School and Four Secondary Schools
District/s/HO	Gauteng East, Gauteng West, Tshwane North, Tshwane West, Johannesburg Central, Johannesburg North, Johannesburg West and Tshwane South.

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

The following conditions apply to GDE research. The researcher may proceed with the above study subject to the conditions listed below being met. Approval may be withdrawn should any of the conditions listed below be flouted:

31/10/2019

1

Making education a societal priority

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

1. *Letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*
4. *A letter / document that outline the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year. If incomplete, an amended Research Approval letter may be requested to conduct research in the following year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher/s must supply the Director: Knowledge Management & Research with one Hard Cover bound and an electronic copy of the research.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

.....

Mr Gumani Mukatuni
Acting CES: Education Research and Knowledge Management

DATE: 31/10/2019

Office of the Director: Education Research and Knowledge Management
7th Floor, 17 Simmonds Street, Johannesburg, 2001
Tel: (011) 355 0488
Email: Faith.Tshabalala@gauteng.gov.za
Website: www.education.gpg.gov.za

A2 - PERMISSION FROM DISTRICT DIRECTOR

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

[redacted]

LETTER OF NOTIFICATION: DISTRICT DIRECTOR

Dear (District Director Name)

I am a MEd student studying through the University of Pretoria and would like to ask your permission to collect data at a school(s) in your district for a research project titled: *The effect of teachers' feedback during the design process.*

The purpose of this study is to explore how technology teachers use feedback to facilitate learners' thinking during the early phases of the design process. In order to do this the researcher will contact and arrange an information session with principals at their school to explain the nature of this study where they will be invited to participate. The information session will take place at the school at a time that is convenient for the principal.

Based on this, the researcher will arrange an information session with teachers to explain the nature of this study where they will be invited to participate. This information session will be held in the teachers' usual technology classroom during a time that is convenient to the principal and teacher and that does not interfere with teaching and learning activities or other school activities. To participate in this study, each Technology teacher will be invited for an interview of 30 minutes which will be audio recorded. This interview will be used to collect information that might establish technology teachers' prior teaching experience and their views of feedback during the design process.

Based on this information, the researcher may ask the selected teacher to further participate in this study by allowing me to video record and observe a design problem solving lesson of the teachers and technology learners. The video recording will take place during Term 1 2020, during school hours in the teacher's usual Technology classroom at a time which will suit the school, teachers and the learners and will not interfere with teaching and learning activities or other school activities. The teacher will be requested to wear a Go-Pro head mounted camera during the lesson in order to make a micro recording of the teacher's feedback during the lesson. A camera technician will make a macro recording from the back of the classroom. These video recordings are necessary because the researcher aims to establish how, when and on what teachers give feedback.

Room 1-14 Technika Building, -
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)74 619 3003
Fax +27 (0)12 420 5621
Email nele.loubser@up.ac.za
www.up.ac.za

Learners who do not give assent and/or whose parents/guardians do not give consent will be placed strategically in the classroom and the recordings of interactions between the teacher and these learners will be limited as far as possible. Furthermore, footage collected using the Go-Pro camera and video camera of the learners who do not give assent and/or whose parents/guardians who do not give consent will not be considered for the data analysis and dissemination of this study.

In a final data generation activity, the researcher may ask the teacher to review selected segments of recorded data of their feedback during the lesson and comment on their identified feedback behavior. The purpose of this is to investigate how teachers reason about their own feedback behavior. This study will not attempt to evaluate the quality of the teachers' feedback behavior but aims to identify what and how teachers are reasoning when giving feedback during designing.

The results of this study may be presented at conferences or published in scientific journals. On completion of the study the researcher will supply the Director of Knowledge Management & Research with one electronic copy of the research. If it is required, the researcher will be available to provide short presentations on the purpose, findings and recommendations of her research to both GDE officials and the school concerned.

The principal, teacher, parents and learners will be provided with letters that will elicit their informed consent and the researcher will only commence with data gathering once all these have been granted. The interview transcripts, interview notes, observation notes and video recordings will only be used for research purposes and the content will remain confidential.

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the school and identities of the participants will be treated confidentially, and will not be disclosed.
2. The video recordings, observation notes, interview transcripts and interview notes will be treated confidentially. Only the researcher (Miss Nelé Loubser) and the supervisor (Dr. Nicolaas Blom) will have access to the interview notes, observation notes, video and audio recordings and the transcribed data.
3. If stills from the video recordings should be used in publications or public presentations, the researcher will ensure that participants' faces and school uniforms will be unrecognizable and censored.
4. Only the researcher (Miss Nelé Loubser) will know the real identity of the teacher and learners that agree to participate in the study.
5. Pseudonyms for schools, the teacher and learners will be used in all spoken and written reports.
6. The information provided by the teacher and learners will be used for academic purposes only.
7. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
8. The teachers and learners will not be exposed to acts of deception at any point in the research study.
9. The teachers and learners will not be placed at risk of any kind.
10. No incentives will be offered to any of the research participants.
11. The videographer involved in the research study will be trained in all matters of ethics, and in particular, confidentiality and anonymity.

Room 1-14 Technika Building, -
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)74 619 3003
Fax +27 (0)12 420 5621
Email nele.loubser@up.ac.za
www.up.ac.za

The Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or his supervisor.

Your support in this matter will be appreciated.

Miss Nelé Loubser
074 619 3003
nele.loubser@up.ac.za

Dr. Nicolaas Blom (supervisor)
(012) 420 2771
nicolaas.blom@up.ac.za

A3 - PERMISSION FROM SCHOOL PRINCIPAL

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

LETTER OF PERMISSION: PRINCIPAL

Dear Principal,

I am a MEd student studying through the University of Pretoria and would like to collect data at your school for a research project titled: *The effect of teachers' feedback during the design process.*

The purpose of this study is to explore how technology teachers use feedback to facilitate learners' thinking during the early phases of the design process. I will arrange an information session with teachers to explain the nature of this study where they will be invited to participate. This information session will be held in the teachers' usual technology classroom during a time that is convenient to you and the teacher and that does not interfere with normal teaching and learning activities or other school activities. To participate in this study, a Technology teacher will be invited for an interview of 30 minutes in order to collect information regarding their views of feedback during the design process. These interviews will completed during Term 3 2019 in the teacher's technology classroom during a time that is convenient to you and the teacher and will not interfere with teacher and learning activities or other school activities.

Based on this information, I will may the selected teacher to further participate in this study by allowing me to video record and observe a design problem solving lesson of the teacher and technology learners. The video recording will take place during Term 1 2020, during school hours in the teachers' usual Technology classroom at a time that will suit the school, teachers and the learners. The teacher will be requested to wear a Go-Pro head mounted during the lesson in order to make a micro recording of the teacher's feedback during the lesson. A camera technician will make a macro recording of the lesson from the back of the classroom. These video recordings are necessary because I want to establish how, when and on what teachers give feedback. Learners who do not give assent/consent will be placed strategically, with the help of the teacher, to limit the recording of teacher-learner interactions as far as possible. Footage collected using the Go-Pro camera of the learners who do not give assent/consent will not be considered for the data dissemination of this study.

In a final data generation activity, I may ask the teacher to review selected segments of the recorded data of their feedback behavior and comment on their identified feedback behavior. The purpose of this is to investigate how teachers reason about their own feedback behavior. This study will not attempt to evaluate the quality of the teacher's feedback behavior, evaluate the quality of learners' design solutions or give marks

Room 1-14 Technika Building, -
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)74 619 3003
Fax +27 (0)12 420 5621
Email nele.loubser@up.ac.za
www.up.ac.za

for learners' problem-solving abilities, but aims to identify what and how teachers are reasoning when giving feeding during designing.

The results of this study may be presented at conferences or published in scientific journals. On completion of the study the researcher will supply the Director of Knowledge Management & Research with one electronic copy of the research.

If it is required, the researcher will be available to provide short presentations on the purpose, findings and recommendations of his research to both GDE officials and the school concerned.

The teacher, parents and learners will be provided with letters that will elicit their informed consent and the researcher will only commence with data gathering once all these have been granted. The questionnaires, interview transcripts and video recording will only be used for research purposes and the content will remain confidential.

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the school and identities of the participants will be treated confidentially, and will not be disclosed.
2. The video recording, interview transcripts and interview notes will be treated confidentially. Only the researcher (Miss. Nelé Loubser) and the supervisor (Dr. Nicolaas Blom) will have access to the video recordings, questionnaires and the transcribed data.
3. If stills from the video recordings should be used in publications or public presentations, the researcher will ensure that participants' faces and school uniforms will be unrecognizable and censored.
4. Only the researcher (Miss. Nelé Loubser) will know the real identity of the teacher and learners that agree to participate in the study.
5. Pseudonyms for schools, the teacher and learners will be used in all spoken and written reports.
6. The information provided by the teacher and learners will be used for academic purposes only.
7. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
8. The teachers and learners will not be exposed to acts of deception at any point in the research study.
9. The teachers and learners will not be placed at risk of any kind.
10. No incentives will be offered to any of the research participants.
11. The videographer involved in the research study will be trained in all matters of ethics, and in particular, confidentiality and anonymity.

The Gauteng Department of Education, the Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or his supervisor.

Your support in this matter will be appreciated.

Miss. Nelé Loubser
074 619 3003
nele.loubser@up.ac.za

Dr. Nicolaas Blom (supervisor)
(012) 420 2771
nicolaas.blom@up.ac.za

Should you agree to participate in the study under the above stated terms, please fill in the details on the next page:

I, _____(your name only), agree to take part in the research project titled, *The effect of teachers' feedback during the design process.*

....
Signature Date

A4 - PERMISSION FROM SCHOOL GOVERNING BODY

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

Head of the SGB: (School Name)
Address line 1
Address line 2
Address line 3

LETTER OF NOTIFICATION: SGB

To whom it may concern,

I am a MEd student studying through the University of Pretoria and would like to collect data at your school for a research project titled: *The effect of teachers' feedback during the design process.*

The purpose of this study is to explore how technology teachers use feedback to facilitate learners' thinking during the early phases of the design process. To participate in this study, a Technology teacher will be invited to complete an interview, which will not last more than 30 minutes, regarding their views of feedback during the design process. These interviews will be conducted after school hours in the teachers' technology classroom and will not interfere with any teaching and learning activities or other school activities.

Based on this information, I may ask the teacher to further participate in this study by allowing me to video record and observe a design problem solving lesson the teachers and technology learners. The video recording will take place during Term 1 2020, during school hours in the teacher' usual Technology classroom at a time which will suit the school, teachers and the learners. The teacher will be requested to wear a Go-Pro head mounted camera in order to make a micro recording of their feedback during the lesson. A camera technician will make a macro recording of the lesson from the back of the classroom. These video recordings are necessary because I want to establish how, when and on what teachers give feedback in a technology learning environment. Learners who do not give assent/consent will be placed strategically, with the help of the teacher, in order to limit the recording of teacher-learner interactions as far as possible. Footage collected using the Go-pro camera of the learners who do not give assent or whose parents do not give consent will not be considered for the data dissemination of this study.

In a final data generation activity, the, I may ask the teacher to review selected segments of recorded data of their feedback during the lesson and comment on their identified feedback behavior. The purpose of this is to investigate how teachers' reason about their identified feedback behavior. This study will not attempt to evaluate the quality of the teachers' feedback behavior, evaluate the quality of learners' work or give marks for learners' problem-solving abilities, but aims to identify what and how teachers are reasoning when giving feedback during designing.

Room 1-14 Technika Building, -
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)74 619 3003
Fax +27 (0)12 420 5621
Email nele.loubser@up.ac.za
www.up.ac.za

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

The results of this study may be presented at conferences or published in scientific journals. On completion of the study the researcher will supply the Director of Knowledge Management & Research with one electronic copy of the research. If it is required, the researcher will be available to provide short presentations on the purpose, findings and recommendations of his research to both GDE officials and the school concerned.

The teacher, parents and learners will be provided with letters of informed consent and the researcher will only commence with data gathering once all these have been granted. The interview transcripts and video recording will only be used for research purposes and the content will remain confidential.

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the school and identities of the participants will be treated confidentially, and will not be disclosed.
2. The video recording, interview transcripts and interview notes will be treated confidentially. Only the researcher (Miss. Nelé Loubser) and the supervisor (Dr. Nicolaas Blom) will have access to the video recordings, questionnaires and the transcribed data.
3. If stills from the video recordings should be used in publications or public presentations, the researcher will ensure that participants' faces will be unrecognizable and censored.
4. Only the researcher (Miss. Nelé Loubser) will know the real identity of the teacher and learners that agree to participate in the study.
5. Pseudonyms for schools, the teacher and learners will be used in all spoken and written reports.
6. The information provided by the teacher and learners will be used for academic purposes only.
7. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
8. The teachers and learners will not be exposed to acts of deception at any point in the research study.
9. The teachers and learners will not be placed at risk of any kind.
10. No incentives will be offered to any of the research participants.
11. The videographer involved in the research study will be equally trained in all matters of ethics, and in particular, confidentiality.

The Gauteng Department of Education, the Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or his supervisor.

Your support in this matter will be appreciated.

Miss. Nelé Loubser
074 619 3003
nele.loubser@up.ac.za

Dr. Nicolaas Blom (supervisor)
(012) 420 2771
nicolaas.blom@up.ac.za

APPENDIX B - INFORMED CONSENT AND ASSENT

B1-Teacher consent form

B2- Parent consent form

B3- Learner assent form

B1 - TEACHER CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

LETTER OF INFORMED CONSENT: TEACHER

Dear Teacher,

I am a MEd student studying at the University of Pretoria and would like to collect data at your school for a research project titled: *The effect of teacher's feedback during the early phases of designing*.

The purpose of this study is to explore how technology teachers use feedback to facilitate learners' thinking during the early phases of the design process. As a technology teacher, you will be invited to an interview of 30 minutes in order to collect information that might establish your prior teaching experience and your views of feedback during the design process. These interviews will be completed in during Term 2 and 3 in your technology classroom during a time that is convenient to you and the principal and does not interfere with teaching and learning activities or other school activities.

Based on this information, I may ask you to further participate in this study by allowing me to video record and observe a design problem solving lesson of you and your technology learners. The video recording will take place during Term 2 or 3, during school hours in your usual Technology classroom at a time which will suit the you, the school and the learners. As part of the recording I will request that you wear a Go-Pro in order to make a micro recording of your feedback during the lesson. A camera technician will make a macro recording of the lesson from the back of the classroom. These video recording are necessary because I want to establish how, when and on what you give feedback in a technology learning environment. This means that I will examine how you ask different questions during different design activities to facilitate learners in solving design problems. You will be requested to help with placing learners who do not assent/consent to participating in this study in a strategic manner as to limit the recording of your interaction with these learners. Footage collected by your Go-Pro of the learners who do not give assent/consent will not be considered for the data dissemination of this study.

In a final data generation activity, I will ask you to review selected segments of recorded data of your feedback behavior and comment on your identified feedback behavior. The purpose of this is to investigate how you reason about your own feedback behavior. This study will not attempt to evaluate the quality of your feedback behavior, evaluate the quality of learners' work or give marks for learners' problem-solving abilities, but aims to identify what and how you are reasoning when giving feedback during designing.

The results of this study may be presented at conferences or published in scientific journals. On completion of the study, I will supply the Director of Knowledge Management & Research with one

Room 2-25, Natural Sciences Building,
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)12 420 2771
Fax +27 (0)12 420 5621
Email nicolaas.blom@up.ac.za
www.up.ac.za

electronic copy of the research. If it is required, I will be available to provide short presentations on the purpose, findings and recommendations of this research to both GDE officials and your school. The video recording will only be used for research purposes and the content will remain confidential.

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the school and identities of the participants will be treated confidentially, and will not be disclosed.
2. The video recording, interview transcripts and interview notes will be treated confidentially. Only the researcher (Miss. Nelé Loubser) and the supervisor (Dr. Nicolaas Blom) will have access to the video recordings, interview notes and the transcribed data.
3. If stills from the video recordings should be used in publications or public presentations, the researcher will ensure that participants' faces and school uniforms will be unrecognizable and censored.
4. Only the researcher (Miss. Nelé Loubser) will know the identity of the teacher and learners who agreed to participate in the study.
5. Pseudonyms for schools, the teacher and learners will be used in all spoken and written reports.
6. The information provided by the teacher and learners will be used for academic purposes only.
7. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
8. The teachers and learners will not be exposed to acts of deception at any point in the research study.
9. The teachers and learners will not be placed at risk of any kind.
10. No incentives will be offered to any of the research participants.
11. The videographer involved in the research study will be trained in all matters of ethics, and in particular, confidentiality and anonymity.

The Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or his supervisor.

Your support in this matter will be appreciated.

Miss. Nelé Loubser
074 619 3003
neleloubser@gmail.com

Dr. Nicolaas Blom (supervisor)
(012) 420 5631
Nicolaas.blom@up.ac.za

B2 - PARENT CONSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

LETTER OF INFORMED CONSENT: PARENTS

Dear Parent(s)/Guardian(s),

I am a MEd student studying at the University of Pretoria and would like to collect data at your child's school for a research project titled: *The effect of teachers' feedback during the design process.*

The purpose of this study is to explore how technology teachers use feedback to facilitate learners' thinking during the early phases of the design process. Your child's teacher was selected to participate in this study. I would appreciate it if you will allow me to video record and observe a design problem solving lesson of the teacher and your child. The video recording will take place during Term 1 2020, during school hours in your child's usual Technology classroom at a time which will suit the school, the teacher and the learners. The observation will not interfere with your child's teaching and learning activities or other school activities. The video recordings will be made by the teacher wearing a Go-Pro head mounted camera and a camera technician at the back of the class. These video recordings are necessary because I want to establish how, when and on what teachers give feedback.

The design task that your child will be engaged in will be a typical design activity posed in the Technology classroom which is appropriate for Grade 7-9 learners and which they should complete in a term The purpose of this study is to investigate how, when and on what teachers give feedback on during the design process and therefore will not attempt to evaluate the quality of feedback, the competencies of teachers, evaluate the quality of learners' design solutions or give marks for learners' problem solving abilities but aims to identify what and how teachers are reasoning when giving feedback during designing.

Learners who do not give assent/consent to participate in this study will remain in the classroom during the observation and recording but will be placed strategically, with the help of the teacher, to limit the recoding of interactions between the teacher and such learners. Footage collected using the Go-Pro camera of learners who do not give assent or who's parents do not give consent to participate will not be considered during the data dissemination of this study.

The results of this study may be presented at conferences or published in scientific journals. On completion of the study, I will supply the Director of Knowledge Management & Research at the Gauteng Department of Education with one electronic copy of the research. If it is required, I will be available to provide short presentations on the purpose, findings and recommendations of this research to both GDE officials and your school. The video recordings will only be used for research purposes and the content will remain confidential.

Room 1-14 Technika Building, -
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)74 619 3003
Fax +27 (0)12 420 5621
Email nele.loubser@up.ac.za
www.up.ac.za

Faculty of Education
Fakulteit Opvoedkunde
Lefapha la Thuto

Participation is subject to the Ethics Committee of the Faculty of Education at the University of Pretoria's regulations, and the following will apply:

1. The names of the school and identities of the participants will be treated confidentially, and will not be disclosed.
2. The video recording, interview transcripts and interview notes will be treated confidentially. Only the researcher (Miss. Nelé Loubser) and the supervisor (Dr. Nicolaas Blom) will have access to the video recordings, interview notes and the transcribed data.
3. If stills from the video recordings should be used in publications or public presentations, the researcher will ensure that participants' faces and school uniforms will be unrecognizable and censored.
4. Only the researcher (Miss. Nelé Loubser) will know the identity of the teacher and learners who agreed to participate in the study.
5. Pseudonyms for schools, the teacher and learners will be used in all spoken and written reports.
6. The information provided by the teacher and learners will be used for academic purposes only.
7. Participation in this project is entirely voluntary. Participants have the right to withdraw at any time, and without any prejudice.
8. The teachers and learners will not be exposed to acts of deception at any point in the research study.
9. The teachers and learners will not be placed at risk of any kind.
10. No incentives will be offered to any of the research participants.
11. The videographer involved in the research study will be trained in all matters of ethics, and in particular, confidentiality and anonymity.

The Faculty of Education and the Ethics Committee at the University of Pretoria have approved this study. For any further queries, you are more than welcome to contact the researcher or his supervisor.

Your support in this matter will be appreciated.

Miss. Nelé Loubser
074 619 3003
nele.loubser@up.ac.za

Dr. Nicolaas Blom (supervisor)
(012) 420 2771
nicolaas.blom@up.ac.za

Should you agree to participate in the study under the above stated terms, please fill in the details below. Should I not receive the signed consent form by 5 February 2020, consent will be assumed.

I, _____(your name only), agree that my child may take part in the research project titled, *The effect of teachers' feedback during the design process.*

....
Signature Date

B3 - LEARNER ASSENT FORM

UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
YUNIBESITHI YA PRETORIA

Faculty of Education

FACULTY OF EDUCATION
DEPARTMENT OF SCIENCE, MATHEMATICS AND TECHNOLOGY EDUCATION
Groenkloof Campus
Pretoria 0002
Republic of South Africa
Tel: +27 12 420 –5572
Fax: +27 12 420-5621
http://www.up.ac.za
29 January 2020

LETTER OF INFORMED ASSENT: LEARNERS

Dear Learner

Why am I here?

Sometimes when we want to find out something, we ask people to join something called a project. What you are taught in your class and how your teacher teaches it is often based on research. To continue to improve on what you are taught and how you are taught, there are research projects to look at what happens in a typical classroom. This is such a research project. In this project I shall ask you to do an activity which is focused on your own development and learning. Before I ask you to be part of this study, I want to tell you more about it first.

This project will give me a chance to look at different ways that your teacher helps you when you solve design and technology problems. This will help me to train future technology teachers on how to better teach design problem solving.

What will happen to me?

If you will be part of my study, you will be video recorded during school in your usual Technology classroom during a design and technology activity, while your teacher, I and a camera technician will be in the classroom. Your teacher will ask you to complete a fun activity in which you will investigate and solve a problem. There will be no right or wrong answers, only what you feel is best. You can ask your teacher to remind you of previous work that you have done as well. I will not use your name on the recording or in any report. The recording will only be used for me to check what you have said (like notes), so there is no need to worry about what others may think about you or how you might look or act in the class, since the recording will not be shown to anyone (except your teacher, the camera person and my teacher). If you do not want to say anything about the activity, you do not need to.

Room 2-25, Natural Sciences Building,
Groenkloof Campus, University of
Pretoria, c/o Leyds and George Storrar
street, Groenkloof 0181
Tel +27 (0)12 420 2771
Fax +27 (0)12 420 5621
Email nicolaas.blom@up.ac.za
www.up.ac.za

Will the project help me?

This project might help you to improve your thinking skills during design projects, but this project is a bit like cleaning up a river, building houses in poor areas, or protecting rhinos; it will not necessarily help you immediately, but it may help to improve how technology is taught in future. I do hope that this project will be fun and help you to feel good about yourself and learn more about what you can do in school.

What if I have any questions?

You can ask your teacher any questions you have about this project. If you have questions later that you do not think of now you can phone Ms. Nelé Loubser on 074 619 3003, or you can ask her next time you see her at school.

Do my parents/guardians know about this project?

This project was explained to your parents/guardians in a letter, and they agreed that you could be part of the project if you want to. You can talk this over with them before you decide if you want to be in this project or not.

Do I have to be in the project?

You do not have to be in this project if you do not want to. No one will be upset if you do not want to participate. You will not lose any marks for technology if you do not participate. If you do not want to be in the project, you just have to tell us. You can say yes or no and if you change your mind later, you do not have to be part of the project anymore. It is up to you.

Writing your name on this page means that you agree to be in the project and that you know what will happen when we do the project. If you decide to quit the project at any time, all you have to do is tell me or your teacher.

....

Signature of the learner **Date**

....

Signature of the researcher **Date**

....

Signature of the supervisor **Date**

APPENDIX C - DATA COLLECTION PROCEDURES

C1- Design tasks

C2- Interview protocol for initial interviews

C3- Observation schedule

C4- Interview protocol for follow up interviews

C1 - DESIGN BRIEFS

The design briefs each participant facilitated is presented here. The full design task document including the assessment activities can be accessed on the memory stick.

Participant 1 Design brief

OVERWATER BUNGALOW (MINI-PAT)

DUE DATE: _____ FEBRUARY 2020 **TOTAL MARKS: 100 MARKS**

Individual work

Project brief

The Island Resort® in Dubai has approached you about designing an "Overwater bungalow". The bungalow must be designed to **extend over the ocean** with a **bridge** extending to the bungalow from the shore. The bungalow must be a **2 bedroom building** with **outside decking** no bigger than 100m² (all included). The **framework** below the bungalow must be 5m high (3m in the water).

The Island Resort® would like to see the following:

- Research
- 3 designs
- Final design
- Model build
- Evaluate

http://www.tahiti.com/hotels/vahine-island-private-resort-2988 (2016/04/24)

Projected time allocation:

	Number of periods
Research & Design brief	Homework
3 different designs	4
Final design	2
Cost calculations & Evaluation	2
TOTAL	8

Name:_____ **Grade:**_____

Participant 2 Design brief

Content: Frame structure with mechanisms

Context: Amusement park rides

A large shopping centre is planned near the place where you live. Your community wants a safe recreation area to be build next to the shopping centre. People's suggestions for the recreation are:

- an obstacle course that promotes fitness,
- a skate park
- a play park
- an amusement park

Amusement park
A collection of rides built to entertain a large group of people.

Before the local authorities approach the developers, they need to gather information about the wants and needs of the young people in the community. They have asked high schools for their learners inputs.

The headmaster of your school has asked the Grade 8 learners to suggest ideas on safety for the play areas and to develop models for the amusement park rides. He approached the Technology teacher for assistance. The Grade 8's need to design and make models for rides suitable for the amusement park. The rides need to include a frame structure as well as a mechanism.

Participant 3 Design brief

ONTWERP EN BOU 'N RAAMSTRUKTUUR.

Baie landelike gemeenskappe in Suid Afrika ervaar droogtes. Dit is noodsaaklik om ekstra reserwes te hê. Water is gewoonlik by boorgate of putte beskikbaar, maar die nodige meganismes en strukture om dit na die oppervlak te pomp vir gebruik is duur. Mense hou gewoonlik reservoirs bo-op strukture sodat 'n pomp meganisme nie nodig is nie.

Jy moet 'n raamstruktuur ontwerp wat 'n tenk/reservoir kan behou. Jy moet gaan navorsing doen oor strukture en die beste en goedkoopste opsie kies.

Participant 4 Design brief

Scenario: Voetganger brug

'n Stroompie in die Drakensberge wat gewoonlik vlak is kom tydens die somer maande af in vloed as gevolg van donderstorms in die naby geleë berge.

Die stroompie lê tussen 'n plaaslike gemeenskap en 'n dorpie waar daar ook 'n skooltjie is, dus moet laerskool leerders ook hierdie stroompie daagliks oorsteek.

Daar het al leerders verdrink en dit word gesien as 'n uiters gevaarlike taak om oor hierdie stroompie te beweeg.

Jou taak gaan wees om deur die voorgeskrewe stappe te werk en 'n brug te ontwerp om die gemeenskap te help om die stroompie oor te steek reg deur die jaar.

Belangrik:

1. **Punte A, B, C, D, E** moet in 'n *flipfile* gesit word om geassesseer te word.
2. **Punt G** moet op 'n geheue stokkie geplaas word en saamgebring word om op die klas se rekenaar behandel word.
3. Die groepleier se verantwoordelikheid is om die groep se verantwoordelikhede te delegeer.
4. Indien leerders nie saamwerk nie moet dit vroegtydig onder die personeel se aandag gebring word.
5. GEEN VERSKONINGS WORD AANVAAR OP DIE DAG VAN INHANDIGING NIE.
6. Die taak sal gemerk word volgens die rubriek wat aangeheg word.
7. Hierdie aanbieding mag **nie langer as 3min wees nie.**

Groepleier: _____

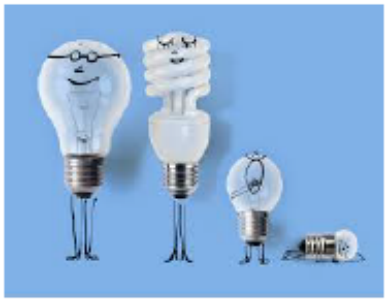
Groeplede: _____ _____

_____ _____

_____ _____

Participant 5 Design brief

DESIGN BRIEF



A light bulb company wants to extend their product range by minimising packaging waste. The company decides to develop a new range of light-bulb packaging that transforms into interesting light features. You are tasked with designing a package that will satisfy their want.

Take note of the following:

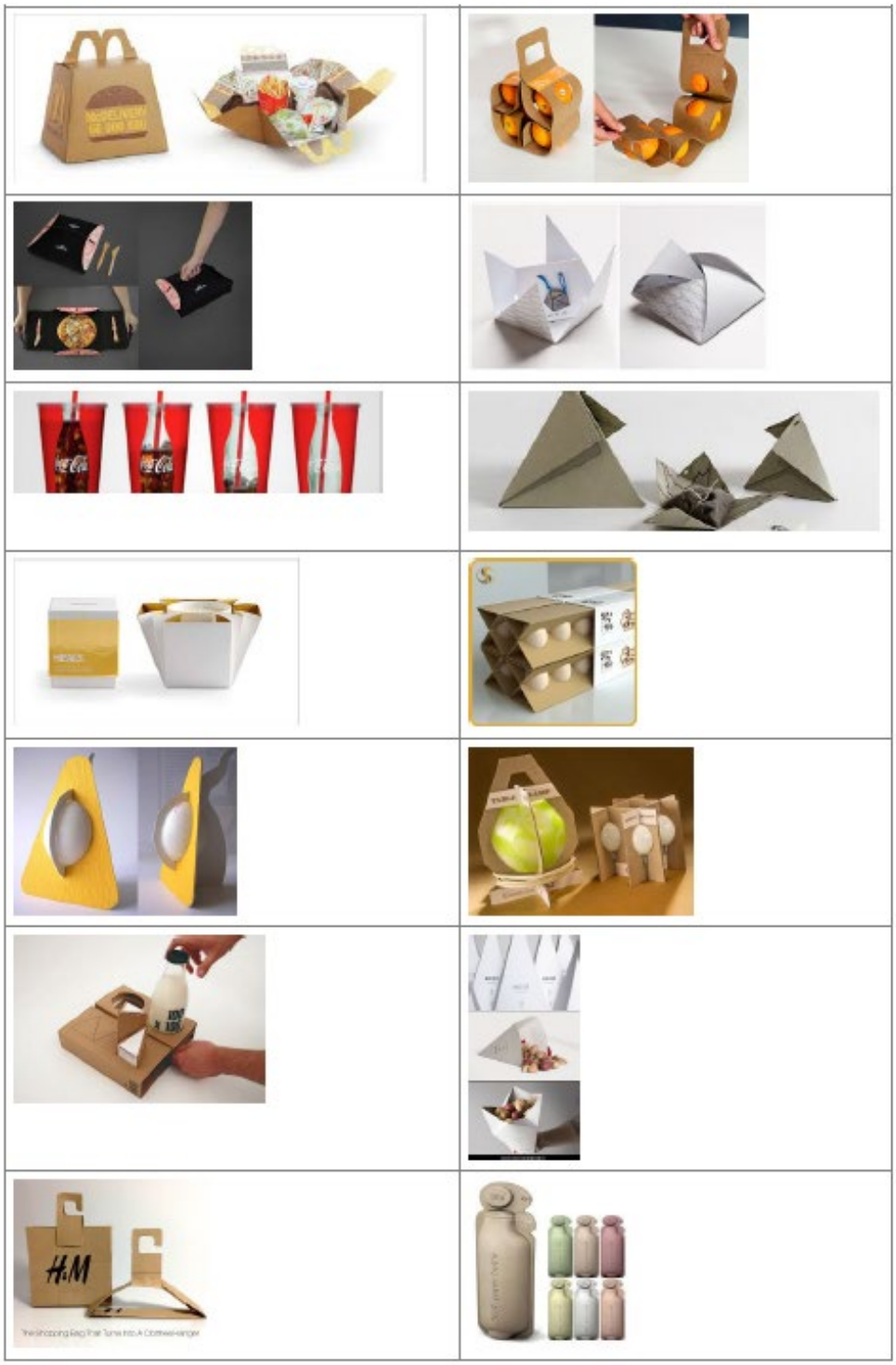
- Bulbs come in different shapes and sizes
- The packaging needs to contain and protect the bulb
- The light feature can be used in any context of your choice (a nursery, a fish tank, a waiting room, a party, a garden etc.)

Types of light bulbs:

Consider the following:

- Where will you design be used?
- Who are your intended clients?
- What are the important things to know and find out to ensure that your ideas are viable?
- Brainstorm design ideas
- Consider the promising and problematic aspects of your ideas

Inspiration:



(Kimbell, 2007)

C2 - INTERVIEW PROTOCOL FOR INITIAL INTERVIEWS

The interview protocol for the initial interviews is presented here. The interview transcripts can be accessed on a memory stick.

Semi-structured Interview

- The interview is planned to take about 45 minutes
- Permission will be asked to record the interview
- Participants are reassured of their anonymity
- I will briefly explain the topic and focus of the study
- There are no right or wrong answers. I am asking for your views and opinions.

Phase 1: Greeting

Good afternoon _____(teacher name), thank you for allowing me to interview you. The purpose of this interview is for me to learn more about your experience as a technology teacher and to find out what strategies you use in your technology classroom. In particular, I am interested in how you use feedback to facilitate problem-solving during the design process. This study does not attempt to comment or evaluate the effectiveness of your feedback behaviour, I am only interested in which strategies you use and how you reason about feedback during the design process.

There are no right or wrong answers, and if you feel uncomfortable answering a question you are allowed to decline to answer. No one other than myself and your school principal will know your identity. This interview will not be discussed with anyone other than my supervisor.

This interview consists of 5 phases, phase 1 welcoming, phase 2 demographics, phase 3 questioning as feedback during design, phase 4 your views on feedback during design and phase 5 salutation.

I would like your permission to make an audio recording of this interview for me to refer back to, should I require additional information not contained in my interview notes.

Permission to audio record interview ☐ **Yes** ☐ **No**

Interview Start : **Interview End :**

Phase 2: Demographics

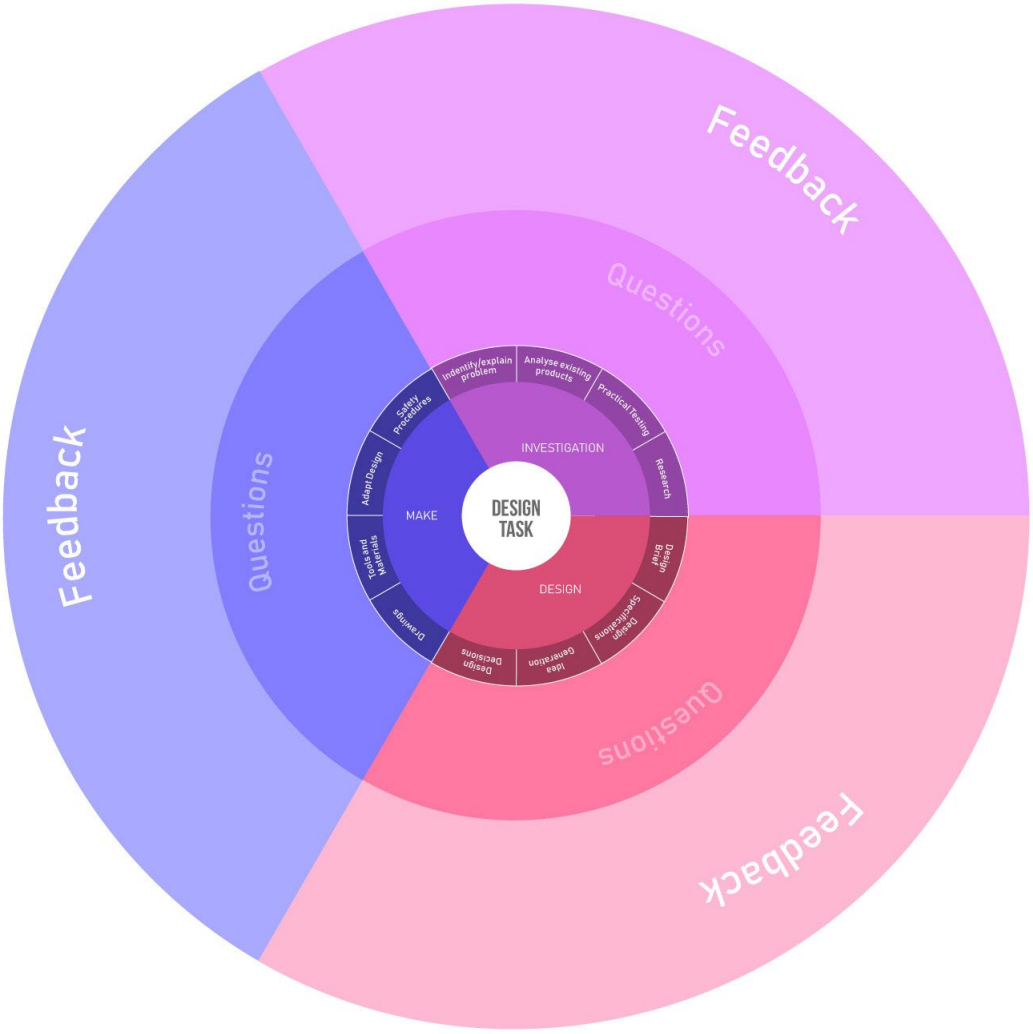
As a teacher, you are the main focus and participant in my study. I am going to ask you a series of questions related to your previous and current teaching experience as well as work experience other than teaching.

1. Which subject do you teach (including technology)?
2. What grades do teach?
3. How long have you been teaching this subject and grades?
4. Do you have any design-related experience outside of the classroom? If yes, please elaborate.
5. What is your highest qualification (in teaching, design, or both)?

Phase 3: Questioning as feedback during the design process

As the focus of my study is on feedback during the design process, I am going to ask you a series of questions related to your use of questions and feedback during the design process. What is the focus of your questions during the design process? For instance, do you focus on problems, promising aspects, form, and value?

6. Are your questions typically directed at specific groups or the class as a whole? (Explain).
7. When a learner asks you a question during a design activity, how do you usually respond? Please explain.
8. Do you plan what questions are going to ask during the design process? If yes, please explain how you plan your questions.
9. How do you know which questions to ask during the design process?
10. Please consider the following diagram and give examples of questions you would typically ask during each of the design activities?
    a. Investigation
        i. Identify/explain problem
        ii. Analyse existing products
        iii. Practical testing
        iv. Research
    b. Design
        i. Design brief
        ii. Design specifications
        iii. Idea generation
        iv. Design decisions



Phase 4: Views on Feedback

In this phase, I am going to ask you a series of questions related to your views on feedback during design. This does not only refer to questions but can also be comments or non-verbal cues such as gestures.

11. How often do you give feedback during the design process?
12. Do you give feedback to learners individually, in groups, or to the whole class? (explain).
13. Explain your typical feedback procedure?
14. How do you know if your feedback is effective?
15. What do you typically give feedback on during the design process?
16. Do you think feedback is a necessary part of the design process? (Explain).
17. How do you know how to give feedback?

Phase 5 Salutation

Thank you for taking the time to conduct this interview with me. Thank you for your valuable responses. I will contact you, should I require you to further participate in my study.

C2 - OBSERVATION SCHEDULE

The observation schedule for the observations is presented here. The video recordings of the observations and observation schedules can be accessed on the memory stick.

P	Structured observation	L

Teacher to learner																						
Learner to teacher																						
Investigation																						
Design																						
Question																						
Comment																						
Task																						
Process																						
Self																						
Self-Regulation																						

C3 - INTERVIEW PROTOCOL OF FOLLOW UP INTERVIEWS

The interview protocol for the follow-up interviews is presented here. The interview transcripts can be accessed on the memory stick.

Question 1:

What does it mean to provide support for learners during the design process?

For example, how do you use feedback to support learners' design processes?

Question 2:

Can you elaborate on how you can use questions and recommendations to support learners during the design process? More specifically, when learners are struggling?

Question 3:

When you ask questions and make recommendations on learners' design processes, do you stand in front of the class or do you walk around and look at what the learners are doing? Can you elaborate on this?

Question 4:

How would you explain what the term formative feedback means to new teachers?

Question 5:

How would you explain to new teachers how to guide the learner through the design process?

APPENDIX D - DATA ANALYSIS PROCEDURES

D1- Thematic analysis of teacher interviews

D2- Qualitative codebook for observations

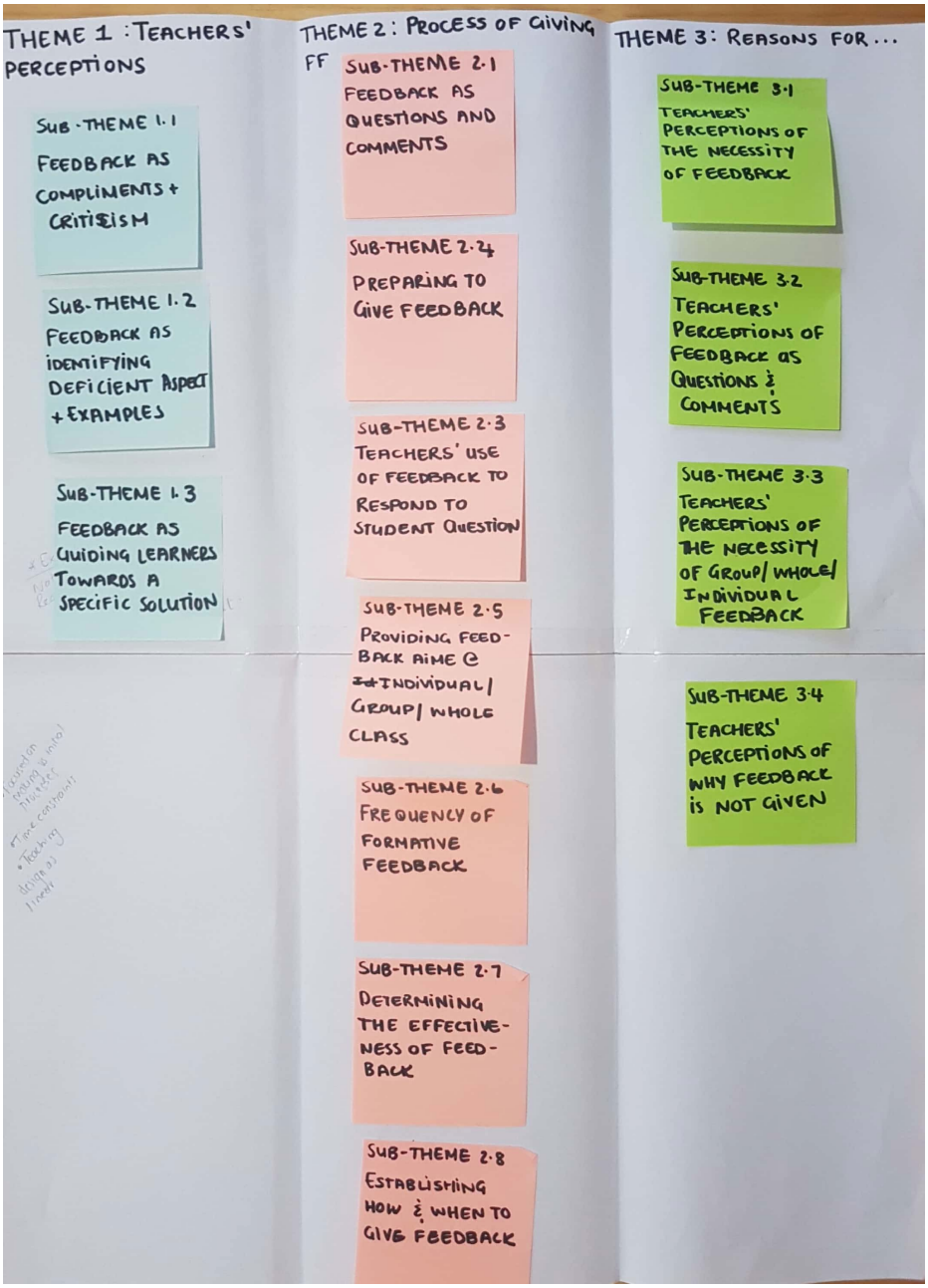
D3- Deductive analysis of observations

D1 - THEMATIC ANALYSIS OF INTERVIEW DATA

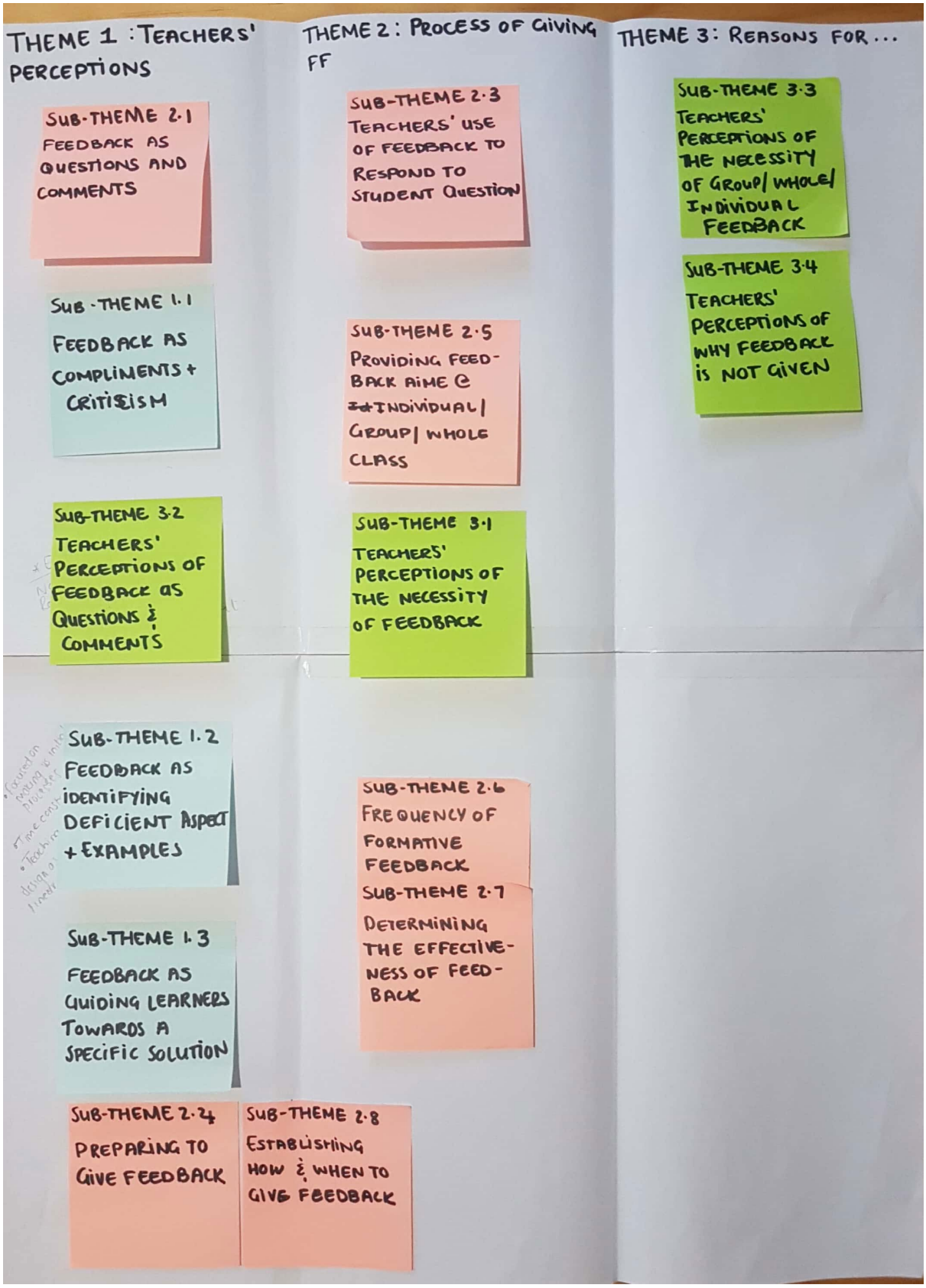
A summary of the themes related to sub-themes and verbatim quotations are presented here. The full data structuring and data analysis procedure can be accessed on the memory stick.

Development of themes:

Phase 1:



Phase 2:



Theme 1: Teachers' perceptions of formative feedback during the early phases of the design process.	Theme 2: Process of providing formative feedback in the early phases of the design process.	Theme 3: Teachers' justification for the necessity of formative feedback in the early phases of the design process.
Sub-theme 1.1: Feedback as compliments and criticism.	Sub-theme 2.1: The use of questions as formative feedback.	Sub-theme 3.1: Teachers' perceptions of the necessity of formative feedback.
I1: Learners want to feel that they have done something right. So I feel giving them positive critique is the best. You tell them, "you are having a positive influence on the whole class". So you first give him that compliment and then you tell him, "but have a look at this". [Description]	I1: What are different types of gears? [Description]	I1: A teacher is a lifelong learner. You can always be innovative. You can always say let's go to the next step. Let's be more creative, let's go bigger.
I1: You first give them that compliment and then you tell them to focus on this. [Description]	I3: why are you doing this? What are we working towards? What is the purpose of…[Description]?	I1: You ask all sorts of questions to find out… [incomplete sentence]. Remember next year you will be able to explain it better to the next group.
I4: What they already have, you have to be very positive. You just tell them how wonderful they are and that they can do it. [Description]	I3: there is not enough investigation go collaborate more here or go do more research there or I make some suggestions. [Description]	I6: Constant feedback, it gives them the opportunity to think about things they actually thought was correct.
I5: Like with the PAT's if feedback is very positive the designs will become better. If the feedback is positive these kids should move from something that is not working into something that is very good. [Description]	I3: what is the purpose of the task? [Description]	I2: On the investigation I want them to find as much information as possible and relevant information

D2 - QUALITATIVE CODEBOOK

Level 1: Design Phase

Layer 1: Design phase	Description	Examples
Code Name	Description	
Problem structuring	Relates to the "investigate" phase of the design process prescribed by the Department of Basic Education (2012) A process of gathering information on the scope of the design problem in terms of the needs of the users, the context of the problem and solution, design requirements, design goals. The knowledge needed to solve the problem. Can be observed in activities such as: • Exploring the problem, context, materials and tools. • Gathering information about the potential users • Researching and analysing existing solutions • Practical testing of tools and materials	Can you identify the material? This is for who? Here they used what mechanism? What is the purpose?
Preliminary Problem-solving	Relates to the "design" phase of the design process prescribed by the Department of Basic Education (2012) A process of exploring design ideas, specification and constraints, making preliminary design decisions This can include the following activities: • Write a design brief • Consider the specifications and constraints of possible solutions • Generating ideas • Making design decisions.	Who can tell me what constraints are? What are you going to use to make this? What are you going to design and make? How are you going to make it strong?

Level 2: Level of feedback

Code Name	Description	Examples
Task	Feedback about how well a learner performs a task. This includes feedback about acquiring information about the problem, context, client, analysis of products, practical testing research, the design brief, design specifications and constraints, generation of possible solutions and design decisions.	What do you have to do? Who has a different idea? Where is the mechanism? Who will benefit from this?
Process	Feedback about the process underlying or related to tasks. This relates to methods learners used to gather information about the problem, context and client. It also relates to how learners analysed existing products, did research and practical testing. In the design phase, process- level feedback relates to how learners write the design brief, identify specifications and constraints, how ideas are collected and how design decisions are made.	Where do you start? How did you do research? How do you design a ride? How do you write a design brief?
Self-Regulation	The feedback guides the learner to consider what they have done and how well they performed a task in relation to the requirements. This relates to how well learners were able to gather information about the problem, context and client. It further relates to how well learners were able to analyse products and perform practical testing. In the design phase, this type of feedback guides the learner to consider how well they were able to write a design brief, how well the specifications and constraints were considered and to what extend the	What could you have done differently? What went wrong? What did you learn from this?

	collected solutions will solve the problem.	
Self	Feedback about the person. Often referred to as compliments or praise. This type of feedback does not place a lot of emphasis on the task.	That is a good idea. You are on the right track. I like that idea.

Code Name	Description
Request	The questioner does not want to know anything but wants a specific action to be performed.
Verification	The questioner wants to know the truth of an event. Typically, yes or no answers.
Disjunctive	Verification with multiple concepts
Concept completion	The questioner wants to know the missing component in a specified event. (Fill in the blank).
Feature specification	The questioner wants to know some property o the given person or thing.
Quantification	The questioner wants to know an amount
Definition	The questioner wants to find out what a question concept means.
Example	The questioner invites examples of the question concept.
Comparison	The questioner wants to compare the similarities and/or differences between the question concepts.
Judgemental	The questioner wants to elicit judgement from the answerer by requiring a projection of events rather than a strict recall of events.
Compliment	Praise for what the learner did/accomplished
Critique	The teacher makes an assessment or judgement of the learner's work.
Direct recommendation	The teacher tells the student specifically what to do to improve the design.
Description	A description of a part of the design task that can be observed.
Interpretation	The questioner wants to know the meaning of the question concept based on given information.
Procedural	The questioner wants to know the partially or totally missing instrument in the question concepts?
Causal Antecedent	The questioner wants to know the states or events that have in some way caused the concept in question (what lead to…?)
Causal Consequence	The questioner wants to know the concept or causal chain the question concept caused.
Rational/Function	The questioner wants to know the motives or goals behind actions. (Why?)
Expectational	The questioner wants to know the causal antecedent of an act that presumably did not occur (why not)
Enablement	The questioner wants to know the act or the state that enabled the question concept
Future	A question about the future state of the task
Future Description	A description of the future state of the task that can be observed
Enablement	The questioner wants to construct acts, states or resources that can enable the question concepts.
Method generation	The questioner wants to generate as many ways as possible of achieving a specific goal.
Proposal/negotiation	The questioner suggests a concept or negotiates an existing or previously stated concept.
Scenario creation	The questioner constructs a scenario involving the question concepts and wants to investigate the possible outcomes.
Ideation	The questioner wants to generate as many concepts as possible from an instrument without trying to achieve a specific goal.

D3 - DEDUCTIVE ANALYSIS OF OBSERVATIONS

An example of the deductive coding procedure of the observational data is presented here. The full data structuring and data analysis procedure can be accessed on the memory stick.

ID	Quotation Content	Data collection	Codes
31:32	What are the overall dimensions?	Observation 1	Feature specification Problem-solving Solution-focused Task
31:52	Do you see how it stands out?	Observation 1	Feature specification Problem-solving Solution-focused Task
10:37	Why do you think people will annotate a sketch?	Observation 2.1	Problem-solving Task Causal antecedent Solution-focused
30:80	Is a soft seat safe or comfortable?	observation 2.3	Comparison Problem-solving Solution-focused Task
34:26	Gebruik daai triangulasie want dit gaan jou model baie vinniger baie sterker maak	Observation 3	Direct recommendation Problem-solving Solution-focused Task
34:29	So jy gaan nou vir my 'n raamstruktuur gaan bou.	Observation 3	Direct recommendation Problem-solving Solution-focused Task
32:75	Spesifiseer hulle hy moet 'n gewig van 20 mense kan vat?	Observation 4	Problem-focused Problem structuring Task Verification
32:21	Hoekom sit ons nie zebra strepe op 'n highway nie?	Observation 4	Problem-solving Scenario creation Task
33:74	Like, will it be cardboard?	Observation 5	Example Problem-solving Solution-focused Task
33:31	What's your idea?	Observation 5	Ideation Problem-solving Solution-focused Task

APPENDIX E - TAXONOMY OF QUESTION FOR PLANNING AND IMPLEMENTING FORMATIVE FEEDBACK IN TECHNOLOGY CLASSROOMS

Task level

Low-level questions

1. Can you explain what the goal of this task is? (Request)
2. Does your problem relate to ….? (Verification)
3. Is your investigation focused on finding information about…? (verification)
4. The purpose of this task is to solve a problem relating to….? (Concept completion)
5. The design need/problem or opportunity in this task is ……? (Concept completion).
6. What materials were the existing product made of? (feature specification)
7. What was the need did the existing products meet? (Feature specification)
8. What should the dimensions of your solution be (Quantification)
9. What is the budget for this task? (Quantification)
10. What is a structure? (Definition)
11. What materials can you use to make …?(Example)
12. What are your specifications? (Examples)
13. What are examples of existing products (Examples)
14. Is this material stronger than…? (Comparison)

Process level

Low-level questions

1. Did you start your design process by considering the design brief? (Verification)
2. The key concepts that you will need to complete the task are….(Concept completion)
3. The key questions we need to answer in this task are…(Concept completion)
4. What are examples of skills that you will need to successfully complete this task? (Example)
5. You could improve your research skills by….(Example)
6. Which strategies may help you to solve the task more efficiently? (Comparison)

Low-level comments

7. This strategy works well (Compliment)
8. I don't think this concept is related to the task (Critique)
9. I think you should use this strategy (Direct recommendation).
10. I see you used this concept/strategy to do…. (Description)

Self-regulated level

Low-level questions

1. How will you use the design brief to complete the task? (Examples)
2. The strategies you could use to monitor your progress are….(Concept completion)
3. Are you on track with your work? (Verification)
4. To which extent are you meeting the goals of this design task? (Judgemental).
5. What material/content/skills are most important for completing this task? (Judgemental)

Deep Reasoning Questions

6. What is the relevance of what I'll be learning about …? (Interpretation)
7. How does what I am learning to relate to what I already know? (Interpretation)
8. What will I move forward from here? (Procedural)

Generative Design Questions

9. How can I review what I have done? (Method generation)
10. What strategies did I use to review my progress? (Enablement)

Self-level

Low-level comments

1. This part of your project is presented well (Compliment, Task)
2. This is a very interesting idea (Compliment, Task).
3. I like that you considered/included this in your research/analysis/design brief/preliminary designs (Compliment, Task).
4. It is good to see that you have done this task in such detail (Compliment, Task).
5. The strategies you have chosen to use are well thought out (Compliment, Process).
6. I like that you used this method/strategy to ….. (Compliment, Process).
7. I like that you are improving your knowledge/skills by …. (Compliment, Process).
8. You have related the concepts of this task to previous concepts well (Compliment, Process).
9. I like that you are monitoring your progress (Compliment, Self-regulation).

Task level	Process level	Self-regulated level	Self-level
15. Which solution are you going to develop? (Judgemental) 16. Why did you choose (or not choose) to develop this idea? (judgemental)	**Deep reasoning Questions**	11. What are your next steps to deepen your learning? (Ideation). 12. What changes should I make in approaching …. ? (Ideation)	10. I like that you have considered the relevance of what you are learning (Compliment, Self-regulation) 11. I like that you are continuously reviewing what you have done and making adjustments and improvements to your work as you go along (Compliment, Self-Regulation).
Low-level comments 17. I like the idea where you… (Compliment) 18. That is a really good idea (Compliment). 19. I don't think this aligns with the goals of this task (Critique). 20. I don't think this part of your design will work (critique). 21. Instead of …. Rather …. (Direct recommendation). 22. Use this method because it will…. (Direct recommendation) 23. I see that you included ….(Description).	11. How do you understand the key concepts of this task? (Interpretation) 12. How does your understanding of the concepts relate to the task? (Interpretation) 13. How did you identify the design problem/need or opportunity to solve in this task (Procedural) 14. How did you do research? (Procedural). 15. How do write a design brief? (Procedural) 16. Why is this strategy not working (Expectational)? 17. Why does this strategy work better? (Causal antecedent)		
Deep reasoning Questions 24. Who will benefit from this solution? (interpretation) 25. What are you designing? (interpretation) 26. How does …. Work? (procedural) 27. How can you measure…(procedural) 28. What reinforcement methods can you use (Procedural) 29. Why are we designing…(Causal Antecedent). 30. What makes …. Happen (Causal antecedent). 31. What happened when you …. (Causal consequence). 32. What is the purpose of… (Rationale/function)	**Generative Design Questions** 18. How do you design a ride? (Method generation) 19. How can you find more information about the design problem? (method generation) 20. Where can you find information about ….? (Method generation) 21. How are you going to make this turn? (Method generation). 22. How do you know what you need for your model to work? (Enablement) 23. You could improve your understanding/skills about….by….? (Enablement).		

Task level	Process level	Self-regulated level	Self-level
33. Why would your client want to see…(Rationale/function) 34. Why does …. not work? (Expectational). 35. Why does your model not… (Expectational)	24. Can we use ….(method) instead of ….(method)? (Proposal/Negotiation)		
Generative Design Questions			
36. What makes…. Happen (Enablement) 37. How would you give it to the customer? (Future). 38. If you need to replace…., how would you do it? (Future) 39. How are you going to make your solution…(method generation)? 40. Or what you could do is….(Proposal/negotiation). 41. Why would you not implement your solution…..(Scenario creation)? 42. What if your clients were.(Scenario creation). 43. What if you were only allowed to use ….(Scenario creation). 44. How can adjust your solution for….(Ideation)? 45. How you adapt…. For your context? (Ideation).			

(Adapted from Brooks et al., 2019; Swathi et al., 2020 and research evidence from this study)

APPENDIX F - POLICY DOCUMENTS

F1-CAPS Document (memory stick only)