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SOUTH AFRICAN GRADE 6 MATHEMATICS TEACHERS' IMPLEMENTATION OF PROJECTS

A dissertation

presented to the Faculty of Education at the University of Pretoria

in partial fulfilment of the requirements for the degree of

Magister Educationis (Masters) in Mathematics Education

By

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September 2024

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ABSTRACT

This study explores how Grade 6 mathematics teachers implement projects as formative and summative assessments using Project-Based Learning (PBL) and Project-Based Assessment (PBA). My conceptual framework was influenced by the George Lucas Education Foundations' model for implementing Project-Based Learning (PBL) along with other scholars' work regarding the factors influencing the use of projects. The main research question guiding this study is: How do Grade 6 mathematics teachers implement projects? Through convenience sampling and a questionnaire on the use of PBL (distributed by the Skoleondersteuningsentrum), I was able to select three participants who could contribute to answering this research question. This is a qualitative study encapsulated by the interpretive paradigm where an in-depth exploratory case study design was used. Using document analysis, observations and interviews, I was able to explore how teachers design and implement projects for formative and summative assessments, but also come to understand the challenges that they experience. The findings of this study reveal that these teachers face significant challenges in designing and implementing projects for *both* formative and summative assessments. There is a notable gap in their conceptual understanding of PBL and PBA. Additionally, the projects created do not align with the intentions of the Curriculum and Assessment Policy Statement (CAPS), highlighting a disparity between the intended and the enacted curriculum. These findings indicate the need for intervention programmes aimed at re-equipping teachers. Such programmes should focus on equipping teachers with the necessary skills and knowledge to design and administer effective projects, thereby fostering classroom environments that promote active learning.

Keywords: Project-Based Learning; Project-Based Assessment; formative assessments; summative assessments; intended curriculum; enacted curriculum; active learning

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LIST OF ACRONYMS AND ABBREVIATIONS

ANA	Annual National Assessments
ATP	Annual Teaching Plan
CAPS	Curriculum and Assessment Policy Statement
DBE	Department of Basic Education
GPS	Global Positioning System
HoD	Head of Department
IBL	Inquiry-Based Learning
LTSM	Learning and Teaching Support Material
NPA	National Protocol for Assessment
PBA	Project-Based Assessment
PBL	Project-Based Learning
PCK	Pedagogical Content Knowledge
POPI	Protection of Personal Information
PrBL	Problem-Based Learning
RATP	Recovery Annual Teaching Plan
SACE	South African Council for Educators
SACMEQ	Southern and Eastern Consortium for Monitoring Education Quality
SBA	School-Based Assessment
SOS	Skoleondersteuningsentrum
TIMSS	Trends in International Mathematics and Science Study

CHAPTER 1 BACKGROUND OF THE STUDY

1.1 INTRODUCTION

Mathematics is a human activity (Department of Basic Education, 2011); as such, it requires learners to interact with the curriculum content in constructing their knowledge of the subject (Fisher et al., 2020). Learners in South Africa have been performing poorly compared to other countries' learners (Umugiraneza et al., 2017). This is evident from the recent results of the Annual National Assessments (ANAs) (Arends et al., 2017; Department of Basic Education; Van Staden & Motsamai, 2017), the Southern and Eastern Africa Consortium for Monitoring Educational Quality (SACMEQ) (Bowie et al., 2019; Department of Basic Education), and the Trends in International Mathematics and Science Study (TIMSS) (Arends et al., 2017; Bowie et al., 2019; Bowie et al., 2022; Department of Basic Education, 2018).

In 2018, the Department of Basic Education (DBE) published a framework titled *Mathematics Teaching and Learning Framework for South Africa: Teaching Mathematics for Understanding,* which outlines how teachers could apply better teaching practices. The document encourages using a learner-centred teaching style, and appropriate teaching approaches among other teaching practice aspects. Teachers should not only know various teaching approaches, but need the relevant skills to utilise various types of approaches when teaching mathematics (English & Kitsantas, 2013). These types of teaching approaches should include active learning at their core. Such teaching approaches include, for example, cooperative learning, cognitive-guided instruction, differentiated teaching, Inquiry-Based Learning (IBL), gamification, Problem-Based Learning (PrBL), and Project-Based Learning (PBL). The last two approaches are quite similar as both are rooted in constructivism. However, the main difference is that PrBL is "primarily focused on the process of learning," and PBL "needs to culminate in an end product" (Kokotsaki et al., 2016, p. 268). This means that learners need to be able to present their findings, and demonstrate their overall understanding and what they have learnt whilst doing the project through something they have created.

In the framework of teaching and learning mathematics for understanding, the DBE (2018) states that to change the current state of mathematics education in schools, teachers need to adopt a new outlook that is underpinned by the curriculum. The solution presented by the DBE is to provide more opportunities for active learning, and to use a learner-centred teaching style with the associated teaching approaches. One such approach is PBL, which is a teaching approach rooted in constructivism. It is defined as a learner-centred teaching style that allows for active learning, enhances learner engagement and critical thinking skills, and provides

learners with the opportunity to construct their knowledge by solving a problem or series of problems. The project takes place over a period of time and focuses on the learning of curriculum content such as whole numbers, fractions, geometry and data handling through the use of projects (Bell, 2010).

PBL aligns with the Curriculum and Assessment Policy Statement (CAPS) by fostering mathematical understanding and connecting mathematics to social, economic, and cultural contexts (DBE, 2011a). PBL helps achieve curriculum aims through real-life applications, enhancing creativity, collaboration, and inquiry. Projects, as tasks that challenge learners to solve complex problems, allow learners to construct knowledge independently over extended periods, both inside and outside the classroom (Fisher et al., 2020; Jacobs et al., 2016). Project-Based Assessment (PBA) shares PBL's learner-centred approach, and is also rooted in constructivism, but focuses on testing learners' understanding of a topic through projects. PBA enables learners to demonstrate knowledge differently than in traditional tests.

In South Africa, teachers implement projects through formative and summative assessments. CAPS mandates a summative project assessment for Grade 6, ensuring standardised assessments and reporting (DBE, 2011; Jacobs et al., 2016). However, PBL emphasises the learning process, and should be used as a formative assessment throughout the year, ideally before the summative assessment in Term 3. Furthermore, CAPS suggests topics suitable for projects, such as data handling, while keywords like ‘investigate,’ ‘problem-solving,’ and ‘context’ indicate areas ripe for project development. Both formative and summative project assessments are vital for developing critical thinking, problem-solving, cooperation, and creativity. These assessments measure learners' ability to showcase knowledge and skills independently.

1.2 Problem Statement

The problem statement of this research is broken down into two parts to adequately discuss the prevailing problems in the implementation of projects in South Africa.

1.2.1 Curriculum implementation

Bowie et al. (2022) report that South African Grade 5 learners show basic mathematical knowledge, but struggle with applying it to real-life problems. The DBE (2018) attributes poor international, national, and regional assessment results to ineffective teaching methods. As such, teachers need to incorporate more contextual problems in their teaching to show the relevance of mathematics in daily life, and to enhance problem-solving skills. This is part of Project-Based Learning (PBL), which also develops communication, investigation, reasoning,

and creative thinking skills (Fisher et al., 2020; Kokotsaki et al., 2016; Serin, 2019). However, PBL alone is not enough; learners need formative assessments through PBL and must demonstrate their acquired skills in mandatory summative projects, as per the CAPS guidelines. Despite available resources, teachers often fail to use PBL effectively, and implement summative projects incorrectly, contributing to underperformance in assessments such as TIMSS.

The intended CAPS curriculum (DBE, 2011) allows teachers to use projects as formative assessments, although it does not explicitly mention approaches like PBL. However, the DBE (2018) does encourage the use of appropriate teaching approaches that are preferably learner-centred. In this case, the enacted curriculum is not aligned with the intended curriculum as most mathematics teachers still only use approaches linked to teacher-centred teaching, which focuses on algorithms and teaching procedural knowledge (DBE, 2018; Du Plessis, 2020). Many public school teachers in South Africa use the Revised Annual Teaching Plan (RATP), which was introduced during the COVID-19 pandemic, and is valid until 2024 (DBE, 2023a). The RATP is an adapted version of the Annual Teaching Plan (ATP) that only lists projects as summative assessments. It is, however, an “interim deviation from the original curriculum and a transitional arrangement until the policy amendment processes are completed” (DBE, 2023a). This means that until the DBE, namely the Minister of Basic Education, considers the educational gaps caused by COVID-19 bridged, the Revised Annual Teaching Plan (RATP) is applicable. The problem is that it covers far less content than CAPS and earlier ATPs. It furthermore lists projects only as one of the summative assessment opportunities in Term 3, and should cover the work from Terms 1-3. It is therefore assumed that teachers understand that to be able to use a project as a summative assessment, they need to do at least one project as a formative assessment to familiarise learners with the process. If teachers follow the RATP without referring to the original CAPS, it is also likely that they will omit using projects as part of formative assessment, and learners will be deprived of an opportunity to develop and apply their knowledge and skills through such a project.

1.2.2 The implementation of projects

Several factors hinder teachers in implementing projects as formative assessments, and influence them to incorrectly use projects as summative assessments. A few examples of these reasons are that, firstly, “many teachers view mathematics algorithmically” (DBE, 2018, p. 79), and teaching differently is challenging for them. Their pedagogical beliefs ultimately influence how they implement and design projects based on their perceptions (Campbell et al., 2014; Hughes et al., 2019; Lui & Bonner, 2016). This may cause teachers to rather avoid using learner-centred approaches such as PBL or PBA. Secondly, PBL is a time-consuming

teaching approach (Aksela & Haatainen, 2019), with PBA similarly being time-consuming. Thirdly, teachers' education regarding PBL plays a massive role in their use thereof. The successful implementation of learner-centred teaching approaches, such as PBL, depends on teachers' ability to apply it effectively in terms of how they guide learners (Kokotsaki et al., 2016). However, if teachers do not receive proper training on how to use PBL, they will not be able to use the approach effectively (Guntur & Retnawati, 2020), and the project will not serve its purpose. Also, if teachers are not aware of what PBL is, they will not implement it appropriately (Aksela & Haatainen, 2019). Lastly, teachers who use CAPS and look at the definition of projects as summative assessment might be left with more questions than answers as to what is expected of them:

> Projects are used to assess a range of skills and competencies. Through projects, learners are able to demonstrate their understanding of different Mathematics concepts and apply them in real-life situations. Caution should, however; be exercised not to give projects that are above learners' cognitive levels. The assessment criteria should be clearly indicated in the project specification and should focus on the mathematics involved and not on duplicated pictures and facts copied from reference material. Good projects contain the collection and display of real data, followed by deductions that can be substantiated. (DBE, 2011, p. 295)

This definition is vague, focusing more on what teachers should do in terms of assessment criteria than on actually explaining the definition of a project. However, the definition does hold value if a teacher has accurate prior knowledge of what a project is. However, the lack of specification in the curriculum creates a situation where teachers may incorrectly interpret the definition and requirements of a project. Based on their possible misconceptions, it could lead to a discrepancy between the intended and enacted curriculum.

In conclusion, the limited use of PBL in South African public schools, and even some private schools, poses a significant problem despite the intended curriculum. The source of this problem is vast and complex. The issue stems from teachers' lack of training on PBL, gaps in teacher education programmes, and insufficient workshops for in-service teachers. These assumptions negatively impact mathematics education as learners miss out on developing crucial skills like investigating, creative thinking, justifying, problem-solving, and collaboration. Even teachers who are aware of PBL in CAPS often follow the RATP instead, thus perpetuating the problem.

1.3 Rationale

As a teacher in my fourth year of teaching, I attempted PBL as this teaching approach was taught to me during my teacher education, and we had to set up lesson plans that included it. However, during this process, it became clear to me that only through experience can I learn

to effectively use it. Through my interest in how teachers use projects efficiently, I started a review of the related literature. Despite the growing body of research on projects in mathematics, more research needs to be done in the South African context. Currently, there has been research done on PBL in tertiary education in South Africa (Botha, 2010; Von Kotze & Cooper, 2000) - three studies were found, which had been conducted in primary and high schools (Nxasana et al., 2023; Von Solms & Nel, 2017). Furthermore, Lazić et al. (2021) carried out a study on the influence of PBL on primary school learner achievement, while Nasution et al. (2021) did a study on pre-service teachers' perceptions of the use of PBL in classrooms. In international studies, Aksela and Haatainen (2019), found that PBL is useful in practice in terms of learning; collaboration of learners and teachers; and learners' motivation. Markula and Aksela (2022) and Mentzer et al. (2017) did studies on the design and implementation of projects and found that teachers were unable to properly design the project – specifically referring to the main essential questions that were done incorrectly. However, there is little research done on the use of PBL in South African primary schools. This study aims to fill a part of this gap and provide insight into the use of PBL in the unique South African context. Moreover, Fisher (2019), Kokotsaki et al, (2016), Krajcik and Shin (2014), Bell (2010), and Thomas (2000) conducted literature studies on the use of PBL. These international studies provide valuable insight into how teachers in South Africa should design and implement projects. The studies provide insights into how teachers struggle to set up the main essential question and what the characteristics of a good project are. These studies allow thus for teachers to make informed decisions on how to adapt projects in the unique South African context.

The use of projects speaks to many of these aims. However, from personal experience, the proper implementation of projects does not take place in most teachers' practices. Although teachers realise the value of projects, many teachers lack the knowledge and skills, and are scared to use learner-centred approaches such as PBL, PrBL, or Inquiry-Based Learning (IBL). Using projects as a formative and summative assessment was daunting to me, especially since no other mathematics teachers at my school did it. However, I experienced an immediate change in how my learners interacted with the content, and how their interest and enthusiasm increased. It is for this reason that I advocate for teachers to use PBL and PBA as teaching approaches. By exploring how teachers use PBL in Grade 6 mathematics classrooms, this study may contribute to more teachers using it, and will add suggestions for pre- and in-service teacher development in this field. This research also enhances my teaching, and will consequently benefit my learners. However, it is important to note that the study's original focus shifted from the sole implementation of PBL to including PBA as well. It is for this reason that PBA is focused on, but to a lesser extent than PBL.

1.4 PURPOSE OF THE STUDY

Based on the problem and rationale presented above, it can be concluded that teachers generally neglect teaching approaches such as PBL. Projects play a crucial role in developing 21st-century skills such as communication, critical thinking, creativity, problem-solving, and collaboration (Bell, 2010), but also serve as formative and summative assessments. However, designing and implementing projects proficiently requires teacher creativity, and a specific teaching approach that will allow for the best outcome of the activity (Umugiraneza et al., 2017). Bearing this in mind, this study aimed to determine how Grade 6 teachers apply PBL when using projects as formative assessments, and how teachers implement projects as summative assessments. With this said, the study focused on teachers who have experience in using PBL and can therefore contribute to the body of existing knowledge regarding teachers' reasons for using it, and how they plan and prepare for the process. This research also focused on the design of summative assessment projects, and teachers' views on the definition and requirements of a project. It was not in the best interest of this study to focus on teachers who have misconceptions about what PBL entails or teachers who have never used it. By observing teachers who use PBL and projects as a formative and summative assessment, I realised that I could contribute to how these teachers use projects in the South African context. The objectives of this study were to investigate what factors influence teachers' implementation of PBL and PBA, how teachers prepare and plan to use the related teaching approaches, and how teachers implement these teaching approaches when using projects.

1.5 CONCEPT CLARIFICATION

The following operational concepts used throughout this study are explained in Table 1.1.

Table 1.1

Clarification of the concepts used in this study

Concept	Definition
Intended curriculum	The intended curriculum is the official government document that is meant to inform schools on what content should be taught and what assessments should be carried out (Penuel et al., 2014). In the case of South Africa, this was the South African Curriculum and Assessment Policy Statement (CAPS), which was used until the subsequent RATP was implemented nationwide from 2023 onwards (DBE, 2023a).

Concept	Definition
	However, it is my argument that these two documents should be used in conjunction with one another.
Enacted curriculum	The enacted curriculum is the content actually taught in the classroom (Penuel et al., 2014). In South Africa, this comprises not just the content that is taught using CAPS, but also the assessments provided to learners.
Learner	The South African School's Act 84 of 1996 (South African Government, 1996) defines a learner as any person from Grades R-12 who receives education, as outlined by the Act, and who is held accountable under all regulations of the Act.
Student	In this study, a student is viewed as an individual who is busy with tertiary coursework, unless utilised in a direct quote from international studies where a school learner is referred to as a student.
Active learning	Active learning is a concept best understood for what it does rather than an operational definition. Active learning entails learners taking on a dynamic role in their education (Petress, 2008). They are not dependent on the teacher for knowledge, but the teacher is rather a resource to guide them to further understanding (Petress, 2008). Active learning involves learners' discovery (Fisher et al., 2020).
Formal assessment	Formal assessment is a "systematic way of assessment used by teachers to determine how well learners are progressing in a grade and in a particular subject" (DBE, 2012, p. ix).
Summative assessment	Summative assessment is "carried out after the completion of a mathematics topic or a cluster of related topics. It is therefore referred to as assessment *of* learning since it is mainly focusing on the product of learning" (DBE, 2018, p. 7). Summative assessments are also used to get a mark for promotion purposes in South Africa (DBE, 2011).
Formative assessment	Formative assessment is "used to aid the teaching and learning processes, hence assessment *for* learning where learners get feedback on their performance in a way that helps them to improve" their overall understanding of the topic and the subject (DBE, 2018, p. 7).
Main essential questions	A main essential question is a central, guiding question that directs the project, provides context, and maintains the purpose of activities within it (Blumenfeld et al., 1991; Hasni et al., 2016; Hmelo-Silver, 2004; Krajcik & Shin, 2014; Thomas, 2000). It ensures continuity and cohesion

Concept	Definition
	throughout the project (Mentzer et al., 2017), culminating in an end product that addresses the question (Blumenfeld et al., 1991). A well-crafted main essential question in mathematics is authentically linked to real life and engages learners. It is open-ended and intellectually challenging, yet appropriate for their age and skill level. It also necessitates understanding core mathematical concepts (Hasni et al., 2016).
End product	Projects revolve around creating an artefact or end product that addresses the main essential question (Blumenfeld et al., 1991; Krajcik & Shin, 2014; Tal et al., 2006). An end product, which sets PBL and PBA apart from PrBL and IBL, encapsulates learners' understanding in concrete creations like games, posters, models, plays, websites, or drawings that answer the main essential question (Hasni et al., 2016; Novak & Krajcik, 2020; Sahin, 2013).
Project	A project is a class activity that is often done both in and out of the classroom. It takes place over a period of time, and requires learners to solve problems that are often based on real-life situations (Jacobs et al., 2016). It places learners in a situation where they must investigate and substantiate their answers, and provide an end product that answers the main essential question (Blumenfeld et al., 1991; Krajcik & Shin, 2014; Tal et al., 2006). By nature, projects are a process of inquiry (Bell, 2010).
Project-Based Learning (PBL)	Project-Based Learning (PBL) is an instructional approach that involves learners in activities that require the application of knowledge and skills to investigate project-related problems, and produce an end product that answers the main essential question (Fisher et al., 2020; Kokotsaki et al., 2016; Lazić et al., 2021; Nasution et al., 2021; Serin, 2019). Beyond this, PBL requires learners to analyse gathered information (DBE, 2011a; Serin, 2019), and foster the skills of interpreting data and devising problem solutions (DBE, 2011; Fisher et al., 2020). A pivotal aspect involves learners presenting their findings, which emphasises effective communication (DBE, 2011). PBL transforms the teacher into a knowledge facilitator, encouraging a shift from being the sole provider of information to guiding learners in exploring and understanding the curriculum content (Bell, 2010; Petress, 2008). This approach cultivates

Concept	Definition
	investigative, analytical, representational, and interpretative skills, contributing significantly to holistic learning outcomes.
Project-Based Assessment (PBA)	Project-Based Assessment (PBA) holds the same characteristics as PBL in that it encourages problem solving, critical and creative thinking, constructive investigations, and collaboration. It contains a main essential question that guides learners to create an end product that represents their cumulative understanding. The emphasis here is on testing what learners have already been taught as opposed to teaching them the topic.

1.6 RESEARCH QUESTIONS

The following questions were formulated to guide this study:

Primary research question:

How do South African Grade 6 mathematics teachers implement projects?

Secondary research questions:

Formative assessment of projects:

1. What factors influence teachers' implementation of PBL as a teaching approach?
2. How do teachers plan a project by using PBL?
3. During the implementation of PBL, how do teachers facilitate learning?

Summative assessment of projects:

4. What are teachers' understanding of a project as a summative assessment, and PBA?
5. How do teachers plan a project by using PBA?
6. What opportunities does a project provide for learners to develop the required knowledge and skills?

1.7 WORKING ASSUMPTIONS

It was assumed that PBL and PBA are the most appropriate approaches for the implementation of projects as formative and summative assessments. This is because they provide learners with the best opportunity to develop 21st-century and 4th Industrial Revolution skills to cope in the real world. These skills can range from learners applying their knowledge to real-life situations to improving communication, writing, problem-solving, and critical

thinking skills. I assumed that most mathematics teachers in South Africa do not design and administer projects following the requirements of the CAPS curriculum. I also experienced that some teachers fail to adjust their teaching approaches to suit the needs of the project, thus not allowing for the best possible outcome of the aims of the project. In such cases, the project will not be as effective as it could be, and might not be in line with the CAPS purpose and goals as set by the DBE (2011).

1.8 CONCEPTUAL FRAMEWORK

I developed a conceptual framework that is rooted in established literature, and which aligned with my research questions. The first part of the conceptual framework considers internal and external factors that might influence the implementation of PBL and PBA. These factors were all well-researched and considered when designing the framework. The second part of the framework breaks down the steps that a teacher should follow to implement PBL and PBA in their classroom. There is a total of six steps, but only five of them will be focused on in this study. A comprehensive explanation is provided for each step regarding what it entails, and what teachers would have to do and consider.

1.9 METHODOLOGICAL CONSIDERATIONS

I used a qualitative research approach, which enables the collection of detailed data to answer research questions. This study adopted an interpretative research paradigm, which influenced its epistemological, ontological, axiological, and methodological assumptions. An exploratory case study design was employed to investigate how Grade 6 mathematics teachers design and administer formative and summative projects using PBL.

The study focused on Grade 6 mathematics teachers in South Africa who use PBL, and who are required by the curriculum to implement the use of projects as a summative assessment. Through purposive sampling, three schools were selected, with one Grade 6 teacher per school. Convenience sampling was also applied, focusing on schools in Gauteng, where I reside. The participants were further identified using results from the Skoleondersteuningsentrum (SOS) questionnaire[1].

Three data collection strategies were employed: document analysis, observations, and interviews (see Appendices A-C). These strategies were aligned with the conceptual framework and research questions. The data collection began with a document analysis of the

[1] This questionnaire is discussed in depth in Chapter 3.

teachers' formative and summative projects, followed by interviews and observations. Checklists based on established literature guided the document analysis.

The observations varied by project phase. The first observation occurred when the project was introduced, and the second after the first phase's completion, allowing for formative assessment and feedback. The observations were video-recorded, focusing on the teacher and the backs of the learners, with faces blurred.

The interviews were conducted in phases, designating two phases for discussion. Four semi-structured interviews were held at different project implementation stages, each lasting 30-45 minutes. The first interview, which occurred after the initial observation, discussed factors influencing the teachers' use of PBL. The second interview, which was conducted post-second observation, focused on the project introduction. After the second observation, the third interview addressed feedback at the end of Phase 1. The final interview, post-project completion, reflected on the teachers' use of PBL and their experiences. The interviews were held after school hours, and were voice-recorded and transcribed verbatim.

During the data analysis, I mainly used deductive analysis, and coded the data according to the different components in the conceptual framework. An inductive thematic data analysis approach was used to further identify trends in PBL and PBA usage.

1.10 ETHICAL CONSIDERATIONS

This study prioritised ethical considerations by obtaining clearance from the University of Pretoria and the Gauteng Department of Education. The research focused on the teachers, but in observing them in class, the Grade 6 learners were present and I needed to obtain their assent through an assent letter that was explained to, and signed by them. If and when their faces appeared on the video-recordings, their faces were blurred. Further consent was obtained from the principals, teachers, and parents in adherence to the Protection of the Personal Information (POPI) Act of 2013, requiring parental consent. Consent was received through signed letters, which assured anonymity through the use of pseudonyms, and provided information regarding confidentiality, non-compulsory participation, and the option to withdraw at any stage, emphasising clear boundaries.

1.11 QUALITY ASSURANCE

To ensure the validity, reliability, and trustworthiness of this study, I focused on the key aspects highlighted by Maree (2016) and Creswell (2017). Credibility was achieved through carefully considered research design and methods, including participant verification of data. Transferability was addressed by using a specific sample of Grade 6 teachers and providing

a detailed context, along with a thick description and purposeful sampling. Dependability was ensured by meticulously documenting any changes or decisions made during the study. Finally, confirmability was maintained through triangulation to avoid researcher bias, ensuring that the findings reflected the participants' perspectives rather than my own.

1.12 Conclusion

This chapter outlined the study's background, problem statement, rationale, purpose, concept clarification, research questions, working assumptions, conceptual framework, methodological considerations, and ethical considerations. The problem statement highlighted that South African learners have basic mathematical knowledge, but struggle to apply it to contextual problems. This is due to poor teaching approaches and a predominantly algorithmic view of mathematics among teachers. Many teachers use the RATP, a variation of the ATP, which lacks focus on the use of projects beyond summative assessment. The effective implementation of learner-centred approaches like PBL depends on teachers' ability to guide learners. Without this, learners miss the chance to develop a deeper conceptual understanding. The study aimed to investigate how Grade 6 mathematics teachers use PBL in designing and administering projects for formative and summative assessments. The research posed one primary, and six secondary questions. The participants were selected through purposive and convenience sampling, and the data were collected using document analysis, observations, and interviews. The next chapter discusses the literature and conceptual framework guiding the study.

1.13 Structure of the Dissertation

The chapters of this dissertation are structured as follows:

Table 1.2

Structure of the dissertation chapters

Chapter 1: Background of the study
This chapter provided the background of the study, as well as the problem statement, rationale, purpose of the study, and research questions. It also provided a brief overview of the research approach, research design, population and sample, data collection methods, data analysis strategy, and ethical considerations of this research.
Chapter 2: Literature review and conceptual framework
In this chapter, I review the literature concerning the teaching and learning of mathematics. I specifically focus on teaching approaches and learning theories relevant to the

implementation of PBA and PBL; the design and implementation of the project; and departmental guidelines. The conceptual framework was guided by the literature review, as well as the research questions. An in-depth explanation is provided of how the literature, the conceptual framework, and the research questions relate to each other.

Chapter 3: Research methodology

The research methodology includes the study's research philosophy, research design, target population, and sampling methods. I also discuss the data collection instruments and data analysis strategy. Lastly, I detail the quality assurance criteria and ethical considerations of this study.

Chapter 4: Presentation and discussion of data

In this chapter, I used the conceptual framework to guide the presentation of the data obtained from the three participants, namely, Emily, Benjamin, and Sophia. To avoid repetition, I simultaneously presented and discussed the data, but also related it to the existing literature.

Chapter 5: Discussion of the findings and implications

In this final chapter, I discuss the findings of the study. This is done through discussing the research questions, reflecting on the study, discussing the limitations of the study, making recommendations, and suggesting that further studies be conducted. Lastly, the study is brought to a close with concluding thoughts.

CHAPTER 2 LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

2.1 INTRODUCTION

This chapter reviews the literature on the various methods of teaching mathematics, and how children learn through project-based approaches. It examines the factors that impact the implementation of projects, including teacher education, pedagogical beliefs, and the planning and preparation involved. The chapter also explores the design and implementation of projects using PBL and PBA. Additionally, it considers the role of departmental guidelines in shaping the design and implementation of these projects. The chapter concludes by discussing the conceptual framework, its connection to the research questions, and the relevant literature.

2.1.1 The teaching and learning of mathematics

In a country that has seen as much change to its educational landscape as South Africa has, mathematics is still a subject with which many learners struggle. A lot can be said about how a country approaches the teaching and learning of mathematics, especially regarding the aims and goals of the curriculum, what content is being taught, and how teachers are meant to implement the content.

2.1.1.1 What is mathematics?

There are various perspectives on what mathematics is. According to Turnbull et al. (2015), mathematics is “the science of numbers and shapes” (p. 930). Courant et al. (1996) described mathematics as “an expression of the human mind [that] reflects the active will, the contemplating reason, and the desire for aesthetic perfection” (p. 1). When looking at various mathematics curricula, each country views mathematics, and the teaching and learning of it, differently. For example, Singapore’s curriculum does not provide a succinct, one-paragraph definition of mathematics. Instead, they elaborate over various pages and chapters in their curriculum what mathematics means for the teaching and learning of it, the skills that learners require in the 21st century, and what the mastery of mathematics implies for society (Ministry of Education, 2012). Alternatively, CAPS defines Mathematics as:

> A language that makes use of symbols and notations to describe numerical, geometric, and graphical relationships. It is a human activity that involves observing, representing, and investigating patterns and quantitative relationships in physical and social phenomena and between mathematical objects themselves (DBE, 2011, p. 8).

Although there is nothing inherently wrong with the way South Africa defines mathematics as compared to Singapore, it depends on how a person views it.

2.1.1.2 How do children learn?

A learning theory describes the process of how learners receive, process, and store the knowledge gained through instruction. This means that when a teacher selects a certain teaching approach, that approach is informed by a learning theory (Lessani et al., 2016). Thus, teachers need to be aware of different types of learning theories, how they relate to teaching approaches, and the implications thereof for how children learn. According to Lazić et al. (2021), the implementation of projects lies in the use of constructivist and sociocultural theories, which is why they will be discussed along with other learning theories that are commonly used in mathematics. I also analysed which of these learning theories my participants used when implementing their projects.

- **Behaviourism**

Behaviourism is the theory that learning occurs through conditioning. It was established by Skinner (1972) and further refined by Watson (1996). It primarily focuses on a reward and punishment system. People who subscribe to this learning theory also believe that the behaviours of learners can be shaped through continuous drills and practice.

This learning theory is evident in a classroom where the teacher is the primary source of knowledge, and where the teacher uses what is called a ‘telling’ teaching approach. This learning theory thus best informs a teacher-centred approach in the classroom. Mathematics teachers who are behaviourists follow a basic lesson structure where they review homework from the previous day, explain the next concepts, and then have learners do the related activities. Moreover, they explain the next topic using low-level problems, and have learners do work that imitates the teacher’s methods (Stonewater, 2005).

The implications of this learning theory for the use of projects are astronomical. Projects require learners to be independent from the teacher. Thus, if a teacher believes that learning occurs through drill and practise, and that they are the main source of knowledge in the classroom, projects might not be implemented as intended in the curriculum.

- **Constructivism**

Constructivism is rooted in Jean Piaget’s (1936) work and is a learner-centred approach where learners are encouraged to participate in their knowledge construction and development of understanding. Learners are not passive receivers of knowledge, but rather, they are agents of their learning (Lessani et al., 2016). Constructivism implies that learners need to build their

own understanding of a given topic (Lessani et al., 2016). The main responsibility of the teacher is to serve as a mediator between the content and the learners, and to create opportunities for active learning. A project is such an activity where learners can be in control of their learning, and the teacher is merely a Global Positioning System (GPS) that guides them to the right destination. The responsibility of getting there, and how they get there, still lies with the learner.

- **Social constructivism**

Social constructivism is a theory that posits that human development and understanding are deeply embedded in social interactions and cultural contexts (Snowman & McCown, 2013). This theory suggests that individuals construct knowledge through interactions with others and their environment, rather than discovering pre-existing truths (Snowman & McCown, 2013). Originating from the works of Lev Vygotsky (1978), social constructivism emphasises the significance of language, social context, and cultural tools in cognitive development. Vygotsky's (1978) seminal ideas on the Zone of Proximal Development (ZPD) highlight how learners achieve higher levels of understanding through guided interaction with more “knowledgeable others” (Van de Walle et al., 2016, p. 51).

Using social constructivism with projects in mathematics involves creating tasks that require learners to work together to solve complex problems, thereby mimicking real-life scenarios where collaboration and negotiation of meaning are essential. For instance, a project might involve learners designing a model or conducting a statistical study.

2.1.1.3 The role of teachers

Learning theories, teaching approaches, and a teacher’s beliefs and experiences will impact the role that they assume in the classroom. The question then is, what is the ideal role of a teacher in the mathematics classroom? According to the *Mathematics Teaching and Learning Framework for South Africa: Teaching Mathematics for Understanding* (DBE, 2018), a teacher should not be the sole provider of knowledge. Teachers should use the interests and experiences of learners to create meaningful activities where learners can become agents of learning. All of these refer to active learning in the classroom. In light of this, Petress (2008) defines an active learner as:

> [A student who] is not overly dependent on a teacher; active learning makes the student a partner in the learning process. Active learners commonly use their teachers as resource people, as guides to the learning process, and as motivators for further endeavours. Active learning, as the term implies, is a process where the student takes a dynamic and energetic role in one's own education (p. 566).

Active learning is indicative of learner-centred teaching, while passive learning aligns with teacher-centred approaches. Sahin (2013) describes a PBL teacher as a "guide who monitors students' progress and ensures collaboration" (p. 60). Suherman et al. (2021) emphasise that learning activities are learners' responsibility, implying that active participation is essential for constructing knowledge, especially in PBL or PBA contexts. They further state that active learning involves physical actions, thoughts, and attention (Suherman et al., 2021). Active learning extends beyond discussions to continuous engagement in thinking, researching, and testing theories. Properly executed projects support this dynamic learning process. Teachers should be adaptable, employing a mix of teacher-centred and learner-centred approaches based on the topic and classroom situation. In mathematics projects, passive learning is ineffective. Teachers must therefore allow learners to independently process and apply information, which will foster their understanding. When teachers control the learning environment and provide all of the knowledge, it results in passive learning, which in turn undermines project quality. Often, teachers struggle with this balance due to a lack of clarity on their role in facilitating projects.

2.1.1.4 The influence of PCK and pedagogical beliefs

Pedagogical Content Knowledge (PCK), as established by Lee Shulman in 1986, involves the integration of content knowledge and pedagogical knowledge. PCK refers to teachers' knowledge of how to make the content comprehensible to learners, such as the teaching approach used, worksheets or Learning Support Materials (LTSMs) that could help learners understand the topic better (Shulman, 1986). For example, teachers must have deep content knowledge of data handling, and must know the best way to teach it to develop their learners' content knowledge and skill to apply that knowledge. Although teachers should know the best teaching practises to use in their subject, their subject head and Head of Department (HoD), who have more expertise, should guide them towards the best teaching practices as well (Viro et al., 2020). Teachers also need to utilise the curriculum for further guidance as it will provide them with the tools to choose the best teaching approaches for the addressed content areas and topics. For example, CAPS prescribes the use of projects for teaching and learning data handling, and provides recommendations on what summative assessment projects should be based (DBE, 2011). For experienced teachers who used the original curriculum and various ATPs over the years, one would assume that they understand how to implement projects using PBL and PBA. Thus, they should have an established PCK that is rooted in the intended curriculum.

Richardson (1996) stated that teachers' beliefs come from three sources: (1) Personal experiences when teaching; (2) Experiences from when they were learners; and (3) What they

learnt from workshops and teacher educator programmes. With this in mind, and considering the history of the South African education system (which has seen much reform), it is clear why there are so many varying teaching practices in schools depending on the experience of the teacher. Most teachers approach mathematics in a teacher-centred way, meaning that they do not let learners construct their own knowledge, and rather provide the information to them to complete the topic they are teaching (DBE, 2018). Due to this tendency to use teacher-centred approaches (DBE, 2018), the Minister of Education as of 2023, Angelina Motshekga, called for:

> [An overhaul] of the South African pedagogical-content knowledge outlook in Mathematics. [She] said that [South African teachers need] to reinvigorate the teaching of mathematics in its entirety – classroom learning practices, content, teaching, and assessments. [She] emphasised the urgent need to pay particular attention to the development of a new curriculum for initial teacher education, induction and continuing professional development. (DBE, 2018, p. 3).

This was detailed in the DBE's (2018) framework to shift teacher practises in mathematics. The framework details how teachers can use a learner-centred classroom to focus on teaching conceptual knowledge and procedural knowledge while achieving the aims of CAPS. It also gives examples of how this can be done across all phases, and through different mathematics topics. The document, therefore, is a roadmap for teachers to be able to apply the curriculum as intended. However, the document also states that although this could improve mathematics, it should be borne in mind that teachers have set pedagogical beliefs, and thus their own PCK.

Since the PCK of a teacher aims to facilitate effective teaching practices, teachers with limited exposure to alternative teaching approaches may struggle to determine the best way to teach a topic. The utilisation of teaching approaches such as PBL and PBA may remain limited if teachers lack familiarity with it, or fail to adjust their thinking about teaching (Aksela & Haatainen, 2019; Guntur & Retnawati, 2020). Guntur and Retnawati (2020) state that teachers' perception of a teaching approach will affect how they implement it, while Aksela and Haatainen (2019) state that for teachers to implement projects, they need to adjust how they think about teaching. This implies that the use of diverse teaching approaches across South African schools may be restricted by entrenched PCK and the pedagogical beliefs of teachers. To encourage the broader adoption of PBL, PBA, and similar methodologies, teachers must undergo a fundamental shift in their perspectives on the curriculum and the teaching of mathematics (DBE, 2018). The framework created by the DBE concludes with a series of recommendations to ensure that teachers will implement it. One of the ways in which the DBE wants to achieve this is through workshops and development programmes. This

means that if South Africa wants to see a change in how teachers teach mathematics, they need to change teachers' beliefs.

2.1.1.5 The education of teachers

A teacher's identity is influenced by both their training and their own school experiences (Mtika & Gates, 2010). While observing their educators and lecturers, they form ideas about effective teaching, which they carry into their careers. However, new concepts learned at university do not always translate into practice (Di Biase et al., 2021). This section examines what teachers learn in their training programmes, and the impact of school culture and pedagogy on the implementation of PBL and PBA.

- **Teacher educator programmes**

Developing learner-centred teaching approaches has been a major focus in Sub-Saharan Africa (DBE, 2018; Mtika & Gates, 2010). Despite curriculum and policy encouragement, PBL and PBA are still underutilised. This indicates that teachers are deeply rooted in traditional pedagogical beliefs, making it challenging to adopt new methods. Teachers' reluctance to adopt PBL or PBA, despite substantial evidence of its efficacy, highlights their resistance to change. Schweisfurth (2020) notes that teachers may resist policy changes consciously, or due to their own identities and perceived limitations.

Mtika and Gates (2010) found a paradox where student teachers in Malawi were taught learner-centred approaches through teacher-centred lectures. This issue likely extends to universities in South Africa. Du Plessis (2020) has observed that student teachers struggle to understand and implement learner-centred methods during practicums. Moreover, a participant in Mtika and Gates' (2010) study noted lower marks for not using learner-centred approaches, suggesting that student teachers might adopt these methods for grades rather than a belief in their efficacy. This lack of understanding can lead to ineffective implementation or abandonment thereof post-graduation.

The Initial Teacher Education Research Project (Deacon, 2016) shows significant variation in the mathematics content taught across five South African universities, contributing to knowledge gaps among teachers. Furthermore, Bowie et al. (2019) find that fourth-year student teachers perform worse in mathematical content knowledge, such as whole numbers, patterns functions, and algebra, than first-year students, which impacts the quality of mathematics education. They also find that overall, all student teachers from first year to fourth year struggle to answer higher-order questions. Teachers with insufficient mathematical understanding or reluctance to use learner-centred methods provide sub-par education. Effective teaching requires both a strong grasp of mathematical topics, as well as the ability

to employ learner-centred approaches. Without both, even well-planned lessons based on the use of projects cannot be expected to succeed.

- **Factors influencing teachers to not use learner-centred approaches**

Teacher education programmes play a crucial role in shaping teachers' beliefs. Although not the only factor, training teachers how to design and implement projects significantly influences the success thereof. Aksela and Haatainen (2019), Mentzer et al. (2017), Tsybulsky and Muchnik-Rozanov (2019), and Viro et al. (2022) all conclude that there is a need for teacher training in the use of projects for pre-service and in-service teachers.

In my own university experience, our coursework primarily promoted a teacher-centred approach. Some lecturers used learner-centred methods to demonstrate various approaches, while others adhered to teacher-centred methods. We were assigned tasks to plan lessons using teacher-centred approaches like PBL or PBA. Despite this training, and the resources available, many teachers, including myself, predominantly use teacher-centred approaches on a day-to-day basis. This phenomenon is widespread, prompting the question: Why has there not been a complete pedagogical shift in South Africa despite extensive research and education? The answer lies in the schools where teachers work.

Each school has its own culture, further shaping teachers' beliefs and practices in the classroom. This culture, along with its pedagogical orientation, influences teachers' epistemological beliefs (Du Plessis, 2020; Mtika & Gates, 2010). Consequently, new teachers often conform to the school's overall pedagogical orientation, disregarding their training. Schools thus "wash out" incompatible pedagogical ideas as student teachers become socialised into the school system (Mtika & Gates, 2010).

2.1.1.6 Lesson planning

One possible way in which teachers could ensure that projects are designed and administered correctly, and use PBL effectively, is how they plan and prepare for lessons (Bell, 2010). Lesson planning is the blueprint of teaching designs, and this will follow in their lesson (Ndihokubwayo et al., 2022). Teachers in public schools in South Africa are meant to align their lesson plans to those of CAPS, or in this case, the RATP, as required by the DBE (2023a). However, the use of a lesson plan, and its effectiveness in playing a role in the delivery of a lesson, is widely contested by teachers (Li et al., 2009). However, all primary school teachers in the public school system are expected to prepare lesson plans. This comes from the requirements stipulated by the South African Council for Educators' (SACE, 2011) code of Act 31 of 2000, and the National Protocol for Assessment for Grades R - 12 (2012), where teachers need to have a 'teacher file' that contains their 'planning documents'. These planning

documents are "the formal programme of assessment, evidence of learner assessment/performance, all formal assessment tasks and marking guidelines, annual teaching plan/work schedule, textbook used and other resources" (DBE, 2012, p. xii). Thus, the creation of lesson plans is mandatory for any public school teacher in South Africa; and the use thereof will allow for a connection between the curriculum, textbooks, and what is enacted in the classroom (Li et al., 2009).

If teachers already plan to do a project and use PBL or PBA, it ensures a more solid foundation for the lesson (Li et al., 2009). Teachers could even be more conscious of following the CAPS curriculum when designing a lesson. The use of lesson plans to prepare for the application of projects could allow for the overall better utilisation thereof, and could narrow the gap between the intended and enacted curriculum. Planning and preparing beforehand is also crucial to the success of PBL and PBA (Guntur & Retnawati 2020).

2.1.2 Teachers' use of teaching approaches

To be effective, teachers must know and utilise different approaches when teaching mathematics (English & Kitsantas, 2013). There are various teaching approaches, such as constructivism, discovery, learner-centred, teacher-centred, IBL, PBL and PrBL. Through the literature below, I further discuss the use of teacher- and learner-centred approaches.

2.1.2.1 Teacher-centred approaches (provider of knowledge)

In recent years, teacher-centred approaches have been viewed as the villain in education. In other words, it is seen as the reason for many of the shortcomings in learner performance in mathematics across an international scale. Teacher-centred approaches can be described as 'reception learning' (Jacobs, 2016), which refers to teaching content that is in its final form. This form of teaching favours the Behaviourist Learning Theory, and is used by teachers who subscribe to that theory. The use of this teaching approach leads to passive learning, which is where the learner is dependent on the teacher for knowledge and is a recipient of information, not a collaborator. People who advocate for this method believe that if the learner does not learn the information correctly, for example, a formula, then it will take a significant amount of time to correct the problem (Snowman & McCown, 2013).

According to Snowman and McCown (2013), this teaching approach has five characteristics:

- Teachers focus most classroom activities on mastering basic knowledge and skills. They do not focus on teaching skills such as collaboration, or help learners to build self-confidence or a curiosity in the topic.

- Teachers make all of the instructional decisions, such as how much work will be covered in the lesson, and if there is group work.
- Teachers keep the learners on task, always to progress their academic knowledge.
- Teachers design all of the lessons to include three main parts: demonstration, practise, and feedback.
- Teachers maintain a positive environment in the classroom.

Research on teacher-centred approaches shows mixed effectiveness. In America, these methods help struggling learners to improve (Snowman & McCown, 2013). However, in South Africa, issues like large class sizes and discipline problems make learner-centred approaches challenging (Chiphiko & Shawa, 2014; Du Plessis, 2020). Jacobs et al. (2016) argue for balancing both approaches in South African schools, noting that teacher-centred methods are not inherently detrimental. However, critics point out that these methods can lead to passive learning, and may limit student engagement (Ghafar, 2023; Namgyel, 2013; Petress, 2008). It should be noted, however, that properly integrating both approaches can enhance mathematics education.

Some of the notable teacher-centred approaches mentioned by Jacobs et al. (2016) are:

- The telling method – also known as ‘chalkboard talk’ or lecturing method;
- Scaffolding;
- Demonstrations; and
- Questioning.

2.1.2.2 Learner-centred approaches (facilitator of knowledge)

The use of a learner-centred approach creates an opportunity for active learning. The *Mathematics Teaching and Learning Framework for South Africa: Teaching Mathematics for Understanding* (DBE, 2018) defines a learner-centred classroom as one where there is a positive culture for interactions between the teacher and learners. This implies that learners actively engage in the classroom without being afraid of saying the wrong thing, or retaliation from the teacher. Darsih (2018) states that learner-centred teachings allow teachers to use a variety of methods to teach content, and “shifts the role of the teachers from givers of information to facilitator in student learning” (p. 33).

According to Weimer (2012), there are five characteristics of learner-centred teaching, where teachers:

- Should not teach all of the content. Learners should also be part of the lesson, doing examples, presenting ideas, asking questions, and perhaps even organising content to present to the class as a flipped classroom activity.
- Should teach learners problem-solving, critical thinking, evaluation, and analytical skills. This is accompanied by a good knowledge base of the topic they are learning about.
- Should encourage learners to reflect on what they are learning and through what methods they are learning it.
- Need to get learners curious about the subject, and inspire them to learn more about the topic by making them the centre of the learning process.
- Must allow learners to collaborate and learn from each other. They should encourage learners to draw on each other's ideas, experiences, and prior knowledge.

Implementing PBL and PBA in South African Grade 6 mathematics classes exemplifies a learner-centred teaching approach with numerous benefits. These methods provide opportunities for learners to develop effective communication and collaboration skills. This may empower learners to take control of their knowledge development by completing activities independently, and it could foster an interest in the subject matter (Fisher et al., 2020; Kokotsaki et al., 2016; Serin, 2019). However, despite these advantages, these approaches have drawbacks. For example, noise and disruption in the classroom, if not properly managed, can adversely affect learners' learning (Chiphiko & Shawa, 2014). These challenges can be particularly pronounced in South Africa due to differences in classroom environments and resources. Du Plessis' (2020) has identified three main challenges faced by South African student teachers in implementing learner-centred approaches: difficulties in maintaining classroom discipline; challenges in using the approach in overcrowded classrooms; and time constraints that prevent teachers from focusing adequately on each learner or group. Thus, while PBL and PBA can significantly enhance Grade 6 mathematics education, the implementation thereof must be carefully adapted to address these specific challenges within the South African context.

There are many learner-centred approaches that teachers can use. Teachers will often use a combination of them, suggesting that they adapt the approach to the needs of their classroom. Some of these approaches are:

- Inquiry-based learning;
- Discovery-learning;

- Gamification;
- Co-operative learning;
- Experimentation;
- Problem-based learning;
- Project-based learning; and
- Project-based assessment.

Another important aspect of learner-centred education is the teacher as a facilitator (Darish, 2018; Di Baise et al., 2021; Muhtarom et al., 2019; Smart et al., 2012). In the context of mathematics education, a facilitator of learning is an educator who guides and supports learners in their learning journey rather than simply delivering content (Darish, 2018; Di Baise et al., 2021; Muhtarom et al., 2019). Their role in the use of projects in mathematics is to create an environment that encourages exploration, critical thinking, and problem-solving (Darish, 2018; Di Baise et al., 2021; Muhtarom et al., 2019). Facilitators design and implement PBL activities that are meaningful and relevant to learners, helping them to see the real-life applications of mathematical concepts. Moreover, they provide the necessary resources and scaffolding to support learners as they work on projects, ask probing questions to stimulate deeper thinking, and encourage collaboration and communication among students. Additionally, facilitators assess both the process and the product of learners' work, providing feedback that helps learners to reflect on their learning and improve their skills. Through this approach, facilitators aim to develop learners' autonomy, confidence, and enthusiasm for mathematics.

2.1.2.3 Mixed approach

In this study, a mixed approach to teaching is considered a blend of learner-centred and teacher-centred methods. While limited research has explored this combination in South Africa, existing studies on the individual approaches indicate that a hybrid method could be beneficial for the country's unique context. Du Plessis (2020) notes that after evaluating the pros and cons of the learner-centred approach, combining both approaches could mitigate their respective disadvantages (Du Plessis, 2020).

In Mtika and Gate's (2009) study, they noted that in earlier literature from 1993, teachers were already mixing teaching approaches. They then suggested that this is because of teachers' pedagogical beliefs, but also due to curriculums being unable to fully support learner-centred teaching every day in class. Their study found that student teachers do not regard themselves

as being able to apply a learner-centred approach all the time due to the curriculum (Mtika & Gates, 2009).

It would appear that South Africa faces a similar issue with the CAPS curriculum. While it supports learner-centred approaches like PBL, PBA, and other methods, the extensive content that needs to be covered in a year presents challenges. Teachers who are managing large classrooms of around 40 learners, along with class time disruptions and discipline problems, may find it difficult to consistently implement learner-centred approaches. A balanced approach, combining both learner-centred and teacher-centred approaches, could be more effective. Teachers could use both approaches within the same topic, or choose one approach for one topic and the other for a different topic. However, teachers must be well-educated about the curriculum and understand that for projects, PBL and PBA are often the best methods to teach the content.

2.1.3 Teachers' design and administering of projects as a formative assessment with PBL and PBA

The CAPS curriculum encourages teachers to design projects that are relevant, meaningful, and engage learners in using multiple competencies (DBE, 2011). Additionally, the DBE (2011) aims to create opportunities for learners to develop and apply their understanding, highlighting the importance of PBL. However, Penuel et al. (2014) have identified a persistent issue where a gap exists between the intended and enacted curriculum. The DBE also acknowledges this discrepancy, stating that the CAPS curriculum is on par with international standards and that learners should be able to apply their content knowledge to solve contextual problems. The problem lies in how teachers interpret the curriculum. This suggests that when the curriculum requires teachers to implement projects and conduct both formative and summative assessments, teachers either fail to do so or do not fully adhere to the curriculum's aims and requirements.

2.1.3.1 Projects in mathematics

Since the start of democracy in South Africa, the DBE has moved away from traditional summative assessments towards continuous, formative assessments in all subjects (Van Staden & Motsamai, 2017). In mathematics, formative assessments are crucial and should be used throughout the year, aligning with the curriculum's cognitive levels and addressing learner misconceptions (DBE, 2018). While summative assessments remain mandatory, the curriculum highlights that projects, especially in data handling, are encouraged (DBE, 2011). Projects can also be used in other topics like geometry and geometric patterns.

To design an effective project, teachers need to understand its essential characteristics. Fisher et al. (2020) describe projects as tasks where learners solve real-life problems over time, while Lazić et al. (2021) view them as interdisciplinary problems tied to mathematical content. Projects should build on existing knowledge, aligning with constructivist principles. Thomas (2000) outlined five key features of a good project: (1) A central idea; (2) Essential questions; (3) Opportunities for problem-solving; (4) Learner agency; and (5) Realism. The first two characteristics of a good project are imperative for a successful project. A project is considered successful if there is evidence that learners were allowed to construct their own knowledge about a topic, and could demonstrate a deeper understanding thereof (Fisher et al., 2020). One can assess whether a deeper understanding was attained by learners through a presentation of their work, or from their solution to the problem (Fisher et al., 2020). For a learner, a project that might be regarded as successful helps them to understand the topic better (Serin, 2019).

Projects are guided by main essential questions with a central idea to underpin the whole activity. Main essential questions, also known as driving questions, are fundamental to a project as they guide the work, set the context, and continuously remind learners of the objective behind the various activities within the project (Blumenfeld et al., 1991; Hasni et al., 2016; Hmelo-Silver, 2004; Krajcik & Shin, 2014; Thomas, 2000). Driving questions also ensure that a project has a purpose, is cohesive, and sticks to a central topic (Mentzer et al., 2017). For younger learners, I argue that there should not be one question that directs the entire project as these learners still need guidance and prompting to do the project. Thus, sub-essential questions should exist. In their literature study, Fisher et al. (2020) include an example of a project that possesses the qualities of a good project. They further explain how it could be implemented using the George Lucas Educational Foundation (2007) model for the implementation of PBL. This project had a main essential question and guiding instructions to help learners complete the project. These instructions can be seen as sub-essential questions. Sub-essential questions should guide learners to answer the main essential question, which usually takes the form of an end product (Blumenfeld et al., 1991; Krajcik & Shin, 2014; Tal et al., 2006).

End products are seen as a distinguishing feature of PBL, setting it apart from problem-based and inquiry-based learning (Hasni et al., 2016; Sahin, 2013). These end products showcase learners' cumulative understanding of the topic (Blumenfeld et al., 1991; Novak & Krajcik, 2020). They include tangible creations, such as posters, PowerPoint presentations, models, websites, or drawings (Blumenfeld et al., 1991; Krajcik & Shin, 2014). The process of creating end products enhances learning as learners are likely to learn more effectively when they create tangible representations of their ideas (Krajcik & Shin, 2014).

Teachers need to ensure that the projects they design contain these characteristics, especially if they are being used as a formative assessment. Furthermore, usually, if a project is being assessed, teachers need to assess each part/phase/section of the project before a learner can carry on with the next part so that they do not carry over their mistakes to the next part. For example, if a project concerns data handling where learners have to (1) Collect data; (2) Find the mean, median, and mode; (3) Draw a bar graph; and lastly (4) Write up conclusions guided by certain questions, teachers should first make sure that the learners collect the data correctly according to the main essential questions before they can proceed with finding the mean, median and mode. If the data is collected correctly, teachers then have to make sure that the mean, median and mode have been calculated correctly before learners can draw a bar graph. Thus, in doing so, teachers ensure that learners can learn from their mistakes and achieve the best mark possible.

The use of projects allows for various advantages in the classroom. In light of this, the DBE (2018) emphasises the use of assessments that are more than just control tests, which is why the use of a project is not only progressive of the DBE, but valuable to learners. Cline et al. (2019) state that projects can (1) Allow learners to think creatively and critically; (2) Be used across the curriculum to cover more content; (4) Improve their writing skills; and (5) Help learners build their communication skills (if done in group settings). The last of these directly contributes to the 21st-century skills that are crucial for learners to function in society. If learners feel like they “listened well to other students’ ideas, and if they believed their own opinions were heard,” they will eventually master this skill (Bell, 2010, p. 41)

With this in mind, we can see how projects can be useful in a mathematics classroom. However, Cline et al. (2019) also state that projects have the potential to be ineffective in certain situations. If teachers mark the final project at the end of a term or the end of a given topic, learners will not have time to improve. Another possible reason why projects might be ineffective is if teachers let learners take projects home, where they can plagiarise or cheat using online resources like open-source artificial intelligence, or their parents do the projects for them. Lastly, projects cannot be used for every topic in mathematics effectively. However, many of these concerns can be worked around or prevented. Teachers could, for example, prohibit learners from doing projects at home, or they could be more diligent in choosing when to do the projects and on what topic(s). For these reasons, I agree with the DBE that projects should be done in the classroom as a formative assessment.

2.1.3.2 PBL and PBA in mathematics

PBL has a kaleidoscope of definitions. Serin (2013) defines PBL as “a method which helps students develop their skills and knowledge while investigating a challenge for a period of

time" (p. 223). Fisher et al. (2020), maintain that PBL is "a learning model that focuses on the main concepts and principles of a discipline, engages students in problem-solving and reasoning activities" (p. 2). Another perspective of PBL is provided by Nasution et al. (2021), who state that PBL is "a learning model that is conceptualized as a process, timed, problem-focused, meaningful learning unit by integrating concepts from several components of knowledge, discipline and collaborative learning activities" (p. 110). Each of these perspectives of PBL gives a broader understanding of what it entails and how to employ it.

In line with the above statements, projects have various advantages. Fisher et al. (2020) state that PBL allows for (1) Authentic real-life activities that allow for the strengthening of conceptual knowledge; (2) Learner agency; (3) Active learning; (4) The potential for feedback from teachers for improved critical thinking; (5) Improvement in learner motivation; and (6) Improvement of a learner's problem-solving skills. From these advantages, it can be seen that PBL holds many benefits for the teaching and learning of mathematics in South Africa. However, Aksela and Haatainen (2019) pose an interesting view on possible barriers to the implementation of PBL in the classroom. They state that teachers could be opposed to learner-centred teaching approaches such as PBL due to inexperience with this type of teaching approach, which was supported in Guntur and Retnawati's (2020) study. Aksela and Haatainen (2019) further state that the inability to design and administer assessments effectively could hinder the use of PBL in conjunction with those assessments. Lastly, they state that another possible barrier is teachers' ability to manage time effectively. Aksela and Haatainen (2019) also state that if teachers do not receive adequate support and training to apply PBL, it will not be effective, and may be something that teachers shy away from. Although these barriers could be predominant in South African classrooms, it does not take away the from fact that it is an effective teaching approach, and that teachers need to be educated on it, especially if it will enhance the use of a project.

The George Lucas Educational Foundation (2007) proposes six steps for implementing PBL in the classroom: (1) Set up essential question(s); (2) Design a plan for the administration of the project; (3) Set due dates; (4) Monitor the learners; (5) Assess the learners' final product; and (6) Evaluate the learning experience. A teacher must understand that PBL is, by design, a constructivist and learner-centred approach as well, which inherently makes it a teaching approach that allows for active learning (Fisher et al., 2020; Iwamoto et al., 2016; Sahin, 2013). PBL thus allows learners to play an active role in the creation of their understanding and knowledge (Jacobs et al., 2016).

PBA is a teaching approach that uses summative assessments to measure the understanding and skills that learners gain through PBL. However, there has been limited research on PBA.

Kokotsaki et al. (2016) discuss PBL specifically in light of assessments, emphasising the "importance of grading students using a variety of assessment methods, including individual and group grades, with a focus on individual performance over group performance" (p. 282) They also highlight the need for adequate debriefing of projects by demonstrating reflection strategies and collecting formative evaluation information from students about the project and how it might be improved.

This primarily addresses how projects should be assessed in PBL, but can also be considered in the context of PBA. While PBL serves as a formative assessment focused on learning through projects, PBA functions as a summative assessment that evaluates learners' understanding through the use of projects. Thus, the two teaching approaches are quite similar, with the key difference being that PBL is implemented to teach content, whereas PBA is conducted after the content has been taught. I argue that the George Lucas Educational Foundation's model for PBL can also be applied to PBA, with the primary difference being the focus of each project.

2.1.4 Departmental guidelines

Navigating the education system in South Africa demands a comprehensive understanding of the guiding principles encapsulated in the departmental guidelines of the DBE. These directives (circulars, policies, legislations, acts, CAPS, ATP, and RATP) form the backbone of the nation's educational framework, outlining the standards and expectations to which educators and institutions must adhere. In the context of teaching, departmental guidelines serve as a roadmap, shaping pedagogical approaches, curriculum design, and assessment strategies. The following section discusses the original CAPS, the RATP, and assessments.

2.1.4.1 CAPS and RATP

A curriculum can be defined as a "national program of learning for all learners in all schools" (Jacobs et al., 2016, p. 74). It is also understood as "a body of knowledge or content that needs to be transmitted" and "a means to achieve certain ends in learners" (Jacobs et al., 2016, p. 74). These aspects are evident in the CAPS curriculum, which outlines extensive educational goals and content for learners. However, there exists a distinction between the intended and enacted curriculum, both playing crucial roles in shaping educational outcomes. The intended curriculum in South Africa reflects the national policies and educational objectives set by the DBE to provide a comprehensive framework across subjects and grades. In practice, the enacted curriculum often deviates due to factors like resource limitations, teacher interpretations, and school-related circumstances such as learner behaviour. The way in which teachers interpret the curriculum significantly influences how projects are

implemented, and should be considered in discussions about curriculum design and administration.

Additionally, according to the National Education Policy Act (NEPA) No. 27 of 1996, Section 3 (4)(l),

> The Minister [of Basic Education] shall determine national policy for curriculum frameworks, core syllabuses and education programmes, learning standards, examinations and the certification of qualifications, subject to the provisions of any law establishing a national qualifications framework or a certifying or accrediting body. In terms of this legislation, the Minister has the power to develop national policy and the power to amend, repeal or vary such policy (DBE, 2022, p. 1).

This in turn means that the decisions of the DBE about what teachers should use to guide them in administering subject content lies with them. In the Circular (DBE, 2022), they amended the RATP from 2022 and stated that it would be implemented for 2023-2024. All teachers were then expected to use the 2023-2024 RATP as of January 2023.

Annual Teaching Plans (ATPs) were originally intended as a guide for lesson planning aligned with the curriculum. The ATP has evolved and adjusted certain aspects of the curriculum for practical implementation while maintaining its core principles. Key differences include the omission of explicit curriculum and subject aims, cognitive level guidelines, and a dedicated section on assessments, thus lacking detailed definitions of assessment. The ATPs initially posed minimal issues in the early 2000s, when they were closely aligned with the curriculum. However, challenges arose later, particularly in 2020, due to the COVID-19 pandemic. This prompted the DBE to introduce the RATP to compensate for lost class time. This adjustment led to debates and disparities among schools, with some insisting on adhering to the full curriculum despite DBE directives, exacerbating educational inequalities in South Africa.

Furthermore, the RATP lacks comprehensive information on assessments compared to the original curriculum, omitting detailed definitions such as those for projects. Instead, it focuses more on prescribed actions without the broader educational context or cognitive level guidance. For instance, in the mathematics RATP for Grade 6, references to projects are minimal, and it only informs teachers on what content the project should cover. The RATP also does not include the aims of the curriculum or the cognitive levels. The aims referred to are to:

- Identify and solve problems and make decisions using critical and creative thinking.
- Work effectively as individuals and with others as members of a team.
- Organise and manage themselves and their activities responsibly and effectively.

- Collect, analyse, organise, and critically evaluate information.
- Communicate effectively using visual, symbolic and/or language skills in various modes.
- Use science and technology effectively and critically showing responsibility towards the environment and the health of others.
- Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation (DBE, 2011, p. 5).

Speaking from personal experience, it is fair to state that the DBE assumes that teachers know of these aims and the cognitive levels as they are mentioned at every subject meeting, along with the implementation of formative assessments. However, at schools like my own, not all of the teachers attend these subject meetings. Only one teacher per grade attends, and those who do not attend might not read up on the meeting minutes or go through the PowerPoints that were used. Thus, they are ignorant of these concerns.

Lazić et al. (2021) further state that knowledge that is specific to the curriculum should be achieved or addressed in a project. Viro et al. (2020) explain that projects should be aligned with the curriculum to allow for in-depth content teaching to take place. Thus, projects need to be aligned with the objectives of the curriculum, and should address concepts and skills that lend themselves to being developed into a project. Thus, when the curriculum uses keywords such as ‘investigate’, ‘problem-solving’, ‘context’, ‘interpret’, and ‘real-life’ when describing the concepts and skills that need to be covered in each content area and topic, the concept and skill can be covered and successfully achieved through the use of a project. This also extends to the aims of the curriculum that need to be achieved at the end of Grade 6.

2.1.4.2 Assessments

The purpose of assessment is to help learners determine how they are performing in a subject or topic (Jacobs et al., 2016). Assessments in South African schools are governed by the National Protocol for Assessment (NPA). Its purpose is to ensure that assessments are standardised, and that they allow for the “recording and reporting process for Grades R-12 within the framework of the National Curriculum Statement” (Jacobs et al., 2016, p. 313). The NPA defines assessments as:

> A process of collecting, analysing and interpreting information to assist teachers, parents and other stakeholders in making decisions about the progress of learners… Classroom assessment should provide an indication of learner achievement in the most effective and efficient manner by ensuring

> that adequate evidence of achievement is collected using various forms of assessment (DBE, 2012, p. 3).

The NPA describes multiple types of assessments used within the curriculum, but for this study, the focus is drawn to formative and summative assessments. Formative assessment is defined as an aid to the teaching and learning process, hence the term 'assessment *for* learning' (DBE, 2011; DBE, 2012; DBE, 2018). Whereas summative assessment can be defined as an assessment that counts marks towards learners' reports, and is completed after the content the project is based on has been taught (DBE, 2011; DBE, 2012; DBE, 2018). CAPS stipulates that a project as a summative assessment must be done as part of learners' School-Based Assessments (SBAs) in Term 3, but it does not explicitly state that a project as a formative assessment must be done during the year. It could be that the department assumes that teachers are aware of formative assessments since they mention it often in the circulars sent out yearly, as well as in CAPS as the DBE states that "[assessments] should be both informal and formal" (DBE, 2011, p. 293).

In Circular 1 of 2023, the DBE states that formative assessments "should be used by teachers during teaching and learning to support and prepare learners for summative assessments. This in turn will assist teachers to obtain evidence for use in supporting learners to improve their knowledge, understanding and skills" (p. 3). Circular 1 of 2023 mentions formative assessments, but the majority of the document focuses on summative assessments, specifically the subject weightings, compliance with the assessment programme in the RATP, and mid- and end-year examinations. However, despite the documents explaining what summative and formative assessments are, there are teachers who still confuse the terms. Arrafii and Sumarni (2018) found in their study that teachers have a limited understanding of formative assessments. In this study, the data presented indicates a similar occurrence, raising the question as to why teachers confuse these assessments despite the resources available to them. Aside from a workshop hosted by the GDE in 2023 about PBL that I attended, there has not been much more support on how to use it. As for formative assessments, in general, they are mentioned in subject meetings but are brushed past quickly, just being another bullet point to cover. It is a concern of the department, but not much effort is put into encouraging and supporting its usage as opposed to summative assessments.

2.1.4.3 Cognitive levels

For a teacher to achieve the outcomes of assessments such as projects, they must also achieve the outcomes of the curriculum (Mhlolo & Venkat, 2009). Part of the correct design of a project in South Africa is how it aligns with the cognitive levels. Any assessment given to Grade 6 learners needs to comply with the cognitive levels of CAPS, no matter if it is a

formative or a summative assessment. Cognitive levels describe the different stages or levels at which people think and process information. These levels can be categorised into various models, referring to the CAPS' mathematics curriculum cognitive levels, which can be broken down into four hierarchical levels, namely: (1) Knowledge; (2) Routine Procedures; (3) Complex Procedures; and (4) Problem Solving (DBE, 2011).

The NPA does not explicitly mention adherence to the cognitive levels in the curriculum, but it states that SBAs should be "guided by assessment components as specified for each subject in Chapter 4 of the Curriculum and Assessment Policy" (DBE, 2012, p. 8). Additionally, CAPS states in Chapter 4 that "formal assessments should cater for a range of cognitive levels and abilities of learners" and "the forms of assessment used should be appropriate to the age and cognitive level of learners" (DBE, 2011, p. 295). The NPA and CAPS refer specifically to aligning SBAs with the cognitive levels. In Chapter 4 of CAPS, the cognitive levels have an allocated percentage. This percentage indicates the distribution of questions that should be on that level. The cognitive level and corresponding percentage are displayed in Table 2.1 below.

Table 2.1

Spread of CAPS' cognitive levels (DBE, 2011)

Cognitive Level	**Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines**
Knowledge	25%
Routine procedures	45%
Complex procedures	20%
Problem-solving	10%

The main essential questions need to be on the cognitive level of 'problem-solving' because they involve real-life situations and higher-order thinking. The cognitive level of problem solving is defined by CAPS as problems where non-routine, higher-order understanding, and the possible deconstruction of the question, are needed (DBE, 2011). As for sub-essential questions, I argue that they should be on the other cognitive levels, but the project need not achieve a perfectly balanced number of questions on each level, as the curriculum prescribes. There merely needs to be a sense of balance in the questions, meaning that they range in difficulty, but most importantly, that they guide learners to complete the project.

2.2 LITERATURE REVIEW CONCLUSION

This literature review examined the processes of teaching and learning mathematics, with a specific focus on the use of projects. It addressed the design and implementation of projects, as well as Project-Based Learning (PBL) and Project-Based Assessment (PBA). Additionally, it considered departmental guidelines and their impact on the use of projects, formative assessments, and summative assessments.

This literature review highlighted both the benefits and challenges associated with PBL, PBA, and project use. It emphasised the need for teachers to carefully interpret the curriculum and utilise tools such as the RATP to ensure the effective application of PBL and PBA. There is a need to understand the barriers that prevent South African teachers from employing PBA, and how they design and implement projects. Insight into these factors could provide valuable guidance to other Grade 6 teachers regarding this teaching approach and formative assessment.

2.3 CONCEPTUAL FRAMEWORK

The conceptual framework of this study explores the use of PBL and PBA by Grade 6 mathematics teachers in South Africa. Through the associated literature, it assisted in providing insight into the internal and external factors influencing the adoption of PBL and PBA. Adapted from the George Lucas Educational Foundation's PBL steps (2007), the framework accommodates PBA, noting that PBL is linked with formative assessments (assessment *for* learning), and PBA with summative assessments (assessment *of* learning).

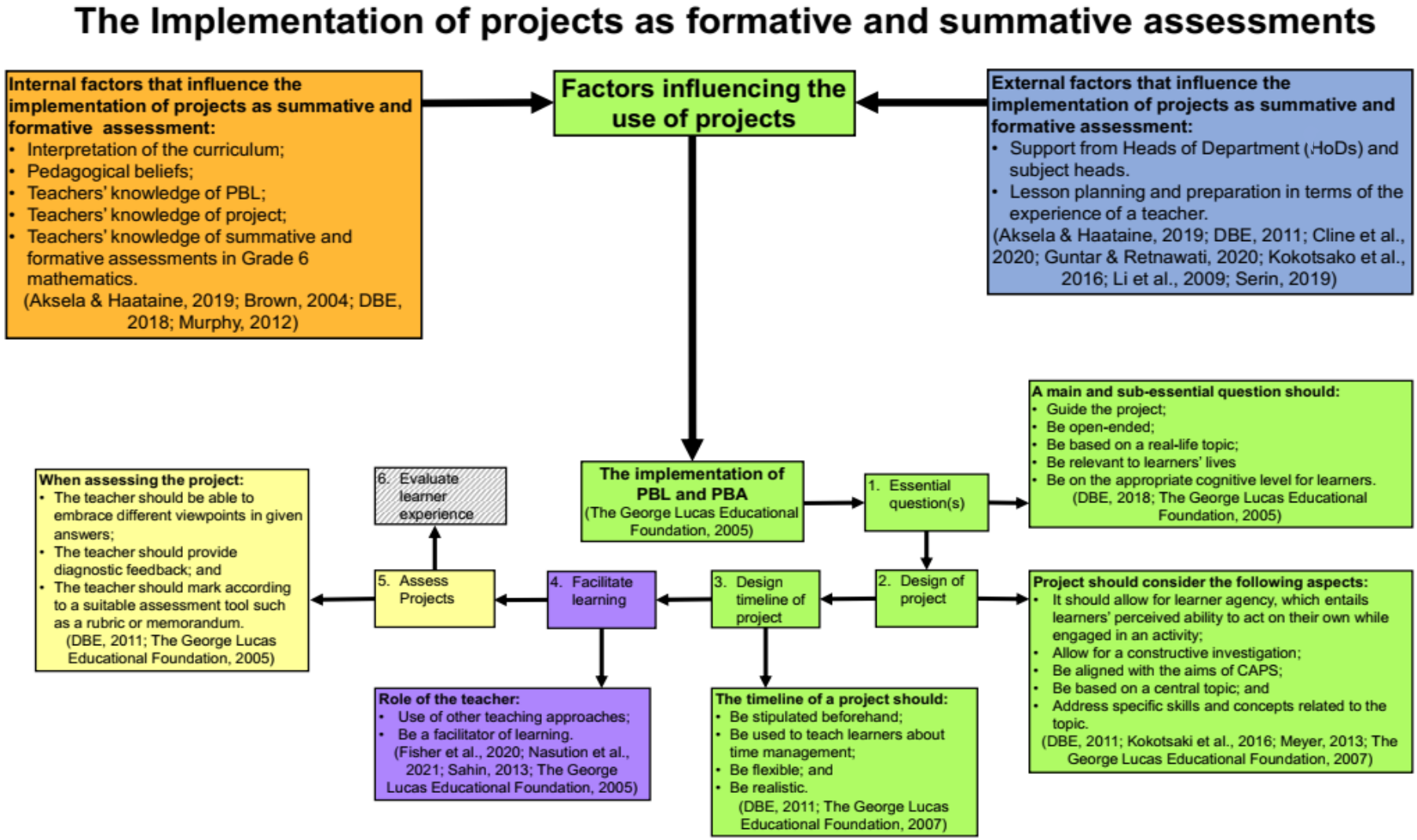
The framework addresses essential questions, project characteristics, timeline design, and teacher facilitation. Figure 2.1 visualises the framework, detailing the process from choosing PBL and PBA, to project administration. The key components include:

- Internal factors influencing the choice to use PBL (Aksela & Haatainen, 2019; Brown, 2004; DBE, 2018; Murphy, 2012).
- External factors influencing the choice to use PBL (Aksela & Haatainen, 2019; Cline et al., 2020; DBE, 2011; Guntar & Retnawati, 2020; Kokotsaki et al., 2016; Li et al., 2009; Serin, 2019).
- Steps to implement PBL and PBA (George Lucas Educational Foundation, 2007).
- Essential questions (DBE, 2018; Kokotsaki et al., 2016; George Lucas Educational Foundation, 2007; Serin, 2019).

- Project design (DBE, 2011; George Lucas Educational Foundation, 2007; Thomas, 2000).
- Design of the timeline (DBE, 2011; George Lucas Educational Foundation, 2007).
- Facilitation of the project (Fisher et al., 2020; Nasution, 2021; Sahin 2013).

Figure 2.1

Conceptual framework: The implementation of projects as formative and summative assessments



2.3.1 Explanation of the conceptual framework

The conceptual framework of this study was shaped by the research questions and existing literature on this topic. Figure 2.1 illustrates the process through which teachers choose to use PBL or PBA as their instructional approach, and then proceed to design and implement a project using either method.

Within this framework, the first mediating factor is external influences, such as time management and support from superiors, which impact teachers' choice of approach. The second mediating factor is internal influences, including prior beliefs and pedagogical knowledge, which also shape this decision.

The next stage in the framework outlines the process of implementing either PBL or PBA. Each step in this process adheres to specific criteria for success, as outlined by the George Lucas Educational Foundation's (2007) framework. Steps relevant to both PBL and PBA are denoted in green, while those specific to PBL are in purple, and those specific to PBA are in yellow. Step 4, *facilitation of learning*, while applicable to PBA, was only recognised for PBL because I observed teachers using PBL and not PBA. This was due to a later decision after the data collection process to shift the view of the study to not only focus on PBL, but also on PBA to a lesser extent. Step 5, *assess the project*, applies only to projects as summative assessments, in my opinion, since they need to be evaluated promptly and feedback provided to learners as the project's marks contribute to their end-of-term report. Although teachers could use this method for formative assessment, it is not necessary because Step 4 requires teachers to monitor learner progress by marking project phases before advancing to the next phase. This process should also be done for summative assessment projects as well, but as stated, I did not observe this and thus cannot report on it. The final step, *evaluating learner experiences*, is shown in grey to indicate that it was not observed in this study, although it is part of the overall PBL and PBA process, and should be acknowledged.

2.3.1.1 Internal factors influencing the implementation of PBL

The following internal factors impact teachers' decision to use PBL and PBA. These factors, as highlighted in the literature, have been considered within the South African context. Each concept is interconnected, with overarching themes and influences affecting the use of projects. It is for this reason that these factors are considered for PBA and PBL since they impact the implementation of both.

- **Interpretation of the curriculum**

Curriculum interpretation involves understanding and analysing curriculum content and requirements. Teachers are expected to examine the curriculum to grasp the goals and expectations set by educational authorities. However, teachers' interpretations thereof may differ, leading to a gap between the intended and enacted curriculum (DBE, 2018). This disparity often results in teachers not teaching content as prescribed by CAPS, such as improperly designing and administering projects. Today, South African teachers also use the RATP, which does not suggest projects as formative assessments, potentially contributing to the lack of PBL and PBA implementation. Misunderstandings about the curriculum further affect teaching practices. Chapter 4 will examine how participants enact the curriculum, providing a comprehensive view of both the intended and enacted curriculum. In this study, observing classroom practices, project designs, and pedagogical beliefs further revealed how the participating teachers interpreted the curriculum.

- **Pedagogical beliefs**

The pedagogical beliefs of teachers significantly influence how they prepare for lessons, interpret curriculum content, and deliver instruction. These beliefs, which are synonymous with their teaching philosophy, provide deep insights into why teachers adopt specific classroom practices. Teachers with well-established PCK rooted in teacher-centred practices may resist adopting approaches like PBL or PBA due to the required shift in their mindset (Aksela & Haatainen, 2019). For instance, some South African mathematics teachers predominantly use teacher-centred, algorithmic methods, aligning more closely with Platonist or Instrumentalist views than Constructivist ones (DBE, 2018). Consequently, it becomes challenging for them to implement teaching approaches that necessitate PBL or PBA, which comprise learner-driven knowledge construction (Aksela & Haatainen, 2019; Mentzer et al., 2017). Conversely, educators who strongly endorse learner-centred methodologies are predisposed to embrace such approaches, demonstrating openness, even towards unfamiliar methodologies like PBL or PBA.

- **Teachers' knowledge of PBL**

Teachers who do not know what PBL is will not apply it in the classroom. Mentzer et al. (2017) suggest that if teachers do not know about PBL or how to properly implement it, they will not implement it accordingly. Subsequently, the beliefs a teacher has regarding what PBL is and how it should be applied will determine their application thereof in the classroom. If their belief is skewed, then this will influence their application thereof (Auslander et al., 2023). Most teachers in South Africa require training to use PBL effectively and to learn about what it

entails (Aksela & Haatainen, 2019; Mentzer et al., 2017). Once teachers are better prepared to use it, and their PCK has developed in this regard, they will apply it more often in the classroom.

- **Teachers' knowledge of the use of projects**

Teachers are aware that projects are required components of the SBAs for Grade 6 (DBE, 2011). However, fewer teachers may be aware that projects are recommended by CAPS for use as formative assessments. Without this knowledge, teachers may not utilise projects in this capacity. Moreover, teachers need to understand the essential qualities of a good project, as outlined by Thomas (2000). Without this understanding, teachers may struggle to design and administer projects effectively. Conversely, armed with this knowledge, teachers are likely to feel more confident in utilising projects appropriately.

- **Teachers' knowledge of formative and summative assessments in Grade 6 mathematics**

Since CAPS (DBE, 2011) mentions formative assessments without providing a detailed explanation of what they entail, the DBE assumes that teachers are knowledgeable about them and know how to administer them correctly. However, CAPS mandates formative assessments less rigorously than summative assessments, despite DBE (2011) recommendations. Consequently, teachers often prioritise content delivery over formative assessments (DBE, 2018), possibly due to a lack of understanding or proper application of formative assessments. These assessments should align with the curriculum's cognitive levels, preparing learners for summative assessments. In this study, I initially focused on formative assessments, later including summative assessments as I realised that it would better answer the primary research question.

2.3.1.1 *External factors influencing the implementation of PBL*

The following are external factors that influence teachers' choice in the use of PBL and PBA. These factors stood out in the literature, and were considered for the South African context as well. Each concept is interrelated with the other as some overarching themes and factors influence PBL, PBA, and projects. As with internal factors, these factors were considered for PBA and PBL.

- **Support from subject heads and Heads of Departments (HoDs)**

Aksela and Haatainen (2019) stress the need for teacher support and training for effective PBL and PBA implementation. Subject heads and HoDs play a crucial role in shaping

classroom practises as new teachers often follow the prevailing pedagogical beliefs of their school (Du Plessis, 2019; Mtika & Gates, 2010). The misdesign and bad administration of assessments often stem from inadequate guidance from these leaders, who typically approve assessments. PBL focuses on using projects as formative assessments, while PBA uses them as summative assessments. If subject heads and HoDs lack knowledge about these approaches or CAPS requirements, teachers are unlikely to adopt them (Aksela & Haatainen, 2019).

- **Lesson planning and preparation**

Bell (2010) stated that the planning and preparation of PBL and projects is one of the most important preparation that teachers have to do. If teachers plan their lessons, they set up a blueprint that they will follow (Ndihokubwayo et al., 2022), and it provides a solid frame for the lesson to operate. It will also ensure that teachers consider parts of the curriculum, such as the prescribed use of projects as a formative assessment. If teachers have lesson plans where they plan the use of PBL and projects as a formative assessment, they will be prepared and probably more confident using it. The participants in Guntur and Retnawati's (2020) study also suggested that exceptional planning for projects allowed them to function more effectively. They recommended that teachers plan clear instructions for their learners, and determine all of the resources they need for the project; the time allocated for the project needs to be appropriate; groups need to be divided fairly and must be thoroughly; and the assessment of the project needs to be transparent and fair.

- **Teachers' experience**

The level of experience that teachers have will influence how they teach content in the mathematics classroom, especially using PBL and PBA. As discussed, experienced teachers usually have an established PCK, making it difficult from them to alter their beliefs (Aksela & Haatainen, 2019). Alternatively, many teachers are still open to further development, which provides an opportunity to develop more workshops for teachers. Thus, teachers who might have many years of teaching experience might not be willing to choose PBL since they are used to the more traditional teaching approaches that they started using many years ago. However, the same could be said about teachers who have too little experience. These teachers might not know about PBL, or if they do, they lack the appropriate experience to implement it properly. Teachers' level of experience also impacts how well they know the curriculum. Teachers who joined the profession in the last three years will be more versed in the RATP, whereas a teacher who has more than five years of experience will be more acquainted with the original curriculum. How long teachers have been in the profession could

also mean that they may have more experience in PBL than younger teachers. However, even though they might have more years of experience, this does not necessarily mean that they are automatically better at using PBL than a teacher who has only just started using it.

2.3.1.2 *The George Lucas Educational Foundation's steps for implementing PBL*

There are six steps described by the George Lucas Educational Foundation to implement PBL. However, for this study, I will only focus on the first five as the last one was not relevant to answering the research questions. The five steps have also been adapted to the South African context, specifically with CAPS in mind.

- **Essential question(s) – Step 1 (formative and summative assessment)**

A main essential question can be defined as a question that is topical, and guides learners to engage in higher-order thinking. It entails a central topic; open-ended question(s); and presents a problem that learners must solve by reaching a conclusion that represents the end product (Blumenfeld et al., 1991; Hasni et al., 2016; Hmelo-Silver, 2004; Kokotsaki et al., 2016; Krajcik & Shin, 2014; The George Lucas Educational Foundation, 2007; Thomas, 2000; Serin, 2019). The main essential question(s) ultimately guide learners to provide answers and an end product in a project (Kokotsaki et al., 2016; Serin, 2019; The George Lucas Educational Foundation, 2007). This end product is the final presentation of learners' understanding. The main essential question targets the highest cognitive level, problem-solving, with sub-questions addressing the various levels. While achieving a perfect cognitive level spread in a project can be challenging, problem-solving remains crucial.

Learners need to answer the main essential question, and it can be answered in any form suitable for the project. For example, the answer could be provided through a PowerPoint presentation, or the creation of a poster or an object. For younger learners, the main essential question is often accompanied by guiding questions to ensure that they get to the final product, conclusion, or answer. I refer to these questions as sub-essential questions. These questions should not function in solidarity, but should rather build upon each other, metaphorically forming steps in a staircase that learners climb to reach the end. These questions should be directly related to the main essential question.

- **Design the project – Step 2 (formative and summative assessment)**

When designing a project, certain factors need to be considered. Based on research from Kokotsaki et al. (2016) and The George Lucas Educational Foundation (2005), a project should branch into other topics in the subject; allow for learner agency; provide the opportunity for learners to conduct a constructive investigation; require learners to use different resources

to do the project; incorporate other subjects; be aligned with the aims of CAPS; be focused on a central topic/idea; and develop specific skills and concepts in the topic, as required by CAPS. Finally, a formative assessment should focus on dispelling misconceptions about the topic. These qualities of the design of a project will be discussed for each participant.

When a project is used as a formative and summative assessment, to achieve all of its outcomes, it must also achieve the outcomes of the curriculum. This means that a project should be set up with the aims of CAPS (DEB, 2011) in mind. This will result in projects being set up correctly, and possessing the qualities of a good project, as established by Kokotsaki et al. (2016).

- **Design of the timeline of the project – Step 3 (formative and summative assessment)**

When referring to the timeline of a project, this is the time that teachers provide learners to do a project (DBE, 2011; Guntur & Retnawati, 2020; The George Lucas Educational Foundation, 2005). Doing projects, and using PBL and PBA imply that it will happen throughout a few lessons. When a teacher sets up a timeline for learners, it should be flexible enough to be adjusted if there are any disruptions to teaching time. This could include, for example, a fire drill or the periods being shortened due to extra mural activities, such as teachers and learners leaving early for sports events.

- Facilitation of **l**earning – Step 4 (**formative assessment**)

When teachers administer a project, they need to pay careful attention to how they facilitate learning. Teachers should not be the centre of attention of the lesson, and should not 'spoon-feed' the content to the learners. Learners must investigate and discover content to solve the problem and complete the project on their own, while the teacher merely prompts them towards success (Fisher et al., 2020; Nasution et al., 2021; Sahin, 2013). Teachers could also use other teaching approaches in conjunction with PBL. This means that they could, for example, use IBL with PBL to better suit the needs of their classroom. They will thus tap into their PCK and pedagogical beliefs to guide them in the best use of PBL in the unique contextual environment of their classrooms. However, these teaching approaches should be used together, and should not overshadow the use of PBL. When learners are busy with the project, teachers need to ensure that learners have enough opportunity to construct their own knowledge and be agents of their learning. This, again, means that they must facilitate the lesson properly.

- **Assessing the project – Step 5 (summative assessment)**

When assessing a project as a summative assessment, teachers need to consider what assessment tools they will use (Fisher et al., 2020). They need to ensure that there is transparency in the assessment process (Guntur & Retnawati, 2020), and that they ultimately provide learners with diagnostic feedback (Fisher et al., 2020; Kokotsaki et al., 2016). According to Bell (2010), it is preferable to use a rubric to assess projects, which allows for greater authenticity. Teachers also need to be considerate of the different viewpoints that learners present in their answers. Since the questions are meant to be open-ended, this means that learners will have the liberty to provide their understanding of the work, which has been shaped by their personal experiences and beliefs.

2.4 CONCEPTUAL FRAMEWORK CONCLUSION

In conclusion, the conceptual framework of this study encompassed various components that are crucial for understanding and analysing the factors that influence teachers' choices and implementation of PBL. The framework integrated perspectives from Aksela and Haatainen (2019), Brown (2004), the DBE (2018), and Murphy (2012) regarding the internal factors that influence teachers' choice of PBL. It also considered insights from Aksela and Haatainen (2019), Cline et al. (2020), Guntar and Retnawati (2020), Kokotsaki et al. (2016), Li et al. (2009), and Serin (2019) on the external factors influencing teachers' adoption of PBL. Furthermore, the framework incorporated the steps for implementing PBL as outlined by the George Lucas Educational Foundation (2007). This emphasised the significance of essential questions, highlighted the importance of designing a project aligned with the curriculum and quality criteria, addressed the timeline for project completion, and acknowledged the role of teachers in facilitating learning. These aspects were based on insights from Fisher et al. (2020), Nasution (2021), and Sahin (2013). Overall, this comprehensive conceptual framework provided a structured and systematic approach to investigating the application of PBL in the context of Grade 6 mathematics teaching in South Africa.

The following chapter will explore the research methodology employed in this study.

CHAPTER 3 RESEARCH METHODOLOGY

3.1 INTRODUCTION

This chapter describes the methodology used in this research. Since the research paradigm and the paradigmatic assumptions are core to how I view the world, and in this case, this research endeavour, I start the chapter by discussing them. I elaborate on the research approach and design, as well as the population and sample for this study. I further discuss the data collection instruments and how the data were analysed. Lastly, I detail the ethical considerations and the quality assurance criteria followed in this study.

3.2 RESEARCH PARADIGM AND ASSUMPTIONS

To obtain knowledge on, and an understanding of the phenomenon being studied, an appropriate paradigm was chosen. This study's paradigm, with its paradigmatic assumptions, is discussed below.

3.2.1 Research paradigm

This study adopted an interpretative paradigm, namely, constructivism (Nieuwenhuis, 2016a). Constructivism suggests that all knowledge is created through human perspective and experience (Honebein, 1996). This echoes the interpretivist idea that social reality is subjective (Stoilescu, 2016) as each person has a different view of the world. This paradigm was deemed appropriate for gaining insight into how Grade 6 teachers use projects as formative and summative assessments.

3.2.2 Paradigmatic Assumptions

This study was guided by four paradigmatic assumptions, namely, ontological, epistemological, axiological, and methodological assumptions. Ontological and epistemological views influence the approach used to obtain the required data to understand the phenomenon (Cohen et al., 2001; Nieuwenhuis, 2016a), whilst axiological assumptions are subjective. In this case, interviews, observation, and document analysis were appropriate data collection methods.

3.2.2.1 Ontological assumption

Ontology is defined as describing what reality is (Nieuwenhuis, 2016a). However, ontological assumptions "give rise to epistemological assumptions" (Cohen et al., 2001, p. 3). This is why it should be considered first in research. I held a nominalist position as my ontological view is

that reality is the result of "individual cognition" (Cohen et al., 2001, p. 6). As a teacher, I believe that reality is subjectively formed through interactions with learners, colleagues, and support from subject heads and HoDs. It is also formed through teacher-educator programmes and workshops. This means that teachers' reality regarding the use of PBL and PBA depends on multiple factors, as described in the conceptual framework.

3.2.2.2 Epistemological assumptions

My epistemological position is interpretive as I believe that knowledge is dependent on a person's experiences and understanding of the world (Nieuwenhuis, 2016a). It is a subjective stance on how knowledge can be viewed (Cohen et al., 2001). This directly relates to the factors in the conceptual framework as they too will influence how knowledge is created for teachers.

3.2.2.3 Axiological assumptions

Axiology refers to whether one views the phenomenon as free of values (objective), or bound by values (subjective) (Creswell, 2018). The nature of this study was subjective as it was my interactions with the teachers and my interpretation of their projects that framed the reality of this research (Cohen et al., 2001; Nieuwenhuis, 2016a).

3.3 RESEARCH METHODOLOGY

This section outlines the key elements of the research methodology, including the research approach, research design, data collection instruments, and data analysis procedures. Together, these guided the overall structure and execution of this study.

3.3.1 Research approach

This was a qualitative study. Creswell (2018) defines qualitative research as "a means for exploring and understanding the meaning individuals or groups ascribe to a social or human problem" (p. 333). Qualitative research as the methodological paradigm guided me in understanding Grade 6 mathematics teachers' implementation of projects. The data collection instruments, namely, the document analysis, interviews, and observations, were iterative. The use of qualitative research was deemed the most suited to providing rich and detailed data.

3.3.2 Research design

I used a case study research design. Yin (2009) defines a case study as the "empirical inquiry about a contemporary phenomenon (e.g., the case), set within its real-world context – especially when the boundaries between phenomenon and content are not clearly evident" (p.

18). Moreover, Cohen et al. (2001) state that a case study is a study of an “instance in action” (p. 181), whereas Creswell (2018) maintains that a case study is a “design of inquiry found in many fields, especially evaluation, in which the researcher develops an in-depth analysis of a case, often a program, event, activity, process, or one or more individuals” (p. 51). In this study, the participating Grade 6 mathematics teachers, and how they designed and implemented projects as formative and summative assessments, were regarded as the ‘case’ that was studied. Furthermore, this study was an exploratory case study as it aimed to explore how teachers implement projects for assessment, and which teaching approach they use, thus there is no predetermined or set outcome (Nieuwenhuis, 2016a). I collaborated with the participants (the mathematics teachers), which allowed for rich and detailed data collection (Nieuwenhuis, 2016a). The use of this design informed the methodology of this research, and opened the path to using observations, interviews, and document analysis so that the phenomenon could be studied through multiple lenses (Nieuwenhuis, 2016b). This design was suitable for this study since it required me to gather detailed information and use various data collection instruments. Case studies are “bounded by time and activity” (Creswell, 208, p. 51) and for this study, it was for the length of time it takes to complete a project using PBL and PBA, making it a lengthy activity.

3.3.3 Data collection instruments

I used three data collection instruments, namely, document analysis, observations, and interviews (see Appendix A-C). These three data collection instruments were informed by the conceptual framework, and subsequently by the research questions. Table 3.1 illustrates the relationship between each data collection instrument and the research questions. The study was originally meant to only focus on the use of PBL as a teaching approach, and therefore projects as formative assessments. During the data collection process, I decided to ask the participants to provide me with their projects as summative assessments too. Every participant should have finished this summative assessment with the learners already, thus I knew they would have it readily available. My supervisor and I thought that the study should also refer to projects as summative assessments to provide an even larger picture of the use of projects in general.

Table 3.1

Relation between data collection instruments and the research questions

Research Questions		Data Collection Instruments	How the data collection instruments answered the concerned research questions
		Projects as Formative Assessments	
1	What factors influence teachers' implementation of PBL as a teaching approach?	Document Analysis	When I *analysed* the project being carried out in class, I gained insight into whether their interpretation of the curriculum influenced the design of the project, along with their understanding of PBL and the project.
		Interviews	Through *interviews*, the teachers revealed whether factors such as pedagogical beliefs, understanding of PBL, types of assessments, support from subject heads and HoDs, lesson planning, and the teachers' level of experience influenced how they design and implement a project.
		Observation	Through *observations*, I saw how these various factors influenced the implementation of PBL.
2	How do teachers plan a project by using PBL?	Document Analysis	Through *analysing* the projects, I was able to uncover what cognitive levels the essential questions covered, and how they related (or did not relate) to each other, guiding the learners towards the completion of the project. I was also able to describe the design and timeline of the project and how it affected the learning experience.
		Interviews	Through *interviews*, I was able to uncover the following: (1) What these teachers knew about using a main essential question, designing a project, and the timeline thereof; and (2) How their PCK influenced their planning and preparation for a project, and subsequently the implementation thereof.

	Research Questions	Data Collection Instruments	How the data collection instruments answered the concerned research questions
3	During the implementation of PBL, how do teachers facilitate learning?	Observations	I used the information gathered from the *observations* to determine how teachers' beliefs and understandings influence how they administer projects. I saw how they used PBL and implemented projects as a formative assessment.
		Interviews	I used the *interviews* with the teachers to gain further insight into their classroom actions, and what they believed they did during the lesson to implement PBL.
		Projects as Summative Assessments	
4	What is teachers' understanding of a project as a summative assessment, and PBA?	Document Analysis	When I *analysed* the project, I gained insight into the teachers' understanding of what constitutes a project, assessed its alignment with a PBL teaching approach, and evaluated its qualities as a formative assessment.
		Interviews	*Interviews* with the teacher provided insights into their understanding of formative assessment.
		Observation	Through *observations*, I observed how the teachers implemented a project and applied PBL principles.
5	How do teachers plan a project by using PBA?	Document Analysis	By *analysing* the project, I identified the cognitive levels of the essential questions, and examined how they related to each other. Additionally, I described the project's design and timeline, and their impact on the learning experience.
		Interviews	Through *interviews*, I discovered the following: (1) Teachers' knowledge about using a main essential question, project design, and timeline; and (2) How their PCK influenced their planning and preparation.
6	What opportunities does a project provide for learners to develop the required knowledge and skills?	Document Analysis	Through *analysing* the project, I was able to determine whether the main essential question (if present) and sub-essential questions guided learners to complete the project, and adhered to CAPS.

3.3.3.1 Document analysis

Bowen (2009) defines document analysis as "a systematic procedure for reviewing or evaluating documents – both printed and electronic" (p. 27). In this research, I analysed the teachers' projects as formative and summative assessments. For both, I focused on the main and sub-essential question(s) (Step 1 of implementing PBL and PBA); the design of the project (Step 2); and the timeline of the project (Step 3). A checklist (Appendix A) was set up according to the criteria listed under the implementation of PBL and PBA in the conceptual framework to analyse the data from Steps 1 and 2. The analysis of the first two steps of the project took place before the observations and interviews.

3.3.3.2 Observations

Through observations (Appendix B), I gained a deeper understanding of how teachers design and administer a project for formative assessment (Nieuwenhuis, 2016b). I used the concept of an observer as a participant. Since projects take place over a period of time, this phenomenon cannot be observed in one sitting (Step 3). The number of observations in this study was thus dependent on the number of phases (phases can also be regarded as sections) in a project. Each participant's project had two phases, which were distinguished by starting a new part of the work that took learners one step closer to completing the project and finishing the end product. There were subsequently four interviews. One took place before the first phase of the project. The second interview took place after the first phase of each project. The third interview was done before the second phase of the project, and the fourth interview was conducted after the last phase.

All observations were video-recorded, with the camera only focusing on the teacher and the backs of the learners. If learners' faces appeared in the video, they were blurred. I also used field notes, specifically maintaining records that entailed detailed continuous accounts of not just the teachers' actions, but the observed situations (Nieuwenhuis, 2016b). This means that I observed how teachers facilitated learning during the projects, paying specific attention to the teaching approaches used (Step 4).

3.3.3.3 Interviews

The use of semi-structured interviews (Appendix C) allowed me to see "the world through the eyes of the [Grade 6 teachers]" (Nieuwenhuis, 2016c, p. 93). During the one-on-one, semi-structured interviews (Appendix C), I came to understand how these teachers chose/created the main essential question(s) (Step 1); designed the project and the timeline (Steps 2 and 3); what influenced their implementation of projects (external and internal factors of choice); how

they ensured that the requirements of CAPS were fulfilled; what feedback they provided to learners at the end of the first phase of the project; and what knowledge they possessed about projects. In this study, the number of interviews depended on the number of phases in each project. As such, there were only four interviews per teacher, one before the observations, one after each phase, and one after all the observations were done. The interviews, which were voice-recorded, took place in meticulous order, as depicted in Table 3.2, and later in Figure 3.1. The interview times ranged from approximately 10 minutes to 45 minutes each. Moreover, the interviews took place where the teachers preferred, as long as it was in a quiet area at their school.

Table 3.2

Elucidation of the interviews

INTERVIEW 1
A semi-structured interview was conducted before the first lesson observation
PURPOSE OF THE INTERVIEW
This interview was aimed at gaining insight into which external and internal factors influenced the teachers' choice of using PBL; how they planned and prepared to use PBL and projects; and what they understood regarding PBL and projects as a formative assessment.
INTERVIEW 2
A semi-structured interview was carried out after the first phase's observation
PURPOSE OF THE INTERVIEW
This interview focused on the first four steps of the implementation of PBL, as well as what was discovered during the first observation. This entailed how the project was explained, the timeline provided to learners, and how the teachers started facilitating learning.
INTERVIEW 3
A semi-structured interview was done after Phase 1 and Phase 2 of the project
PURPOSE OF THE INTERVIEW
This interview was a continuation of the previous interview. It was repeated after Phase 1 and Phase 2 of the project were completed, and a new one started. This interview focused mostly on Step 4, the facilitation of learning. This interview aimed to understand what the teachers did to provide feedback about the previous phase, and how they approached the next phase to facilitate learning and prevent misconceptions.

INTERVIEW 4

A semi-structured interview was done after all of the lesson observations

PURPOSE OF THE INTERVIEW

The last interview was meant to have the teachers reflect on how they designed and administered the project to suit their teaching approach. They were also asked if they felt that they administered and designed the project in a way that allowed learners to create knowledge, and that provided them with a level of autonomy.

3.3.4 Data analysis procedures

I used a deductive and thematic data analysis approach. Thematic analysis allowed me to see patterns of meaning within the dataset (Braun & Clarke, 2012), and find commonalities within the phenomenon. This data analysis approach produced the answers to the posed research questions. I used deductive coding based on the criteria in the conceptual framework, as informed by existing literature and the CAPS requirements, where after I analysed the data accordingly.

To determine how Grade 6 teachers design and administer projects as formative and summative assessments, I had to collect data that applied every angle of the conceptual framework. Thus, the data were very detailed and rich. The overarching themes revealed themselves during the data analysis process, and will be discussed later. The interviews, observations, and document analysis thus confirmed and built off each other during the data collection and analysis.

3.3.4.1 Transcribing

I transcribed the interviews and observations verbatim. I finished transcribing each participant's interviews and observations before starting data collection with another participant. While creating the transcripts, I made field notes of important information, but I was cautious not to start analysing the data. I used the field notes to help guide the analysis of the interviews and observations. These field notes became especially important during one observation where the video cut off prematurely, which I noticed in time. I was then able to make detailed notes of what was happening in the class before I got the camera up and running again.

3.3.4.2 Coding the data

To achieve the aim of exploring teachers' implementation of projects, the conceptual framework comprises two themes: factors that influence teachers' implementation of projects, and the actual implementation of projects. Due to the nature of the data, sub-codes were created to distinguish further what different parts of the data related to. Codes were ascribed to each of these sub-themes using Atlas.ti 24 in terms of the internal and external factors influencing the teachers' implementation of projects.

The first theme's codes are presented in Table 3.3. The first two letters in the code are denoted by *IF* or *EF* to indicate internal and external factors respectively. The second part of the code represents an acronym of the keywords of the specific internal or external factors in the conceptual framework. For example, *IFC* would indicate *internal factors – curriculum*; and *EFS* would indicate *external factors – support*. Table 3.3 also provides a detailed description of each code. The same concept of acronyms is applied in Table 3.4, where *IP* represents the *implementation of projects,* and the second part indicates a step in the conceptual framework. For example, *IP-ES* would represent the *implementation of projects – essential questions*. The table has sub-codes for each step in the conceptual framework because, with each step, specific criteria needed to be considered. For example, *IP–ESR* indicates the *implementation of projects – essential questions – real-life topics*. Table 3.4. also has two sections at the bottom that relate to PBL and PBA respectively. These refer to the step in the conceptual framework which PBA or PBL solely covers, PBL (Step 4) and PBA (Step 5). These codes are separated by the acronyms *PBA* or *PBL*.

Table 3.3

Summary of the indicators used to code the internal and external factors that influence the use of projects as summative and formative assessment

CODE	DESCRIPTION
	Internal Factors (IF)
IFC	Demonstrates their understanding of the curriculum and RATPs through interpretation thereof.
IFPB	Demonstrates what their pedagogical beliefs are through practice and interviews.
IFTKP	Demonstrates their understanding of projects through practice and interviews.
IFFA	Demonstrates their understanding of formative assessment during instruction and interviews.
IFSA	Demonstrates their understanding of summative assessment during instruction and interviews.

CODE	DESCRIPTION
	External Factors (EF)
EFS	Indication of support and the extent of the support received from subject heads and HoDs.
EFT	How the teacher managed their time during the project.
EFD	The extent of disruptions and their effect on instruction time.
EFLP	Views on and how teachers plan their lessons for the project.
EFTE	The effect of teacher experience on their understanding and application of projects.

Table 3.4

Summary of the indicators used to code the implementation of projects as formative and summative assessments

CODE	DESCRIPTION
	Implementation of projects (IP)
IP - ES	How the essential questions, if any, were set up according to the cognitive levels.
IP - DP	How the project was designed according to the criteria of a good project.
IP – T	How the teacher implemented the timeline of the project.
IP – FL	How learning was facilitated during the project of learning.
	Essential Question Sub-code (IP – ES)
IP – ESR	How the topic was based on a real-life topic.
IP – EST	How, if at all, the question(s) were structured to be open-ended.
IP – ESCL	How the project was set up according to the appropriate cognitive levels in CAPS.
IP – ESG	How the questions guided the project to completion.
IPBL – ESM	How the project addressed misconceptions (Formative Assessments).
	Design of project (IP – DP)
IP – DPC	How the project was set up to be in line with the aims of CAPS.
IP – DPT	How the project was set up to have a central topic.
IP – DPI	How the project led to a constructive investigation.
IP – DPA	How the project led to learner autonomy.
IP – DPLI	How learner input was used in the design of the project.
IP – DPR	How the resources were stipulated for the project.
IP – DPRA	Whether learners were given access to resources.
IP – DPT	How the project branched into other topics.

CODE	DESCRIPTION
	Timeline of Project (IP – T)
IP – TS	How the project's timeline was stipulated.
IP – TM	How the teacher helped facilitate time management while learners were doing the project.
IP – TF	The flexibility of the timeline.
IP – TB	Whether benchmarks were set by the teacher when learners carried out the project.
	Formative Assessment (IPBL)
	Facilitating Learning (IPBL – FL)
IPBL – FLTA	Use of other teaching approaches during the implementation of the project.
IPBL – FLFL	The way the teacher facilitated learning throughout the project.
IPBL – FLRG	How the teacher provided resources and guidance.
IPBL – FLDA	The assessment tool used to monitor learners' progress.
IPBL – FLGW	How the teacher helped manage and facilitate groups while learners did the project – only if group work was used.
IPBL – FLAL	How the teacher allowed learners to be agents of learning.
IPBL – FLCK	How the teacher allowed learners to construct knowledge.
	Summative Assessment (IPBA)
	Assessment of summative project (IPBA – A)
IPBA – DF	The diagnostic feedback that the teacher provided.
IPBA – AT	The assessment tool used by the teacher to assess the project.

3.4 SAMPLING OF THE PARTICIPANTS

This section elaborates on the population and sampling methods used in this study, and discusses the selected sample.

3.4.1 Population

The population of this study was Grade 6 mathematics teachers in South Africa who have experience using PBL and PBA. This was a large population and, due to the limits of this study, a representative sample could not be chosen. The rationale for selecting teachers who have experience using PBL and PBA is to be able to report on *how* teachers implement projects.

3.4.2 Sampling methods

For this study to be successful and effective, detailed data collection needed to take place, therefore, I aimed to have a small sample size (Nieuwenhuis, 2016). In this case, the study used convenience and purposive sampling to select three schools where one Grade 6 teacher from each school was observed and interviewed, and their projects for formative and summative assessments were subjected to document analysis. Convenience sampling involves "choosing the nearest individuals to [serve as] respondents and continuing that process until the required sample size has been obtained" (Cohen et al., 2001, p. 102). It entails choosing schools, and therefore teachers, for the study which I had "easy access to" (Cohen et al., 2001, p. 103). It was convenient since I chose schools near to my workplace to reduce travel costs and time usage. Purposive sampling involves researchers "[handpicking] the cases to be included in the sample based on their judgement of their typicality. In this way, [I built] up a sample that is satisfactory to [the study's] specific needs" (Cohen et al., 2001, p. 103). Table 3.5 provides more detail regarding the inclusion and exclusion criteria for the participating schools and teachers.

Table 3.5

Criteria for inclusion and exclusion of schools and teachers for the study

Inclusion	Exclusion
• Teachers must be a Grade 6 mathematics teacher. • Teachers who use PBL as a teaching approach. • Works at a school situated in Tshwane and Johannesburg. • One teacher who has between three and ten years of experience in teaching Grade 6 mathematics using PBL. • Two teachers with more than ten years' experience in teaching Grade 6 mathematics using PBL. • Public schools that follow the CAPS curriculum. • Male and/or female teachers. • Any race.	• A school that is outside Tshwane or Johannesburg. • Teachers who do not use PBL. • Private schools that do not follow CAPS.

3.4.3 The sample

In July 2023, SOS distributed a questionnaire to over 1 000 teachers who were subscribed to their mailing list, focusing mainly on Intermediate Phase mathematics teachers, although teachers from other phases also sent feedback. The purpose of the questionnaire was to gather insights into the use of PBL. Since I subscribe to their mailing list, they allowed me to use the data that they collected from a questionnaire about the use of PBL in mathematics in South Africa. Fifty Intermediate Phase teachers completed the questionnaire. Excluding the Foundation Phase, Senior Phase, and Further Education and Training (FET) Phase, the questionnaire revealed that 90% of teachers who completed the questionnaire reported that they did not receive any training regarding PBL. Sixty-four per cent of teachers stated that they did not use PBL during the school year.

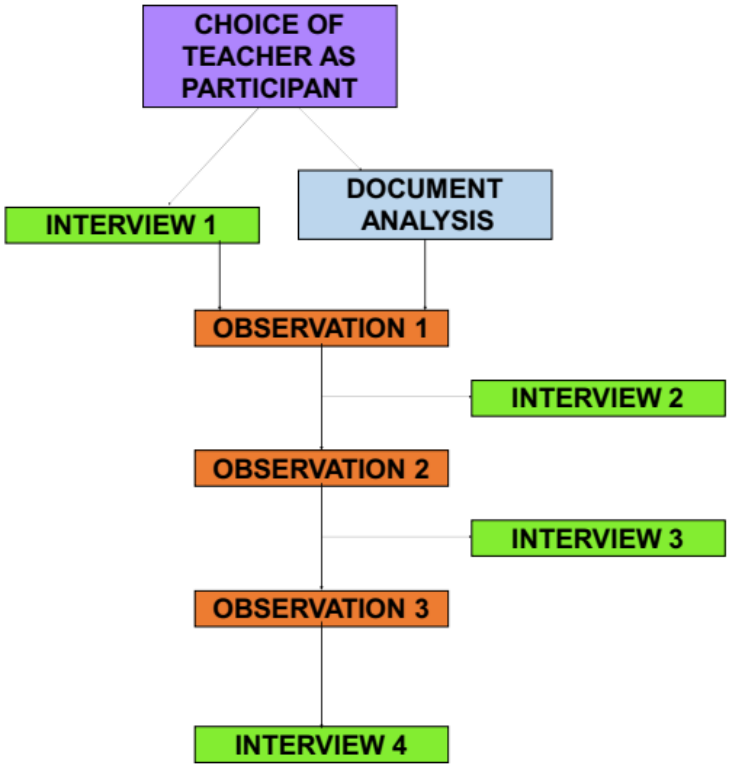
I used the data from the questionnaire to help select this study's three participants, who complied with the inclusion criteria, and would contribute to best answer the research questions. The three participants were Emily, Sophia, and Benjamin (pseudonyms were used). The anonymity of these teachers was protected in the questionnaire, and they were only contacted if they had given their consent.

3.5 THE DATA COLLECTION PROCESS

The data collection took place in Johannesburg during the third term and the beginning of the fourth term of 2023, and is shown in Figure 3.1.

Figure 3.1

Data collection process



I provided an example project to Emily and Sophia. Benjamin was confident in his understanding of PBL, and thus did not need the extra guidance. Sophia knew how to apply PBL, she only needed some examples to help her create a project. Emily was the least experienced out of the three participants in the use of PBL, and teaching in general. Table 3.6 depicts the dates when the data were collected for each participant.

Table 3.6

Timeline of the data collection process

Data collection instrument	Participant	Date
	Document Analysis	
Project as Summative and formative	Benjamin	27 August
	Emily	17 September
	Sophia	9 October
	Interviews	
Interview 1	Benjamin	28 Augusts
	Emily	14 September
	Sophia	10 October
Interview 2	Benjamin	28 Augusts

Data collection instrument	Participant	Date
	Emily	14 September
	Sophia	10 October
Interview 3	Benjamin	29 August
	Emily	15 September
	Sophia	11 October
Interview 4	Benjamin	29 August
	Emily	18 September
	Sophia	11 October
	Observations	
Observation 1	Benjamin	28 August
	Emily	14 September
	Sophia	10 October
Observation 2	Benjamin	28 August
	Emily	15 September
	Sophia	11 October
Observation 3	Emily	18 September

3.6 ETHICAL CONSIDERATIONS

Ethical considerations assisted this study in safeguarding its participants and not overstepping on moral issues. To start with, after I successfully defended the research proposal, I applied for ethical clearance from the Ethics Department at the University of Pretoria, as well as the Gauteng Department of Education. This study was categorised as low risk in the approved ethical application form. Although the participants were video and audio-recorded, which could make them feel vulnerable, I constantly reminded them of the nature of the study and how valuable their contribution would be to the field of mathematics in South Africa. I also reassured them of their privacy, and that they could withdraw at any point should they wish to discontinue. All of this was explained in the consent letters that were signed by the principal and teachers. During the observations, I ensured that the learners' faces were not in the videos, and if they appeared, they were blurred out. I was present during lessons, and thus, according to the Protection of Personal Information (POPI) Act (2013), the parents had to also sign a letter of consent, while each learner had to sign a letter of assent. In the letters provided to all involved parties, I explicitly stated to all stakeholders that the teachers' and schools' anonymity would be safeguarded during and after this study. To help with this, I used pseudonyms. These letters also stipulated that this study would not financially benefit anyone involved, that participation was not compulsory, and that the teachers and the school could

withdraw at any stage. Lastly, it was emphasised that there would be clear boundaries between myself, the teachers, and the school.

3.7 QUALITY ASSURANCE CRITERIA

The results of this study must be valid, reliable, and trustworthy since the results of qualitative studies cannot be replicated as human behaviour differs in various situations (Maree, 2016). Creswell (2017) states that "qualitative validity means that the researcher checks for the accuracy of the findings by employing certain procedures, whereas qualitative reliability indicates that the researcher's approach is consistent across different [studies]" (p. 274). Nieuwenhuis (2016b) describes trustworthiness as one of the most important parts of a qualitative study. To ensure trustworthiness, qualitative reliability, and validity, it is recommended to focus on the "credibility, transferability, dependability and confirmability" (Maree, 2016, p. 40) of the study.

3.7.1 Credibility

Credibility poses the question, "How congruent are the findings with reality?" (Nieuwenhuis, 2016b, p. 123). This was ensured through my choice of research design and methods. The research design and method were meticulously chosen to answer the research questions, as discussed in previous sections. Another way to ensure credibility was through the interviews where I asked the participants to verify the data that I gathered from the initial interviews.

3.7.2 Transferability

Transferability is the notion that the results from a qualitative study cannot be generalised as samples are rarely randomly selected (Nieuwenhuis, 2016b). To ensure this, the participants selected were all Grade 6 teachers who used CAPS, PBL and PBA. The context in which this phenomenon happened is completely explained in this study, as prescribed by Nieuwenhuis (2016b). Two other ways in which I further ensured transferability were through thick descriptions and purposeful sampling (Nieuwenhuis, 2016b).

3.7.3 Dependability

Dependability refers to keeping detailed records of decision-making processes and changes made in the study, such as a change in research design (Nieuwenhuis, 2016b). To ensure this, I kept detailed records of any decisions made during the study, including the change to include projects as summative assessments.

3.7.4 Confirmability

Confirmability refers to the extent to which a researcher remains neutral, and the findings are shaped by the participants and not the researcher (Nieuwenhuis, 2016b). To ensure that there was no bias, I used methodological triangulation by using multiple data collection instruments to develop a comprehensive understanding of the phenomenon.

3.8 CONCLUSION

In this chapter, I discussed the interpretive paradigm and the paradigmatic assumptions upon which this study was based. Regarding the research method, I used a qualitative approach and an exploratory case study design. I further used convenience and purposive sampling to find the most suitable participants possible to answer the research questions. The use of document analysis, observations, and semi-structured interviews as data collection instruments was discussed, along with how I coded and analysed the data. Lastly, this chapter considered the ethical concerns and quality assurance criteria.

Chapter 4 will explore the findings of this study in relation to the data collected, and the implications thereof.

CHAPTER 4 PRESENTATION AND DISCUSSION OF DATA

4.1 INTRODUCTION

In this chapter, I discuss the data analysis methodology, provide information regarding the three participants, and present each participant's data in three sections to ensure a thorough discussion. Section A addresses the internal and external factors influencing the use of projects as summative and formative assessments. Section B discusses projects as formative assessments, while Section C examines projects as summative assessments. The conceptual framework served as a guide throughout this chapter, and should be read in conjunction with each teacher's presentation (See Figure 4.1 on the next page).

The following research questions guided this research project:

Primary research question: How do Grade 6 mathematics teachers implement projects?

Secondary research questions:

Formative assessment of projects:

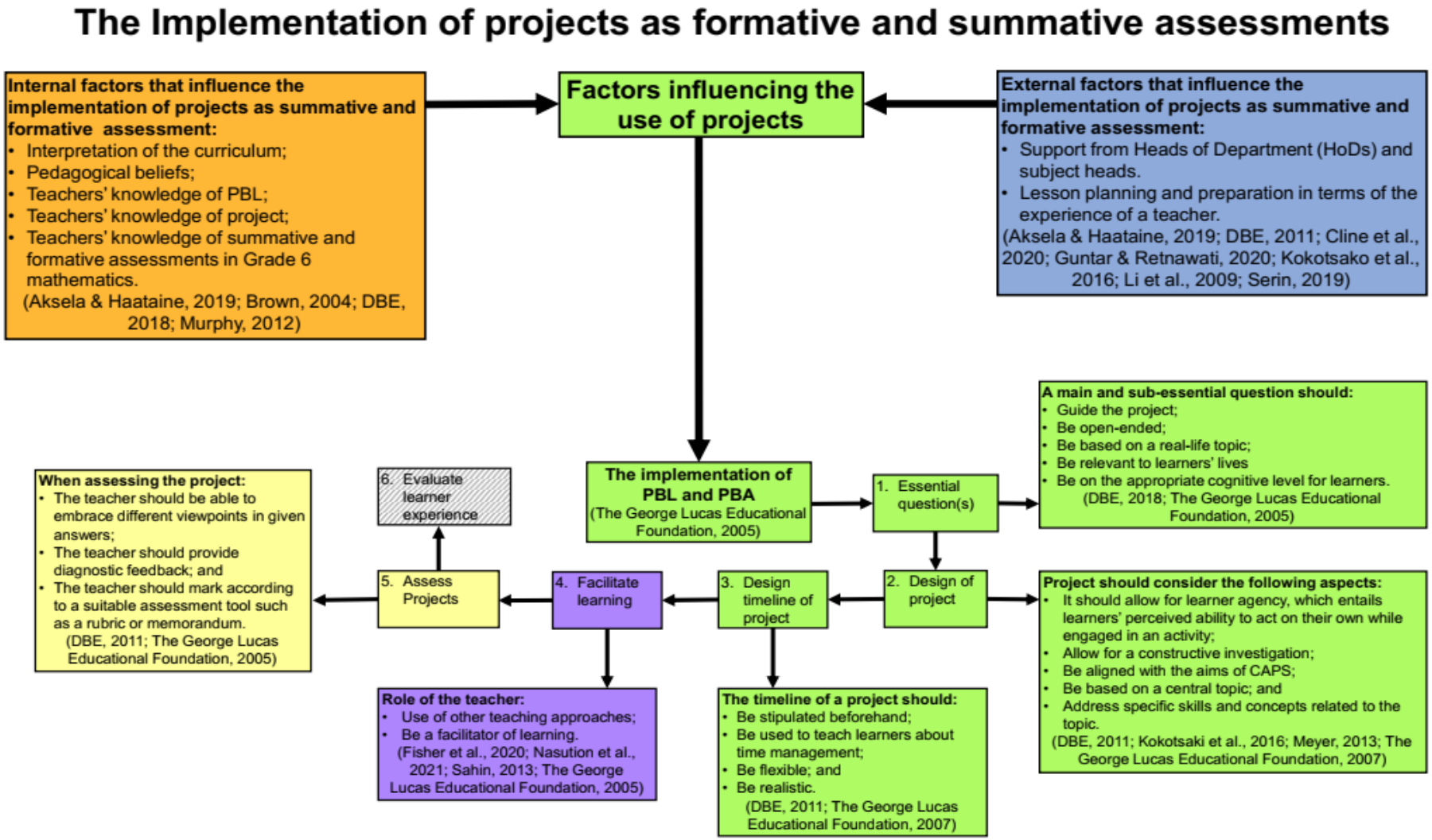
1. What factors influence teachers' implementation of PBL as a teaching approach?
2. How do teachers plan a project by using PBL?
3. During the implementation of PBL, how do teachers facilitate learning?

Summative assessment of projects:

4. What is teachers' understanding of a project as a summative assessment, and PBA?
5. How do teachers plan a project by using PBA?
6. What opportunities does a project provide for learners to develop the required knowledge and skills?

Figure 4.1

Conceptual framework: the implementation of projects as formative and summative assessments



4.2 INFORMATION REGARDING THE THREE PARTICIPANTS

In this section, I provide information regarding the participants – Emily, Sophia, and Benjamin (pseudonyms were used to protect their identities).

4.2.1 Emily

At the time of this study, Emily was 25 years old and a novice teacher in her third year of teaching Grade 5 and 6 Mathematics. Emily completed her degree in Baccalaureus Educationis (BEd) specialising in the Intermediate Phase. She majored in mathematics and Afrikaans, and completed the degree in 2020. Apart from her university education, she had no other formal training in the use of projects as formative and summative assessments, and PBL. During the interviews and observations, it also became clear that she lacked an understanding of PBL.

During the interviews and observations, Emily would speak in Afrikaans and English. Her lessons were primarily conducted in English, as it was the Language of Teaching and Learning (LoTL) of the class. However, she occasionally made remarks in Afrikaans, which the learners clearly understood. I translated all communication from Afrikaans to English.

Emily marked the project with the learners. Emily's summative assessment was based on Space and Shapes, focusing on angles, 2D shapes, viewing objects, and transformations. This project was done before the formative assessment, and had a distinct resemblance to a test as opposed to a project. Emily did her formative assessment project on data handling, specifically mean, median, mode, tally charts, pictographs, bar graphs, and pie charts. The first observation was conducted when she explained data handling. The second observation occurred when the learners carried out the project in class. The last observation happened when Emily marked the project with the learners.

4.2.2 Benjamin

At the time of this study, Benjamin was 54 years old and an experienced teacher who, for 10 years, had pursued another career before returning to teaching. He completed a four-year Higher Diploma in Education at a teacher training college specialising in the Senior Phase, and graduated in 1992. This teacher has an in-depth understanding of projects and PBL, implying that he had prior training regarding the matter, but none formally through workshops from the DBE.

During the interviews, Benjamin spoke in English, but the LoTL at the school is Afrikaans, thus all observations were done in Afrikaans. I translated the quotations used in this chapter into

English. Benjamin's project was also given to the learners in Afrikaans. I translated the figures into English, ensuring that I did not change the meaning of the questions. Furthermore, Bejamin's language usage and sentence construction in the interviews were in broken English. I adapted his quotations to be more coherent, while ensuring that the meaning of the quotations did not change.

Benjamin did his project on measurement, mainly, the perimeter of a square and rectangle, measuring shapes using a ruler, and converting metric length units. During the first observation, he carried out the first phase of the project, which focused on perimeter. The second observation focused on measurements – converting units of measurements and solving contextual problems. Bejamin's project, as a summative assessment, focused on measurement, specifically the perimeter of a square and the volume of a cube. The project took on a similar format to the formative assessment where learners had to construct shapes using jelly tots and toothpicks and then answer questions that followed.

4.2.3 Sophia

At the time of this research, Sophia was 43 years old and had 19 years of experience. Sophia completed a four-year Higher Diploma in Education at a teacher training college specialising in the Senior Phase, and graduated in 2005. Sophia has a comprehensive understanding of projects and PBL, however, she had received formal training on formative and summative assessment and PBL.

The interviews with Sophia were done in English, and all of Sophia's lessons were conducted in English, which is the LoTL at the school. Sophia based her project on data handling, focusing on tally charts and bar graphs. Sophia's project took place over two double periods. In the first observation, Sophia explained tally charts and bar graphs along with other important aspects of data handling, even though it was not entirely applicable to the project. She also guided learners in collecting their own data and drawing a tally chart. In the second observation, she guided learners in completing a bar graph. Sophia's project, as a summative assessment, focused on building 3D objects out of toothpicks and jelly tots. The project did not have sub-essential questions to answer; the learners merely built the figures.

4.3 PRESENTATION OF THE DATA COLLECTED FROM EMILY

The data collected from Emily will be presented in three sections: factors influencing the implementation of projects; the project as a formative assessment; and the project as a summative assessment.

4.3.1 Section A: Factors influencing the implementation of projects

The factors covered in this data presentation were those that had the most impact on how PBL and PBA were used.

4.3.1.1 Internal factors

The section discusses the internal factors that can influence the implementation of projects as formative and summative assessments. These discussions focus on formative and summative assessments at the same time since many of the discussion points overlap.

- **Interpretation of the curriculum**

In this section, I will briefly examine how Emily enacted the curriculum, and will later detail its full utilisation. During our discussion, Emily clarified that she did not adhere to the ATP, but followed the original CAPS curriculum. When asked why, Emily explained:

> I think there are a lot of concepts that are excluded that are important. Understand? They [DBE] want, for example in Term 1, to only do multiplication, division, addition, and subtraction. Whereas we do all the concepts for that term. I also think it is good or better to develop a better understanding since they learn these concepts now and master them…

If Emily used the full curriculum, it stands to reason that she would be familiar with all its facets, including assessment and the cognitive levels prescribed. She also understood the distinction between the original curriculum and the ATP in terms of the content taught each term. Emily believed in using cognitive levels to structure worksheets and projects, which will be discussed further later in this chapter. This is in line with the expectations of CAPS (2011) as assessments should be set up according to learners' cognitive levels.

- **Pedagogical beliefs**

Emily described her teaching philosophy as follows:

> I think it is better if it is visually in front of [learners]. That is why I believe in PowerPoints. I believe in drilling, drilling, drilling the work into them before we start with another concept. So, we teach a concept, we show it visually to the kids and then they have to do the worksheet.

From her statement, it can be seen that Emily mainly used a visual learning style, and favoured a teacher-centred approach that focused on drill work before moving on to the next topic. She also believed in a routine in the classroom: first, she would explain the work, then the learners would do examples, and lastly, they would do worksheets. Snowman and McCown (2013) state that lessons structured in this way utilise a teacher-centred approach. This teaching approach is indicative of a behaviourist who favours being the provider of knowledge. This

learning theory is not in line with the use of PBL, and is not indicative of an active learning environment. Instead, learners would be passive receivers of knowledge (Petress, 2008).

- **Teacher's knowledge of PBL**

To Emily, PBL is "the use of a project to teach a topic to learners." Her definition of PBL comes across as a general interpretation of the word 'Project-based Learning'. Contrarily, scholars like Fisher et al. (2020), Kokotsaki et al. (2016), Lazić et al. (2021), Nasution et al. (2021), and Serin (2019) explain it as an instructional approach that immerses learners in activities requiring the application of knowledge and skills to investigate project-related problems. Guntur and Retnawati (2020) also find that teachers provide general definitions of PBL, showing a lack of understanding thereof. Although Emily is correct in it being a teaching approach used to help learning take place through a project, the emphasis should not be on teaching, but rather on facilitating the learning process and allowing learners to be agents of learning.

Emily's explanation of her use of PBL revealed that she did not apply the approach optimally as compared to the definitions in the literature (Fisher et al., 2020; Kokotsaki et al., 2016; Lazić et al., 2021; Nasution et al., 2021; Serin 2019). For example, she did not state how she allowed for an independent investigation, how she facilitated the learners' independent work, or how she managed the required resources. Instead, her explanation corresponded with the reality of her project (as seen in Section 4.3): she explained the work; gave the worksheet, which had questions bearing no relation to a main essential question to the learners; and let learners finish it mostly on their own. Furthermore, she did not mention how she used PowerPoint, and explained all of the work to the learners before they did the 'project'. Emily thus explicitly contradicted her explanation of PBL with how she administered and facilitated the project. This proves the findings of Campbell et al. (2014), Lui and Bonner (2016), and Hughes et al. (2019) that a teacher's content knowledge is sometimes negatively impacted by their beliefs.

- **Teacher's knowledge of projects**

In terms of Emily's knowledge of what a project comprises, she explained,

> [It] is basically revision of a topic to see if learners understand the work and can do it. So that is how I view a project, it is to test [learners] basic knowledge and that which they already know.

This definition of a project is contradictory to that of scholars such as Bell (2010) and Jacobs et al. (2016), which refer to a project as a class activity that takes place over a period of time, and requires learners to solve problems that are often based on real-life situations. Similarly, Viro et al. (2020) found that over 40% of their participants believed that PBL is used for revision

instead of teaching a new concept. Finally, Emily's definition did not include how it should aim to solve a problem, and allow learners the opportunity to create an end product or to investigate a topic to develop a deeper understanding of the topic.

- **Teacher's knowledge of summative and formative assessments**

Emily described formative assessment as follows:

> **Emily**: So formative assessment is not a formal assessment. It is like a project based on a specific…
>
> **Researcher**: Topic?
>
> **Emily**: Topic and it is to check if learners understand – especially in Grade 6 when there are newer concepts taught. A formative assessment is a good way to make sure learners understand the work 100%.

Emily did not provide a succinct explanation of a formative assessment. She did, however, state that it is different to a summative assessment, comparing its likeness to a project. Formative assessments are assessments *for* learning (DBE, 2012); however, Emily's definition did not speak to this. Her definition was shallow and did not mention that formative assessments are meant to help learners improve, or that they present good opportunities to let learners take on more prominent roles in their learning process. This finding correlates with that of Arrafii and Sumarni (2018), who find that teachers have a limited understanding of formative assessments.

During the second interview, I asked Emily what type of support she received from her subject head and HoD about formative assessments. The conversation turned towards summative assessments, and she responded as follows:

> No, but I think it is because [learners] already have mental math [tests] during the term. We have three mental math tests each term that are summative assessments. So, I think that is why we do not really use formative assessments.

This statement shows that Emily understood that summative assessments function as assignments that count for report marks. However, she seemed to think that because three summative assessments happen over a term, they can replace formative assessments. This perception is misplaced as the two assessments are vastly different, and are used for different purposes, according to Jacobs et al. (2016), Van de Walle et al. (2016), and policymakers (DBE, 2011; DBE, 2018). Emily thus had a limited understanding of what formative assessments truly entail, as well as a basic understating of what summative assessments are.

4.3.1.2 External factors

This section discusses the external factors that can influence the implementation of projects as both formative and summative assessments. These discussions address formative and summative assessments concurrently, as many of the discussion points are relevant to both.

- **Support from HoD and subject heads**

I asked Emily how her subject head and HoD supported her use of PBL. She responded that her subject head and HoD supported whatever teaching approach was preferred by the teachers at her school for a given topic. However, when I asked her how they supported her in the use of PBL, she replied:

> **Emily**: Ooo… We have not actually… [the teacher was implying that the subject head and HoDs never encouraged something like that. I reassured her that in such a case she can just then state the truth even if it is 'no'].
>
> **Researcher**: Then you say 'no'.
>
> **Emily**: No. Yeah-no. We have not actually ever done formative assessments. I mean, all the assessments that we have done in class are… are formal assessments. They are all summative assessments. We might do it in the…
>
> **Researcher**: Future?
>
> **Emily**: The future.

Emily appeared to be caught off guard by the question, and was unsure how to answer since she knew the answer she would provide might not be a positive one. Emily's uncertainty and then subsequent promise that they might use formative assessments in the future indicated that she was open to changing her usual practices/pedagogical beliefs to incorporate formative assessments more often. This indicates that she understood that there needed to be a change in her thinking about PBL. This supports Aksela and Haatainen's (2019) findings that to effectively use PBA, there needs to be a shift in thinking about it. However, her superiors influenced how she approached topics such as projects, supporting the claims of Du Plessis (2020) and Mtika and Gates (2010). The fact that the HoD and subject head did not encourage the use of formative assessments in Emily's class indicates a problem with their understanding of the curriculum, or a disregard for it.

- **Lesson planning and preparation**

When I asked Emily how she prepared and planned for a project, she stated:

> So, when we think of a project, we think of the concepts we have already taught. So, all of our projects that we set up are set up according to concepts that we have already done in class and have already taught to the learners. So, we will take our lesson plans and the learners' workbooks, the worksheets, everything that we have already done in class and set up our project accordingly. So yes, it is according to concepts we have already done.

The project Emily was describing was her summative assessment project, which aimed to consolidate content that had already been taught. Interestingly, Emily never referred to the curriculum, timeline, and resources required when describing how she planned for a project. Although she did mention her lesson plans, which were meant to cover the content prescribed by the curriculum, she did not refer to the aims and goals of the curriculum for a project as required by the DBE (2011). Aligning a project with the objectives of the curriculum ensures that it is set up and administered as intended. It can thus be said that the absence of this could lead to Emily enacting the curriculum in a way that does not allow for the effective use of PBL. This corroborates Bell's (2010) findings, which emphasise that planning and preparing for projects play a vital role when using PBL. Without upholding the aims of the curriculum, any teaching lacks depth and meaning. The absence of these in Emily's description indicates that it was not important or necessary to her in the design, preparation, and planning of her project.

- **Experience of a teacher**

Emily claimed to have three years of PBL experience, yet when questioned, she seemed uncertain. Based on her remarks regarding support from her subject head and HoD, I doubt that she has truly used PBL for three full years. It appeared unlikely that her supervisors advocated for PBL given their apparent neglect of formative assessments. Despite this, at the time of this study, Emily was a novice teacher with limited PBL experience, even if her claim of three years is accurate. When I asked her whether the level of experience a teacher has would influence their use of PBL, she replied:

> No, I do not think so. I don't think so, because I think it's a – it's a good way to actually get the kids involved doing PBL. Not involved but I think… it is a different type of way to teach math and to teach the concept in math is by using PBL.

Emily believed that the level of experience a teacher has is not a factor that influences the use of PBL. She claimed that a teacher would use it, irrespective of their experience, because it is a good teaching approach.

4.3.2 Section B: The project as a formative assessment

Emily's formative assessment project was based on mean, median, mode, tally charts, and graphs. The project was covered over three periods.

4.3.2.1 Essential and sub-essential questions

Emily's formative assessment had no main essential question. The project was split into worksheets, each with multiple sub-essential questions that did not relate to the questions in other worksheets. Markula and Aksela's (2022) study found a similar occurrence where the activities in the project did not relate to each other, and not all of them related to the end product that learners created. They found that the main cause of this discrepancy in the project was the lack of a main essential question. Most of the questions were based on real-life topics such as the ones in Figure 4.2. However, there was no central real-life topic to which they all related. Some of the questions related to their lives, such as questions about ice creams, as seen in Figure 4.3. Whereas, for example, the first question in the project focused on the number of animals on a game farm. These questions were close-ended, requiring a calculation and having only one suitable answer. In Figure 4.2, for example, there was no opportunity for learners to provide their opinions about the graph or to further analyse the answers they calculated. Due to the lack of a main essential question, the project had no clear focus or goal. The learners ultimately could not conduct a constructive investigation. Table 4.1 breaks down the cognitive levels of all of the questions in the project.

Table 4.1

Summary of the spread of CAPS cognitive levels in Emily's project as a formative assessment

Cognitive Level	Number of questions on the CAPS cognitive level	Percentage of questions on the CAPS cognitive level (rounded off to the first decimal place)	Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines
Knowledge	34	59.7%	25%
Routine procedures	19	33.3%	45%
Complex procedures	4	7%	20%
Problem-solving	0	0%	10%
Total	**57**	**100%**	**100%**

Table 4.1 displays the spread of the cognitive levels across Emily's project. There was an imbalance between the cognitive levels of her questions because, according to CAPS (2011), assessments need to be set up according to the *suitable* cognitive levels for the type of assessment. For projects, there needs to be at least one problem-solving question, which functions as the main essential question. The sub-essential questions can be on the other cognitive levels with the intent of guiding learners in answering the problem-solving question. The questions did not guide the learners to complete the project. In the second interview with Emily, I asked her what she believed makes for a good main essential question:

> **Emily:** I think a good question is uhm… is it like one question or is it multiple questions underneath each other?
>
> **Researcher:** It can be one main question, or you can have multiple questions underneath each other that guide -
>
> **Emily:** Oh okay, yes. I think a good like… a good question about a specific topic is one that is according to Bloom's Taxonomy. So, it is when there are two questions that are easy and then a bit more difficult and then an enrichment questions for the children who have a higher understanding. So yes, I think that is a good question in a project.

Emily misinterpreted the difference between a main essential question and a sub-essential question. Emily's description of essential questions emphasised the use of cognitive levels to guide their design. She did not clarify whether there should be an overall main essential question based on a central idea, or whether there were sub-essential questions guiding learners to answer the main essential question. If she believed in the usage of cognitive levels, she would have an understanding of how they are intended to be used according to CAPS for the type of assessments that she set up.

However, Emily did not use CAPS cognitive levels to set up her questions. She used Bloom's Taxonomy, which is not per CAPS regulations (DBE, 2011) as assessments are meant to be set up according to the guidelines of Chapter 4 of CAPS (DBE, 2012), hence the cognitive levels outlined there. This fact could explain why she did not fully understand how CAPS intends for questions in different assessments to be set up. To ensure that her project's questions were analysed fairly, I also analysed her questions according to Bloom's Taxonomy as seen in Table 4.2.

Table 4.2

Summary of the spread of Bloom's Taxonomy cognitive levels in Emily's project as formative assessment

Cognitive Level	Number of questions on the cognitive level	Percentage of questions that should be on Bloom's Taxonomy levels
Remember	12	21.1%
Understand	24	42.1%
Apply	17	29.8%
Analyse	3	5.3%
Evaluate	1	1.8%
Create	0	0%
Total	**57**	**100%**

The table does not have a column with a recommended distribution of questions on each respective level of Bloom's Taxonomy as it uses a triangular model that visually emphasises which of each cognitive level there should be more of in an activity (Anderson et al., 2001). According to Bloom's Taxonomy, Emily's project does not have a good distribution of cognitive levels. 'Remember' questions should appear the most in an assessment, however, Emily's project predominantly had 'understand' questions. The 'create' level requires learners to make something, which is the final product or conclusion that learners need to present in a project. However, Emily's project did not have a question on the 'create' level. Thus, Emily did not understand that projects should contain such a driving question. This is congruent with the findings of Mentzer et al. (2017), where the participating teachers did not use the main essential questions due to a lack of understanding of them. Based on the questions of her project, it did not adhere to the qualities of a good project as listed by Thomas (2000), Kokotsaki et al. (2016), and The Geroge Lucas Foundation model (2007). The absence of a central idea and main essential question left her project directionless, and deprived it of two of the essential qualities that make up a project.

4.3.2.2 Design of the project as a formative assessment

Emily stated in her second interview that when she designed a project, she focused on setting it up according to cognitive levels. The project's cognitive levels were not balanced or set up according to the curriculum-required cognitive levels as per CAPS (2011). However, Emily showed that at the very least, she understood that it is a curriculum requirement. When I asked

her how she ensured that the projects she set up were designed and administered according to CAPS, she said:

> Look, we follow the curriculum throughout the term, so all the work we do is in the curriculum. So, we make sure that we set up projects according to what we do which is stipulated in the curriculum.

She highlighted that the mathematics RATP has significantly less work than the original curriculum. Albeit true when comparing CAPS (2011) and the RATP (DBE, 2023b), the RATP also has less information on projects (both formative and summative). As opposed to the original curriculum, which has a description of projects and recommends topics for projects, the RATP only states that a project as a summative assessment must be done during the term and that it should be based on the topics from Term 1-3. I therefore assumed that because Emily followed the original curriculum, she would be familiar with the curriculum's stipulation of formative assessments and what the aims of the curriculum are, as stated within the document. Looking at which of the aims her project achieved (summarised in Table 4.3) paints a better picture of Emily's understanding of projects.

Table 4.3

Summary of the CAPS aims that Emily's project as a formative assessment achieved (DBE, 2011, p. 5.)

CAPS aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	✓
Work effectively as individuals and with others as members of a team.	X
Organise and manage themselves and their activities responsibly and effectively.	X
Collect, analyse, organise, and critically evaluate information.	X
Communicate effectively using visual, symbolic and/or language skills in various modes.	X
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	X

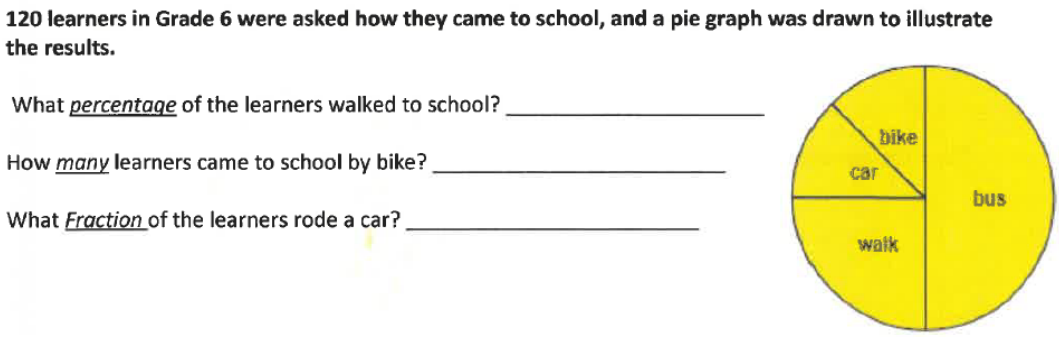
Emily's project did not achieve important aims such as "collect, analyse, organise and critically evaluate information" and "demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation" (DBE, 2011, p. 5). Learners were not provided the opportunity to collect their data, and present and analyse it. The topic of data handling would have provided the perfect opportunity to achieve this aim. The project also did not provide problems based on real life that would have allowed learners to make connections between mathematics and a real-life context. Regarding the other objectives that were not achieved:

- Learners did not work in groups, despite the topic being a suitable opportunity for collaborative learning.
- Learners only answered questions, not taking responsibility for gathering information and building their understanding independently, thus missing out on opportunities to organise and manage themselves during the project.
- Learners presented their understanding solely through written answers. They did not use alternative modes such as PowerPoint presentations, graphs, posters, or objects, thereby not demonstrating their mathematical skills in various formats.
- Lastly, it is challenging to design all projects to address learners' responsibility towards the environment and the well-being of others.

The project did achieve one of its aims, which was to "identify and solve problems and make decisions using critical and creative thinking" (DBE., 2011, p. 5). The project provided various sub-essential questions where learners had to use creative and critical thinking to answer them. One such example is provided in Figure 4.2. However, Emily did not achieve the CAPS aims, reinforcing Schweisfurth's (2020) quote about teachers who "thwart policy objectives" (p. 430). It further indicates how proper planning affects the project, as maintained by Bell (2010).

Figure 4.2

A question from Emily's project as a formative assessment to display the use of creative and critical thinking



In her project, Emily addressed most of the concepts and skills in data handling that were stipulated by CAPS, as seen in Table 4.4.

Table 4.4

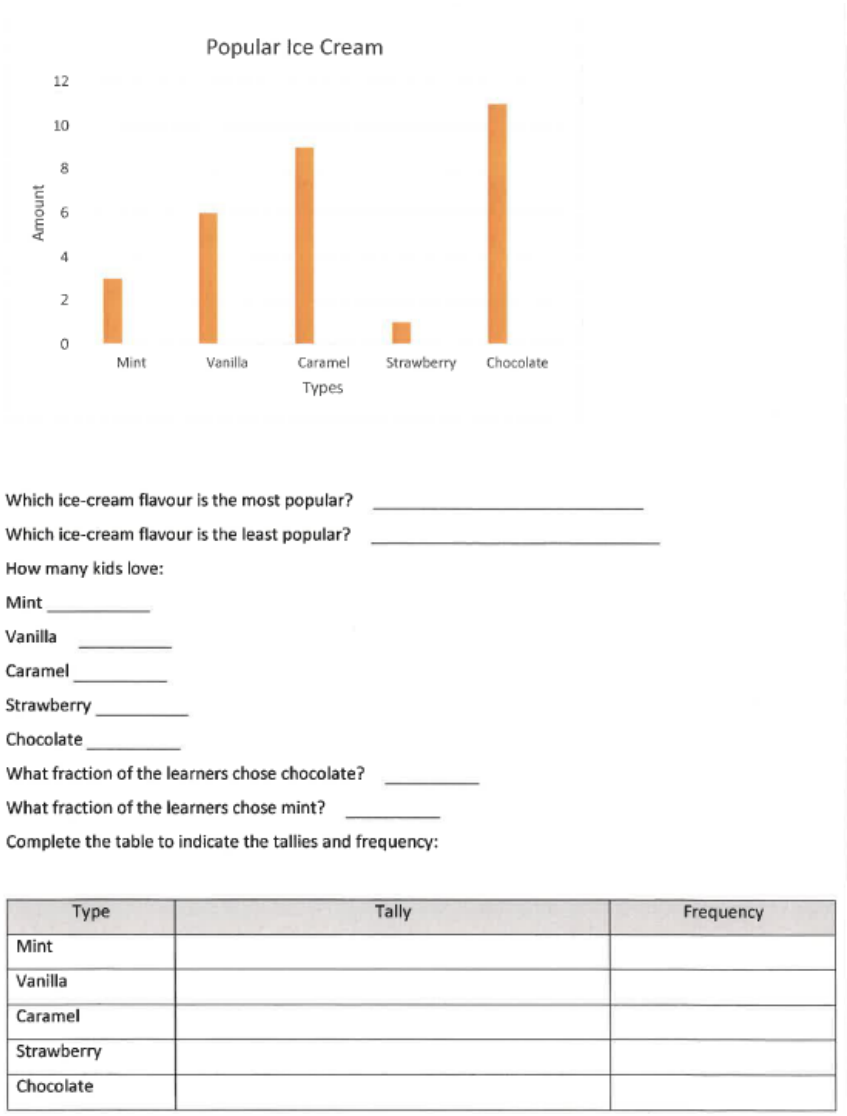
Summary of the concepts and skills in the original CAPS curriculum that Emily's formative assessment addressed (DBE, 2011, p. 268-269)

Content Area	Topic	Concepts and skills
Data handling	**Collecting and organising data**	Order data from the smallest group to the largest group.
	Analysing, interpreting, and reporting data	Learners should be able to critically interpret data represented in: • Words; • Pictographs; • Bar graphs; and • Pie charts. Learners should be able to analyse data by answering questions related to the data. Learners should also be able to summarise data verbally and in short written paragraphs.

However, Emily's project very loosely addressed collecting data through the use of tally charts. The keyword in the curriculum is 'collect', and the learners did not collect the data for the tally chart. As seen in Figure 4.4, instead, they had to use the data provided to them to create the tally chart.

Figure 4.3

A section from Emily's project as a formative assessment to demonstrate how data was provided to, and not collected by the learners



Type	Tally	Frequency
Mint		
Vanilla		
Caramel		
Strawberry		
Chocolate		

Thus, this concept and skill cannot truly be seen as being achieved according to CAPS (2011). Furthermore, the project did not allow learners to draw a graph to represent the data that had been collected, instead, learners only interpreted graphs. The project excluded an overall element of realism and learner agency, thus not adhering to two more elements of a good project as listed by Thomas (2000).

Emily's project functioned more like a test, characterised by its rigid questions and the lack of a central theme. This is similar to Mentzer et al.'s (2017) findings, where teachers set up projects that allowed for only one correct answer, and learners had to follow instructions to complete the project. Emily's pedagogical beliefs significantly influenced how she designed

and administered the project. This occurrence supports the findings of Ernest (1991), and Leatham (2006). In Emily's case, using her own words, she adhered to the philosophy of "drilling, drilling, drilling the work into [learners] before introducing a new concept." This approach was evident in her project design, which lacked opportunities for learner agency or exploratory learning. This is also indicative of a behaviourist who, according to Stonewater (2005), wants learners to imitate their methods when doing activities. This is not indicative of a teacher who uses PBL.

4.3.2.3 Design of the timeline of the project as a formative assessment

Emily did not set a clear timeline for the project. On the second day, she used a 20-minute timer to guide learners through their tasks. When I asked her how she determined the time needed for projects, she explained that she typically gave an hour and adjusted as needed, although this applied specifically to summative assessments. For formative assessments, she informed learners of the allotted time in advance, with much of it devoted to her instructional phase.

4.3.2.4 The facilitation of learning

The section is divided into two sub-sections that make up the facilitation process, namely: the teaching approaches and the facilitation of learning.

- **Teaching approaches**

In the third interview with Emily, when asked about whether she incorporated other teaching approaches, she said "No, I do not think so. No, all our classes are the same throughout." Emily stating that all her lessons were the same throughout implies the use of her usual teaching approach (see Section 4.3.1.1), which is indicative of a behaviourist and someone who does not use PBL. These claims are further justified by looking at the introduction of her lesson:

> **Emily**: Grade 6, today we are working with data. And when we work with data we have three terminologies. [Teacher raises her hand, holding up three fingers]. Can you remember the three terminologies?
>
> Learners raise their hands.
>
> **Emily**: [Learner's name]?
>
> **Learner**: Mode.
>
> **Emily**: We have mode.

Emily: [Learner's name]?

Learner: Mode.

Emily: Mode.

The teacher points to another learner who has their hand up to answer.

Emily: Median.

Emily: Median. And what is the third one? Who can remember?

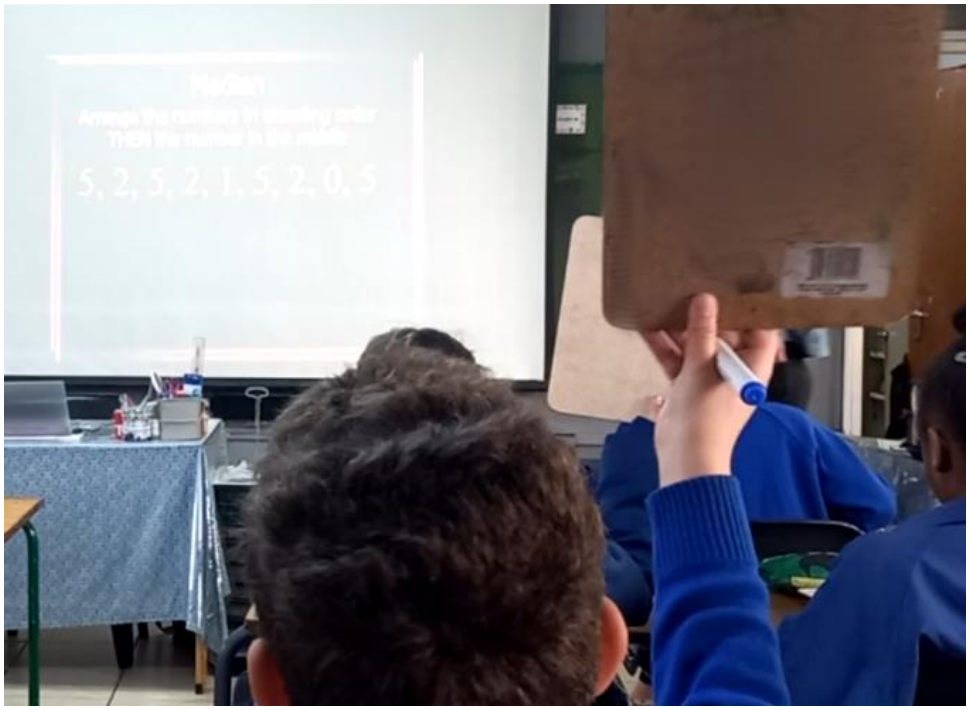
Emily: [Learner's name]?

Learner: Mean.

Emily: Mean, good job.

Figure 4.4

Emily's learners using the whiteboards to answer example questions during the lesson



Emily only used a telling and questioning method. Emily structured her project into three phases. In Phase 1, she explained all of the work. In Phase 2, the learners did the work and Emily explained some of the questions. In Phase 3, she went through the memorandum for the project with the learners, and they marked it themselves. The project thus took on the structure of her daily lessons. Although her lesson was interactive through the use of learners' whiteboards, as seen in Figure 4.4, it still does not uphold the qualities of PBL according to Kokotasaki et al., (2016), and The George Lucas Foundation (2007). Emily structured the

lesson in such a way that she was in control of what the learners did and how they did it. Guntur and Retnawati (2020) report this as a challenge that their participants experienced as well, where they controlled the learners and thus did not provide a learner-centred environment.

- **Emily as facilitator**

The project did not require learners to collect additional resources or information. The learners received a packet of worksheets, requiring only their whiteboards, which they all already had, and their workbooks. The worksheets had one note that explained the mean, median, and mode as seen in in Figure 4.5.

Figure 4.5

Additional note about mean, median and mode provided to the learners in Emily's project as formative assessment

Most of the time, Emily did not provide the answer to learners. She allowed the learners to work on the questions on their whiteboards, and then asked them to provide the answers:

> **Emily**: Okay, lift your whiteboards let me see.
>
> All learners lift their whiteboards.
>
> **Emily**: Kom, [learner's name], lift.
>
> **Emily**: Good job. Good. So, we first have to arrange them in ascending order. Uh, [learner's name] can name the numbers in ascending order for me quickly?
>
> **Learner**: 0, 1, 2, 2, 2, 5, 5, 5, 5.

This portion of the lesson is one of many examples of how Emily ensured that the learners engaged in the lesson, having them provide information and answers. She then often reinforced the answer by explaining how to get to it. However, later in the lesson, she provided a substantial amount of information about graphs to the learners:

> Remember, a bar graph has equal gaps between the bars, né. [Teacher goes to the next slide about a histogram]. A histogram. Look at the difference between a histogram and a bar chart. Okay, do you see there are gaps between the bars of a bar chart? When we have a histogram, do you see we have no gaps? No gaps at all, but it is also not starting against the line, there is also a little gap. You must remember the difference between a histogram and a bar chart. [The teacher

> goes to the next slide about a line graph]. Good, boys and girls there is a line graph. A line graph is where you only plot the dots on the graph and then you use a line to connect the dots. This is also a very easy graph to draw. [Teacher goes to the next slide about pie charts]. Okay. Now a circle graph. Ag, we love a circle graph. We. Love. That. Good. So, you must make sure, when we ask a circle graph or a pie chart, that we love to ask the fractions of the chart as well. You must make sure that you read your questions carefully…

Emily provided all the information about each graph, and learners had to interpret and analyse them in their project. However, the learners never used the data they had collected to draw and analyse the graphs, as required by CAPS (2012). Therefore, the learners had little personal involvement in the work, which is not self-reinforcing (Serin, 2013). This indicates a flaw in the design and administration of the project because it did not allow learners to master the topic of graphs on their own. Emily was a provider of knowledge, which is not indicative of how a project should be administered using PBL.

In the last lesson, Emily marked the work with the learners, but she did not mark the work herself. The project did not have phases that were dependent on each other, meaning that one phase had to be completed and assessed for learners to continue. Thus, it might not have been necessary for her to mark it throughout the three lessons. When I asked her whether she marked the project, she explained that there is not enough time in a day to mark all the learner's work

> **Emily**: A part of the worksheet, yes. So, part of the worksheet, yes.
>
> **Researcher**: With the learners?
>
> **Emily**: With the learners, yes.
>
> **Researcher**: In the class?
>
> **Emily**: In the class, yes. So, we did – I explained, or I explained mode, median, mean. They did a part of that, we marked it and then we moved on to graphs to explain that.
>
> **Researcher**: But you did not mark it yourself one afternoon?
>
> **Emily**: No, no. There is no time for that. There is no time.

Two important things were revealed in this part of the interview. The first is that Emily acknowledged that she explained the work to the learners, and therefore they were not the main constructers of knowledge. The second is the factor of time. Aside from the design of Emily's project being a factor in the marking thereof, it is expected that the teacher mark each phase before learners can continue. However, the expectation of additional marking for a teacher who has other school priorities can sometimes be unrealistic. It can be argued that if a project is a summative assessment, the teacher would do the marking for each phase since

they need the marks for the learners' reports and they might be more obligated to do so. Nevertheless, the data points to a glaring fact - Emily's project was not designed correctly, and she did not use PBL, despite stating she did.

4.3.3 Section C: The project as a summative assessment

Emily's summative assessment project was based on 'Space and Shapes'. The project counted 60 marks towards learners' Term 3 report. This project was subject to document analysis only since I did not observe when the project was administered. This means that I can only report on the aims and concepts from CAPS that the project addressed by analysing the project design. I am not able to report on whether the aims and concepts were addressed verbally, or if the teacher deviated from the project design. This also means that I cannot report on how the project was facilitated, and can only make inferences through the interviews and the design of the project.

4.3.3.1 Essential and sub-essential questions

Emily's project as a summative assessment did not have a main essential question. The project also had the same front cover as the formative assessment, however, the content covered in the summative assessment was very different. I suspect that Emily changed the original front cover of the summative assessment to be used for the formative assessment and forgot to change it back. Emily's project did not have a main essential question or a central topic. The project posed closed-ended questions, as seen in Figure 4.6. There was only one correct answer for each question, and there was no room for learners' opinion or interpretation. This is inherent to the use of closed-ended questions (Agustianingsih et al., 2019; Mentzer et al., 2017). The questions were also not based on real-life contexts, thus they did not create a connection between the subject and real-life contexts.

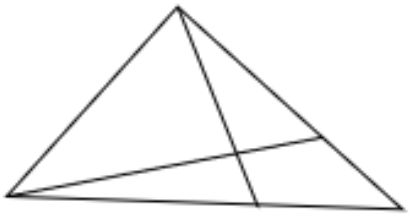
Figure 4.6

Excerpt from Emily's project as summative assessment

- A parallelogram is a 2D shape
- A parallelogram is a polygon
- A parallelogram has 4 straight sides and 4 angles
- Interior angles of a parallelograms will add up to 360°
- _____
- _____
- _____
- _____

(4)

2.5) How many triangles in the following figure? _____ (2)



2.6) Name the following 2D Shape:

2.6.1) Opposite sides are parallel and the same length. Opposite angles are equal, but is not 90°. _____

2.6.2) All closed 2-dimensional figures with 4 sides. _____

2.6.3) All sides are the same length. The opposite sides are parallel. Opposite angles are equal, but are not 90°. _____

2.6.4) A Quadrilateral with zero symmetry lines: _____

(4)

Furthermore, the spread of the cognitive levels in Emily's project is displayed in Table 4.5.

Table 4.5

Summary of the spread of CAPS cognitive levels in Emily's project as a summative assessment

Cognitive Level	Number of questions on the CAPS cognitive level	Percentage of questions on the CAPS cognitive level (rounded off to the first decimal place)	Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines
Knowledge	9	47.4%	25%
Routine procedures	7	36.8%	45%
Complex procedures	3	15.8%	20%
Problem-solving	0	0%	10%
Total	**19**	**100%**	**100%**

Emily's project lacked problem-solving questions, and did not have a main essential question, thus not meeting the qualities of a good project (Thomas, 2000). The majority of the project was made up of questions on the 'knowledge' level, and an almost perfect level of 'routine procedure' questions. Emily, however, had very few 'complex procedure' questions. I also evaluated her questions according to Bloom's Taxonomy again, and the results are displayed in Table 4.6 below.

Table 4.6

Summary of the spread of Bloom's Taxonomy cognitive levels in Emily's project as a summative assessment

Cognitive Level	Number of questions on the cognitive level	Percentage of questions that should be on Bloom's Taxonomy levels (rounded off to the first decimal place)
Remember	7	36.8%
Understand	2	10.5%
Apply	6	31.5%
Analyse	1	5.2%
Evaluate	1	5.2%
Create	2	10.5%
Total	**19**	**100%**

It can be seen from Table 4.6 that the distribution of questions according to Bloom's Taxonomy was uneven. There were insufficient questions at the ‘understand’ level, while the ‘analyse’ and ‘evaluate’ levels were equally represented. Notably, there were two questions at the ‘create’ level, which is the highest in Bloom's Taxonomy, contrasting sharply with the CAPS cognitive levels (2011). These questions (Figure 4.7 and 4.8) required learners to illustrate examples: question 3.3 tasked learners with drawing real-life acute angles like pizza slices or clock hands (1°-89°), and Question 5.3 required a tessellation example using translation.

While these tasks involved creation, they do not qualify as ‘problem-solving’, which in CAPS involves tackling unseen, non-routine problems using higher-order understanding and processes. CAPS notes that such problems may lack real-life contexts, emphasising the connections between different representations (DBE, 2011). Ideally, higher-grade problem-solving questions should incorporate real-life scenarios.

Examining Emily's questions, Question 3.3 addressed a real-life topic, but lacked higher-order understanding or extensive problem-solving processes. Similarly, Question 5.2 lacked a real-life context. The use of different cognitive level taxonomies affects how teachers perceive the balance of assessments. Emily could argue that she included a high-order ‘create’ level question according to Bloom's Taxonomy, but CAPS' standards suggest that questions should be more difficult, requiring more creative and critical thinking.

Figure 4.7

Question 3.3 from Emily's Project as A Summative Assessment

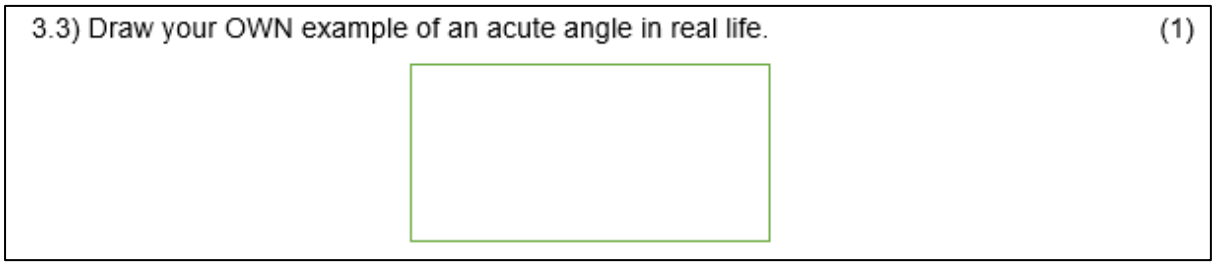
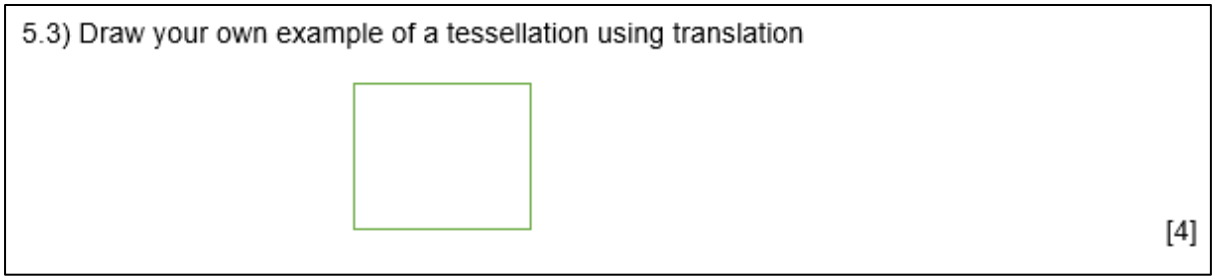


Figure 4.8

Question 5.3 from Emily's Project as a summative assessment



The project did not have phases or sections. Therefore, there were no phases that needed to be completed and assessed before another phase could be started. The sub-essential questions also operated independently without building on one another or guiding learners toward an overall goal. The lack of a central topic or a main essential question means that this project did not meet the qualities of a good project according to Kokotasaki et al. (2016).

4.3.3.2 Design of the project

Emily's project was based on 'Space and Shapes', covering four different topics. The project's alignment with the aims of CAPS was as follows:

Table 4.7

Summary of the CAPS aims that Emily's formative assessment achieved (DBE, 2011, p. 5)

CAPS aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	✓
Work effectively as individuals and with others as members of a team.	X
Organise and manage themselves and their activities responsibly and effectively.	X
Collect, analyse, organise, and critically evaluate information.	X
Communicate effectively using visual, symbolic and/or language skills in various modes.	X
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	X

Although the project allowed learners to "identify and solve problems and make decisions using critical and creative thinking" (DBE, 2011, p. 5), it failed to achieve the other aims of CAPS for the following reasons:

- The project was structured as a test, requiring learners to work individually rather than collaboratively. This hindered the development of skills such as investigation, communication, and responsibility.
- Learners were not given the opportunity to manage themselves as the test format did not hold them accountable for independently collecting information, conducting investigations, or deepening their understanding to advance in the project.
- There was no opportunity for learners to gather, analyse, and evaluate information.
- Learners were limited to writing their answers, without creating posters, pictures, or presentations. Therefore, they did not utilise multiple modes of communication.
- Learners did not demonstrate responsibility towards the environment or the health of others. Although achieving this aim can be challenging in every project, it was not addressed at all in this one.
- The project was not based on a real-life problem. Except for one question requiring learners to draw a real-life example of an acute angle, the questions were not connected to a broader real-life context.

Planning for projects should not just consider the content to be covered. It should ensure the flow of the project and learners' success (Bell, 2010). Merely looking at the aims of the curriculum, one can see how it is geared towards encouraging an active learning environment where projects are used effectively, and PBL is supported. By striving to achieve these aims, Emily's project could have turned out differently since its intent would have been different.

Table 4.8 provides a summary of the concepts and skills that the project covered, and that which it did not.

Table 4.8

Summary of the concepts and skills in the original CAPS curriculum that Emily's formative assessment addressed (DBE, 2011a, pp. 244-265)

Content Area	Topic	Concepts and Skills
Term 2 – The topic is covered again in Term 3		
Space and Shapes	**Properties of 2-D shapes**	Learners need to:

Content Area	Topic	Concepts and Skills
		• Know and name regular and irregular polygons. • State the similarities and differences between rectangles and parallelograms • Describe, sort and compare 2-D shapes in terms of their sides, the length of sides, and the size of the angle. • Angles: recognize and name the angles in 2-D shapes
		Term 3
Space and Shapes	**Viewing objects**	Position and views: Connect the viewer's position to perspectives of individual or composite objects, or groups of objects, encompassing both every day and geometric forms.
	Transformations	Describe patterns: Discuss patterns by referring to lines, 2-D shapes, 3-D objects, lines of symmetry, rotations, reflections, and translations in contexts such as: • Nature; • Modern everyday life; and • Cultural heritage. Enlargements and Reductions: Draw enlarged and reduced versions of 2-D shapes to compare the size and shape of: • Triangles; and • Quadrilaterals.

The project encompassed topics previously covered in Term 2 and Term 3. This alignment could be due to the following reasons:

- CAPS (2011) specifies that by the conclusion of discussions on transformations, percentages, and temperature, students should have been assessed on:
  - 2-D shapes;
  - Transformation;
  - Temperature; and
  - Percentages.

- The RATP mandates that the project should integrate “a combination of topics from Term 1-3 and must be completed before the end of Term 3” (DBE, 2023b, p. 3).

Emily did not adhere to the RATP, but this does not imply that she was unaware of the assessment guidelines it provides, as the GDE is known to check these, based on my experience. Considering both points, Emily might have taken the CAPS and RATP stipulations into account when designing the project, which could explain why it spanned so many topics over two terms. However, given the breadth of the concepts and skills in each of the four covered topics, it would be impossible to incorporate everything into a single project. Emily could have, instead, emphasised real-life applications, investigative skills, and creative thinking by developing a main essential question that encompasses most of the topics. For example, the learners could have looked for different types of angles in nature or on the school grounds, and written up a presentation about it or made a poster.

The project did not allow for learner agency. It forced the learners to work alone without opportunities to broaden their understanding or present it in any format other than test-based questions and answers. In such a situation, learners do not operate independently of the teacher and are not considered the primary source of knowledge. This contradicts the views of Kokotsaki et al. (2016), and The George Lucas Educational Foundation (2007), who emphasise projects as an activity where learners are the driving force behind their learning instead of the teacher. This thus subsequently contradicts CAPS’ standard of a project, meaning that Emily did not fully realise it as the curriculum intended.

4.3.3.3 Design of the project’s timeline

The project did not have a stipulated timeline, which does not align with the stipulations of a good project according to The George Lucas Foundation (2007). There might have been one on the original front cover but, as mentioned, it was changed to suit the formative assessment and was never changed back. In the interviews with Emily, she spoke about the timeline of her projects:

> We tell them you have an hour, so work… It's really just that. And I think the children are actually used to it, especially with the mental math [tests], which [are] only 15 minutes. They know they are running out of time for this, so they only have 15 minutes to finish.

This shows how Emily stipulated the timeline to the learners in a clear manner, and helped them to realistically pace themselves. Her response to my follow-up question about extending the timeline also indicates that she would always ensure that the learners finished the project.

4.3.3.4 Assessment of the project

Emily used a memorandum for her assessment, which might have been discussed with the learners. Since the project did not consist of interdependent sections, it is reasonable to assume that Emily marked the projects only after they were completed, rather than in phases. A memorandum discussion would have provided adequate diagnostic feedback. However, assessing a project should not rely solely on a memorandum. Various assessment tools, such as rubrics and memorandums, should be used as evaluating a project with just one tool is often insufficient.

4.4 PRESENTATION OF THE DATA COLLECTED FROM BENJAMIN

The data collected from Benjamin will be presented in three sections: factors influencing the implementation of projects; the project as a formative assessment; and the project as a summative assessment.

4.4.1 Section A: Factors influencing the implementation of projects

The factors covered in this data presentation were those that had the most impact on how PBL and PBA were used.

4.4.1.1 Internal factors

This section discusses the internal factors that can influence the implementation of projects as formative and summative assessments. These discussions focus on formative and summative assessments at the same time since many of the discussion points overlap.

- **Interpretation of the curriculum**

Benjamin used the RATP to guide his teaching, as expressed below:

> Luckily, with the GDE, the ATP has only been slightly modified to create the revised ATP. Nowadays, a project can still be based on the original ATP, especially since we don't have much content in Grade 6. This ‘Space and Shapes’ makes it a great theme for project-based learning. If time permits, it will always be beneficial to dedicate some time to this aspect

Firstly, it is important to note that the participating teachers referred to the RATP and ATP interchangeably. However, they are vastly different – the RATP is the newest version of an ATP geared towards bridging the gaps in education created by COVID-19. Although topics are indeed covered at different stages in the RATP (2023) as opposed to the original CAPS curriculum (2011), the most glaring difference between the two is the content that is not covered in the RATP. This is not to say that entire content areas have been removed, merely

that some content areas are covered more than once a year in the original CAPS curriculum, and only once in the RATP. An example of this is data handling, which is covered in Term 1 and Term 3 in the original CAPS curriculum, but only once in Term 4 in the RATP. Therefore, Benjamin claiming that the RATP is a "mixed up" version of the original curriculum is misguided. If he had a well-rounded understanding of what is in the original curriculum, he would know of this difference.

- **Pedagogical beliefs**

Benjamin described his teaching philosophy for mathematics as one that focuses on developing logical reasoning, stating:

> The standards of logical reasoning in South Africa are so low that children are struggling to solve problems. To address this, I want to integrate problem-solving into classroom questions and answers to observe their responses. This approach will make the lessons more interactive and engaging for the children.

Benjamin's teaching philosophy is reflective of a teacher who understands that having learners discuss answers and questions provides valuable feedback, and allows them to critically evaluate their understanding in the process. His statement does not indicate a specific learning theory, such as behaviourism or constructivism, but through his interactions with the learners, it is clear that Benjamin is a social constructivist who believes in peer interaction to develop understanding. However, there was evidence of a behaviourist learning theory in his practice as well. Social constructivism is suitable for PBL as it requires group work, and emphasises learners helping each other instead of the teacher helping them, thus the teacher is not the sole provider of knowledge anymore. However, as discussed later, Benjamin did not entirely succeed in allowing learners to be completely independent of him as he provided the information they needed to do the project. This means that they were not self-sufficient, as required in projects according to Bell (2010), Fisher et al. (2020), and Kokotsaki et al. (2016).

- **Teacher's knowledge of PBL**

Benjamin described PBL as:

> [A teaching approach] where you use alternative modes – not just writing on the board. So, again where [learners] construct objects so that they can learn from seeing things rather than just writing down answers. So, they get to reason on their own.

This definition was denoted by his teaching philosophy, which was evident through his desire to have learners be proficient in reasoning and evaluation. Benjamin's explanation of PBL indicates that he understood that projects go beyond mere questions and answers. Learners need to provide an end product, as stated by The Geroge Lucas Foundation (2005). However,

he believed that the end product should be used by learners to answer questions, whereas a more standard approach uses the product to answer the main essential question (Fisher et al., 2020; Kokotsaki et al., 2016; The Geroge Lucas Foundation, 2005). This is not to say that Benjamin is wrong, it is just a different take on how projects are done, thus being something that was informed by his pedagogical beliefs. However, it comes down to whether the main essential question is answered. Similarly, Guntur and Retnawati's (2020) study has found that teachers provide general statements regarding the definition of PBL. Most of them state what a project is used for, and that it is done in groups over a period of time. Although not in this instance, Benjamin emphasised the use of group work in many of his statements on PBL.

- **Teacher's knowledge of projects**

Benjamin defined a project as:

> [An activity] that can be done individually or in groups, where learners engage in tasks beyond mere numerical calculations. It involves constructing tangible objects, allowing learners to visualise their work. By building and manipulating these objects, they enhance their understanding of the problems at hand, enabling them to reason more effectively and answer related questions with greater clarity.

He emphasised that projects are meant to take a step away from the routine mathematics sums, and should be done in groups. He further discussed his definition of PBL, explaining that projects are an opportunity to have learners construct something and use it to help them reason and draw conclusions about a certain topic. Benjamin's views of what a project is show that he understands that it entails a different approach in the classroom – one that places learners at the centre of the learning process. This resonates with the definition of scholars such as Bell (2010) and Jacobs et al. (2016).

- **Teacher's knowledge of summative and formative assessments**

I asked Benjamin to explain his understanding of formative assessments in an interview. He replied as follows:

> Okay, formal right, that is the formal part where you give [learners] marks. Summative assessments are done in class. Well, they are both done in class, but summative assessment is where you can incorporate group work. Whereas formative assessment is where learners get marks for, let's say they did experiments. With formative assessments, you also give learners feedback so that they understand the topic or the assignment.

This interaction brought up a common misconception where teachers confuse the two assessments based on a syllable in the word. Benjamin understood the 'for' portion of 'formative' to indicate 'formal', as in a formal assessment. I had the same experience with the

other two participants who inquired about formative assessments before the interviews and observations. In their study, Arrafii and Sumarni (2018) reveal that teachers have a poor understanding of what formative assessments entail. Similarly, Ussher and Earl (2010) recount that student teachers, and even some experienced teachers, confuse the two types of assessments.

Furthermore, it is not as if the definitions of these types of assessments are inaccessible to South African teachers. They are expected to know what is in the curriculum, and understand what it is they have to do, be it formative or summative assessments. The definitions for each are presented in Chapter 4 of CAPS (DBE, 2011). However, this does not necessarily mean that Benjamin did not know about the two types of assessments and what each entails per se. It may merely indicate that Benjamin could not define the concepts in English.

Benjamin's description of a formative assessment, confusion of the word aside, indicates that he viewed it as something that learners do in groups. He did not mention that it is to aid in the process of learning as CAPS (DBE, 2011) describes it. His description of summative assessment was limited to it merely being an activity done in class. Benjamin failed to mention that it is an assessment done to assess what learners know about a topic after it has been taught. Overall, Benjamin understood that there is a difference between the two types of assessments, mainly that one is for marks, and one is not. He did not, however, understand the purpose of each type of assessment. It can therefore be said that Benjamin displayed a limited understanding of each type of assessment.

4.4.1.2 External factors

The following section examines all of the external factors that can affect the implementation of projects as both formative and summative assessments. These discussions address formative and summative assessments concurrently as many of the discussion points are relevant to both.

- **Support from HoD and subject heads**

When I asked Benjamin what kind of support or encouragement he received from his subject head and HoD in terms of using PBL, he said that their support in a specific subject was influenced by their experience and knowledge in that area. Benjamin noted that he was fortunate to have an experienced HoD who was happy to provide support in the use of PBL. I inquired further about this, asking whether the experience of an HoD matters in terms of support in the use of PBL, to which he replied:

> That's correct because the HoD plays a very important role especially for newcomers. the newcomers. Teachers that finished studying and are starting with their teaching career. So how they guide the new teachers and support them, so that these new teachers are equipped to help the learners.

Benjamin made a significant point regarding new teachers. As previously mentioned, a teacher's pedagogy is largely shaped by the school culture and beliefs (Du Plessis, 2019; Mtika & Gates, 2010), particularly by their subject heads and HoDs. According to Richardson (1996), these individuals' pedagogical beliefs are, in turn, influenced by their personal experiences - experiences from when they were learners, and what they learnt from their teacher education courses and workshops. Additionally, in a study conducted by Viro et al. (2020), the participants expressed the need for support from peers and supervisors, especially from those who have more experience in the use of PBL. This implies that Benjamin's statement about the knowledge and experience of a subject head and HoD is an influencing factor in how they provide support in terms of projects.

- **Lesson planning and preparation**

I asked Benjamin what his approach was to lesson planning and preparation for a project, and he answered:

> Planning is always crucial because it allows you to identify potential pitfalls and determine the best approach. However, its effectiveness can vary from one class to another. In one class, it might work exceptionally well, while in another, poor discipline may hinder cooperation. Thus, lesson planning must include alternative methods to address such challenges, which comes with experience. If your planning is solid and you have experience, you can adapt your lesson plan on the fly to suit the specific class in front of you.

Benjamin emphasised the significance of planning for a project, highlighting the necessity of understanding potential pitfalls and identifying the most effective strategies tailored to each class. This lines up with an imperative point in Li et al.'s (2009) study about lesson plans where they state that these create a blueprint for teachers. This also underscores the importance of adapting teaching approaches to accommodate the unique dynamics and temperaments of different classes. Benjamin compared his interpretation of PBL to a questioning approach and, on a few occasions, to the telling approach.

However, Benjamin did not address how lesson plans should be based on curriculum aims and content as required by the DBE (2011). Using the curriculum guidelines, such as aims and cognitive levels, in the development of a project should be part of the planning and preparation of a project. This resonates with Bell's (2010) statement about the success of a project, and indicates a flaw in Benjamin's perception of designing a project. Bell's (2010)

statement was proven true as the lack of adherence to curriculum guidelines proved detrimental to the overall design of the project, as seen in Section 4.4.3.2.

- **Experience of a teacher**

I asked Benjamin whether he considered a teacher's level of experience to influence the use of PBL and he replied:

> I must say experience is incredibly valuable for a teacher, as it allows them to understand what methods effective and which ones are aren't. Project-based learning involves a lot of group work, requiring effective classroom management. Managing larger groups necessitates ample space and careful planning to avoid chaos. Without experience, handling these dynamics can be particularly challenging.

Benjamin suggested that a teacher's level of experience significantly influences their likelihood of utilising PBL in the classroom, and that they probably have used it during their profession before. His statement supports the findings of Aksela and Haatainen (2019), who state that those teachers who have experience in PBL will not be reluctant to use it again. Due to their experiences, these teachers are more likely to adopt PBL because their years in the profession have provided them with insights into which methods are effective and which are not. It also means that these teachers have opted for learner-centred classrooms before, and would not be opposed to handing over control to the learners (Aksela & Haatainen, 2019). Their accumulated knowledge helps them to navigate the complexities associated with PBL, such as managing group work and maintaining discipline. Therefore, experience not only enhances a teacher's ability to implement PBL effectively, but also helps them to create an environment that is conducive to collaborative learning.

4.4.2 Section B: The project as a formative assessment

Benjamin's formative assessment project was based on measurement, specifically, the area and perimeter of a square and a rectangle, conversions of units, and measuring shapes with rulers. The project was done in three lessons.

4.4.2.1 Essential and sub-essential questions

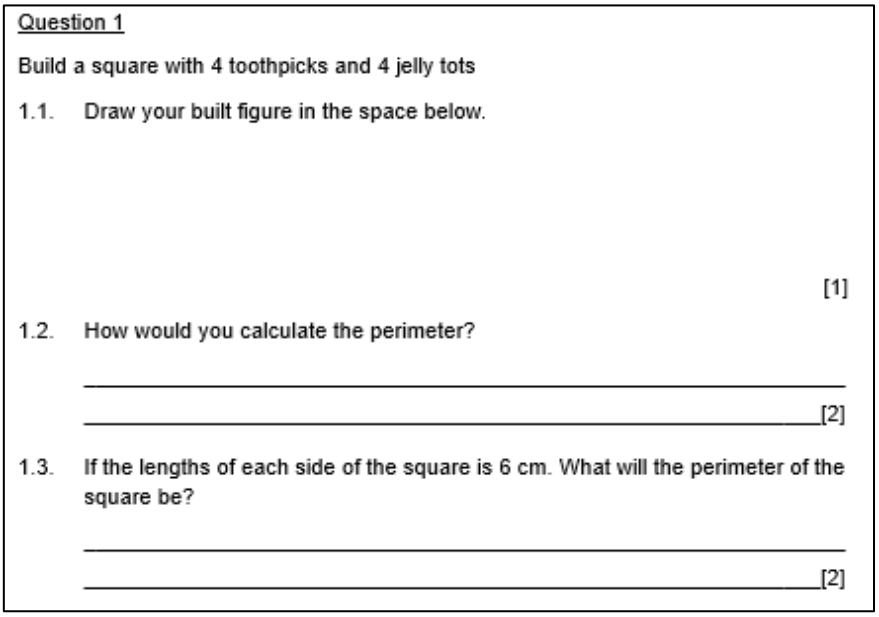
Benjamin's project did not contain a main essential question. There was no stated problem or scenario that learners had to investigate and provide a solution or conclusion for in the form of an end product. Benjamin did appear to know what a main essential question is, however, when asked what makes for a good main essential question, he stated:

> They must be open-ended so that [learners] can give their own input.

He thus understood that a main essential question should be open-ended, where learners display their understanding (The George Lucas Foundation's view, 2007). However, his project had multiple closed-ended questions, as seen in Figures 4.9 and 4.10. Thus, Benjamin contradicted himself, proving that he either did not fully understand what an open-ended question is, or perhaps knew, but lacked the skill to design one. He also did not mention relating the main essential question to a real-life topic, the lack of which was evident in his project. The absence of a main essential question leaves projects without an overarching goal, and deprives learners of an opportunity to conduct a constructive investigation. This is similar to the findings in Mentzer et al.'s (2017) study that teachers often do not include a main essential question in their projects. Such projects are then considered to be directionless.

Figure 4.9

Questions 1.1-1.3 in Benjamin's project as a formative assessment



Question 1

Build a square with 4 toothpicks and 4 jelly tots

1.1. Draw your built figure in the space below.

[1]

1.2. How would you calculate the perimeter?

_____

_____[2]

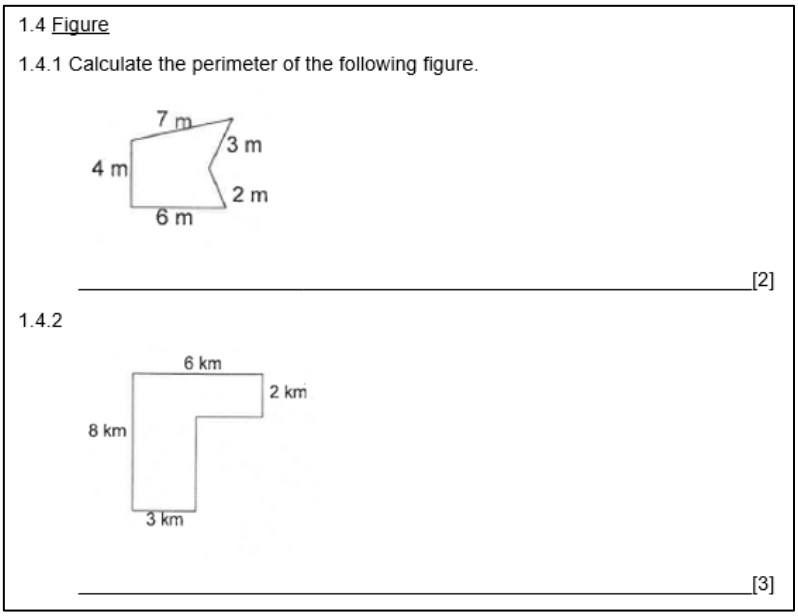
1.3. If the lengths of each side of the square is 6 cm. What will the perimeter of the square be?

_____

_____[2]

Figure 4.10

Questions 1.4.1 and 1.4.2 in Benjamin's project as a formative assessment



The project had two sections: 2D shapes, specifically squares; and measurement. The two sections did not have sub-essential questions that related the two topics to each other; each section was treated in isolation. Mentzer et al. (2017) have had a similar instance as their participants did not present the project as a coherent research project, but rather as separate lessons that did not relate to each other. Table 4.11 displays the distribution of the cognitive levels of the questions in Benjamin's project.

Table 4.9

Summary of the spread of CAPS cognitive levels in Benjamin's project as a formative assessment

Cognitive Level	Number of questions on the CAPS cognitive level	Percentage of questions on the CAPS cognitive level (rounded off to the first decimal place)	Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines
Knowledge	7	22%	25%
Routine procedures	21	67.7%	45%
Complex procedures	3	9.7%	20%
Problem-solving	0	0%	10%
Total	**31**	**100%**	**100%**

The spread of cognitive levels in his project was not perfect, but it was closer to CAPS' expected percentage of cognitive levels in an assessment. However, it lacked a problem-solving question, this being the main essential question. The sub-essential questions should preferably build upon each other. In Question 1, learners had to build a square using Jelly Tots and toothpicks, and draw their built figure in Question 1.1. In Question 1.2, learners had to write down the formula for a perimeter. The learners thus needed to recall the formula for perimeter from prior knowledge and research. Question 1.3 had learners calculate the perimeter of their figure if the sides were all 6 cm. The sub-essential questions took learners from building a figure to being able to calculate its perimeter. However, Questions 1.4.1-1.4.2 (Figure 4.10) felt disconnected from the square they built in Question 1.1. Instead of adapting the built square to resemble irregular polygons or relating it to the question, it was disregarded and not utilised. According to the RATP, teachers should cover the concept of calculating the perimeter of irregular polygons. As such, Benjamin included it in his project, however, Questions 1.4.1-1.4.2 were disjointed as they did not continue building on the prior sub-essential questions (Questions 1.1-1.3).

Additionally, Questions 1.1-1.4 served no purpose in the project as they were not informed by a main essential question. The design of these questions indicates that Benjamin did not understand how to set up a good main essential question or sub-essential questions for a project that will lead learners to an end product. This is why his project was not in line with the qualities of a good project as described by Kokotsaki et al. (2016). Mentzer et al. (2017) had similar findings where their participants set up sub-essential questions that did not lead to a final product.

4.4.2.2 Design of the project as a formative assessment

Benjamin's process for designing projects was closely tied to setting it up according to cognitive levels as seen through this statement:

> You must start with the knowledge that you think they know so baseline, and then work it from there to the more difficult things.

However, his project lacked a problem-solving question. This indicates that his project was not exactly aligned with CAPS (DBE, 2011). This was further substantiated by the fact that he did not consider CAPS in the process of planning his project, as shown in this section. When I asked Benjamin how he ensured that his projects were designed and administered according to the curriculum, he answered:

> If you look at the themes and you work through your revised ATP, it will always guide you to create a good project.

In this statement, Benjamin expressed the importance of using the RATP to guide the design of a project. What he referred to as 'themes' are, in fact, topics and the concepts and skills that need to be covered in each term. He claimed that a teacher must follow the RATP, and that using it will guide a teacher in designing projects. This is true as, according to the DBE (2023a), teachers are meant to use the RATP from 2023-2024 until it is amended in 2025. However, we know that the RATP does (1) Not have a definition of a project, it only states that it must be based on work from Term 1-3; (2) Has less content covered in a year than the original CAPS curriculum; and (3) Does not state the aims of CAPS (DBE, 2011; DBE, 2023a). That said, teachers are also meant to be aware of the aims of the curriculum and what projects are, but it cannot be assumed that all of them have knowledge about this. If Benjamin designed his project to adhere to the curriculum, it would cover the appropriate aims, be well-designed, and have a good spread of cognitive levels. The aims that Benjamin's project achieved are outlined in Table 4.10.

Table 4.10

Summary of the CAPS aims that Benjamin's project as a formative assessment achieved (DBE, 2011, p. 5.)

CAPS' aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	✓
Work effectively as individuals and with others as members of a team.	✓
Organise and manage themselves and their activities responsibly and effectively.	✓
Collect, analyse, organise, and critically evaluate information.	X
Communicate effectively using visual, symbolic and/or language skills in various modes.	✓
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	X

Benjamin's project touched on most of the CAPS aims (DBE, 2011), however, it did not cover the aims which are the most applicable to projects, namely: "demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation" and "collect, analyse, organise, and critically evaluate information" (p. 5). The project did not achieve these aims for three reasons:

- The project was not related to a real-life problem or context, partly due to the lack of a main essential question. At the very least, sub-essential questions could have been used that related to a real-life context.
- The project did not allow learners to independently collect information about how to calculate the perimeter and area of a square or a rectangle. They also were deprived of the opportunity to apply that information in a way that demonstrated and reinforced their understanding.
- It is not always an easy task to design a project that allows learners to use mathematics to solve environmental or social concerns. This hinges on the topic on which the project is based.

Benjamin's project was not planned with these aims in mind, although it would have been more successful if it had been. This corroborates Bell's (2010) statement that the application of PBL hinges on planning, and that of Li et al. (2009) that proper planning emanates from the objectives of the curriculum. The results of Viro et al.'s (2020) study confirms this since it showed that planning a project with the curriculum in mind will ensure in-depth teaching. However, if Benjamin only referred to the RATP, as he stated he did, he would never have considered these aims to start with.

The project was based on the perimeter and area of squares, rectangles, irregular polygons, and length. Looking at the RATP, as this is what Benjamin used, the concepts and skills he targeted were as follows:

Table 4.11

Summary of the concepts and skills in the RATP that Benjamin's formative assessment addressed (DBE, 2023a, pp. 3-4)

Content Area	Topic	Concepts and Skills
Measurement	**Length**	Measure 2D shapes using measuring rulers. Record, compare, and arrange lengths of shapes and objects using different length units of measurement (millimetres, centimetres, metres, and kilometres). Convert length units of measurement between millimetres, centimetres, metres and kilometres.
	Area and perimeter	Measure the perimeter using rulers. Find the areas and perimeters of regular and irregular shapes.

Despite the fact that a project provides the best opportunity to address certain concepts and skills, Benjamin's project did not cover solving problems in contexts involving length; investigate the relationship between the perimeter and area of rectangles and squares; or explore the relationship between surface area and the volume of rectangular prisms (DBE, 2011). The inclusion of these concepts and skills in the project could have made a difference as it would have placed Benjamin in the position to design a project that would address the keywords ‘investigate’ and ‘context’ used in the description of these skills in the RATP. The absence of these skills reveals that Benjamin did not fully understand what a good project entails (Thomas, 2000), or how to effectively set one up according to the curriculum.

4.4.2.3 Design of the timeline of the project as a formative assessment

Benjamin did not provide a timeline for the learners. He went through each question with them, thus managing the time they spent on each section. He stated that if needed, he would provide extra time if the majority of the learners were not done. When I asked him how he ensured that they stuck to the timeline, he said:

> That can be challenging to achieve, but what I've done is to go through different questions and give them time instead of assigning the entire project all at once. This way, you can continue while some groups finish quickly, others might start playing around, and some might still be struggling. By working through it in a structured manner, you can manage your time more effectively.

Benjamin worked through each question in the project with the learners, as seen in Section 4.4.2.4. learners were not afforded opportunities to conduct constructive investigations that allowed them to be independent from the teacher. Working through each question with the learners instead of assigning the whole project at once has its benefits in that Benjamin could be sure that the learners understood the sub-essential questions, and solved them to the best of their abilities. He could also provide more assistance to groups that were struggling. Alternatively, learners who worked faster were left waiting while other groups were still busy. However, the learners were meant to work through phases of the project on their own. Learners cannot always do the whole project alone if there is a need to assess one phase before going on to another, but this project was not designed like that. Benjamin could have given the whole project to the learners and facilitated them on a group-by-group basis.

4.4.2.4 The facilitation of learning

The section is divided into two sub-sections that make up the facilitation process, namely: the teaching approaches and the facilitation of learning.

- **Teaching approaches**

When Benjamin was asked if he used other teaching approaches, he replied:

> Okay, I have used a questioning method and trial and error. Sometimes learners do not understand the project and you need to use other teaching approaches. You can make projects individual work or group work. But, I think, projects should be group work.

Benjamin used a questioning approach with PBL. He allowed for group work, and encouraged learners to discuss the questions and answers, which is indicative of a social-constructivist approach. However, he still provided the information by explaining each concept in the questions, leading to passive learners (Petress, 2008). In this case, elements of a behaviourist approach were apparent because he reverted to a teacher-centred approach. Moreover, this can be seen in his intention to have learners imitate his understanding, as highlighted by Stonewater (2005), or have the learners depend on his explanations for knowledge. All of this is substantiated in the following excerpt from his first lesson:

> **Benjamin**: You don't need to write the formula. You have to tell me what you would do. How are you going to teach someone? How do you explain it to your partner? What is the circumference of a figure? And it can be any figure. It doesn't have to be just a square. It doesn't just have to be a rectangle. So, how will we solve it? Yes [indicating to a learner who had their hand up for the answer]?
>
> **Learner**: Can you say length times breadth?
>
> **Benjamin**: Remember now, I want to quickly say what is length times breadth? It is… [Benjamin looks at the learner who has his hand up to answer].
>
> **Learner**: Surface.
>
> **Benjamin**: It is not. So how are you going to work out the circumference of that figure? Let me ask you this, look at yours. [Benjamin goes to the projector and indicates to it]. Here is this one. What is the circumference? You have to describe to me what is the circumference. You and your partner can now talk a little about it. Just think, now I want you to see what you think it is. You have to learn from your figure.
>
> **Learner**: Length times breadth?
>
> **Benjamin**: No! No! How?
>
> **Benjamin**: Okay, it is group work. What could the circumference be if you had to describe it?
>
> **Learner**: Length times 4?
>
> **Benjamin**: Okay, why do you say that?
>
> **Learner**: We have a square and the sides are the same length.

Benjamin: In this case, in this sketch, this representation, what is the circumference? Is it the middle section?

Learners: No, Sir.

Benjamin: No, is it the Jelly Tot?

Learners: No, Sir.

Benjamin: No. Is it these sides?

Learners: No. Sir.

Learner: It is the toothpicks, Sir!

Benjamin: Just that one toothpick?

Learners: No, Sir. It's all four.

Benjamin: So, this is the perimeter [indicates to the area around the figure]. Now you can describe it to me. in your own words, what the circumference of a figure would be…

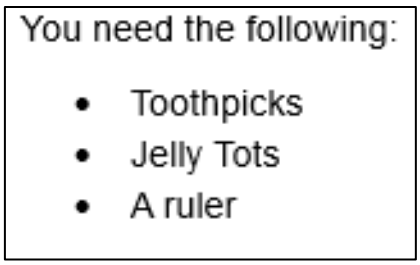
This is not an isolated example. There were large sections in the lesson where Benjamin explained a concept at length while trying not to provide the answer. However, PBL requires learners to function independently (Fisher et al., 2020; Kokotsaki et al., 2016), with the teacher being a facilitator. However, Benjamin did not entrust the learners to complete the project on their own without his explanations. Benjamin could have easily presented the lesson in a traditional teacher-centred manner and left learners to do the project - it would have had the same outcome. This is not indicative of a well-designed project as it would just revert to an 'everyday' lesson.

- **Benjamin as facilitator**

The project stipulated the resources required to complete it (see Figure 4.11).

Figure 4.11

Resources stipulated in Benjamin's formative assessment



The resources were realistic and accessible if learners had been required to obtain them on their own. The only problem with the use of Jelly Tots was the learners' desire to eat them. At some stages, learners were more preoccupied with eating the Jelly Tots than the project itself. This is similar to what Mentzer et al. (2017) noticed in group work projects where some learners were preoccupied with social media while others in the group were working diligently. Benjamin provided the learners with Jelly Tots and toothpicks. Learners did not have to bring their own for this project. However, Benjamin did not have enough Jelly Tots and toothpicks for the learners to build two figures simultaneously, which was necessary for Question 2.3 (Figure 4.12). Benjamin was able to build two figures, as seen in Figure 4.13. He demonstrates to learners how it would look if the two figures were used together to explain doubling. However, the few resources limited many of the learners, and placed Benjamin in the position of being the only provider of knowledge.

Figure 4.12

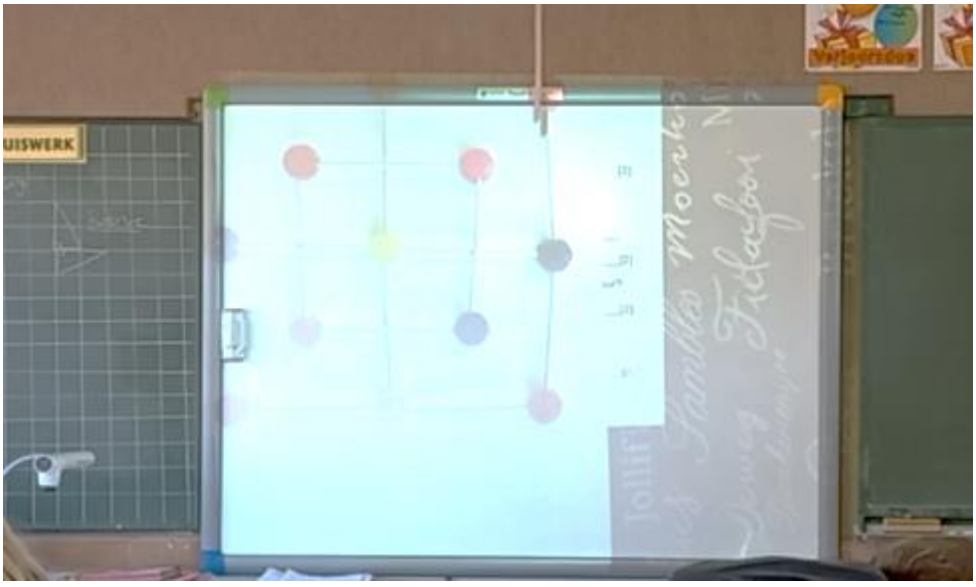
Question 2.3 in Benjamin's formative assessment

2.3 Look at figure 1 and figure 2. How many times can figure 1 fit into figure 2?

_____[2]

Figure 4.13

Photograph of Benjamin's formative assessment activity where he used two constructed Jelly Tots figures to explain Question 2.3



The learners worked in pairs for the first half of the lesson, and then in groups of four with the learners who sat at the desk behind them. Some learners did not have a partner during the

first half of the lesson and thus they worked alone. Benjamin did not attend to this by moving learners to work in pairs, and they therefore only had group members in the second half of the lesson. Benjamin continued emphasising the importance of incorporating group work into PBL. He also mentioned it in his definition of a project. Fisher et. al. (2020) also mention group work in their study, considering it an important facet of projects. However, by not accommodating these learners in the first half of the lesson, this indicated a lapse in Benjamin's judgment during his lesson. If it was truly important to him and his teaching approach, he would have ensured that those learners had partners to work with. These learners had no one to consult when answering the questions, thus placing them at a disadvantage to other learners. This is another example of the contradiction between what teachers say they do and what they actually do (Du Plessis, 2019; Mtika & Gates, 2010).

Benjamin emphasised that the learners had to think critically and creatively to complete the project. He explained most of the concepts, as seen in the following excerpt:

> **Benjamin**: I won't make it difficult for you. So, think. Let me put it like this. You need to use your built square. If I take one step from here… one [takes a step forward] . . . two [takes another step forward]. If this class is eight meters is length and width, and I walked two meters of the length, how far is it from here to that wall?
>
> **Learner**: Seven.
>
> **Other learner**: Six meters.
>
> **Benjamin**: Six meters. Now use your built square. How many meters are behind me? If I walk from this side [Benjamin goes to the opposite side of the class and takes two steps forward like he did at the other side of the class]. How far is it going to be from here to the other side of the class?
>
> **Learners**: Six.
>
> **Benjamin**: Six meters. So, do I have to move in one line all the time?
>
> **Learners**: No.
>
> **Benjamin**: So, take a look. And this is why you and your partner should look at your sketch because it is a representation. You have to go work it out.

In this section, Benjamin explained Question 1.4.2 (Figure 4.10) where learners were meant to calculate the perimeter of the figure but there was one unknown side. Benjamin's explanation aimed to clarify how learners were meant to use the two known lengths to determine the unknown one. In other words, learners had to see that 3km is half of 6km, and that the unknown side is also 3km.

In explaining each question, Benjamin did not provide a sense of independence to the learners when they built their figures and solved the problems. Kokotsaki (2016) states that teachers need to guide learners to understand the content of the project. This means that Benjamin should not have explained the concepts and skills required from the learners in extreme detail. He should have clarified certain questions that learners might have, and monitored them as they worked. If a group appeared to be lost, he could use scaffolding in guiding them to understanding. He should not have explained every question to the entire class. Providing learners with a sense of independence is an important part of active learning (Petress, 2008), which is, in turn, part of the nature of a project. This teaching approach also contradicted his teaching philosophy, which aimed to encourage learners to engage in logical reasoning. Benjamin explained every cognitive challenging question, which defeats the purpose of using them (DBE, 2011), and the challenge of a project according to Kokotsaki (2016). Aksela and Haatainen (2019) similarly report that the teachers in their study were not able to manage learner-centred activities without restricting the learners too much, whilst also not providing them with too many answers.

Finally, when I spoke to Benjamin before the interview, he said that he had no time to mark the first phase of the projects the very same afternoon as he had to deal with personal matters. I then asked Benjamin how he would hypothetically provide learners with diagnostic feedback, to which he responded:

> So, in today's lesson, you would ask them questions about their understanding of yesterday's work. More or less like you did at the end of yesterday's session, by just asking them questions to revise everything…

Although doing revision work is a form of providing feedback, it would have been better if Benjamin had marked each phase first as suggested by Fisher et. al. (2020), Kokotsaki, (2016), and The George Lucas Foundation (2007). That said, the phases of the project were not directly related to one another, thus the success or failure of one phase would not influence the performance of subsequent questions. The main finding from the interview with Benjamin was the matter of time being a factor in the marking of each phase in the project.

4.4.3 Section C: The project as a summative assessment

Benjamin's summative assessment project was based on the area and perimeter of a square and rectangle, as well as the volume of a cube. The project counted for 25 marks in the learners' Term 3 report. This project was subject to document analysis only, since I did not observe when the project was administered. This means that I can only report on the RATP aims and concepts that the project addressed by analysing the project design. I am not able

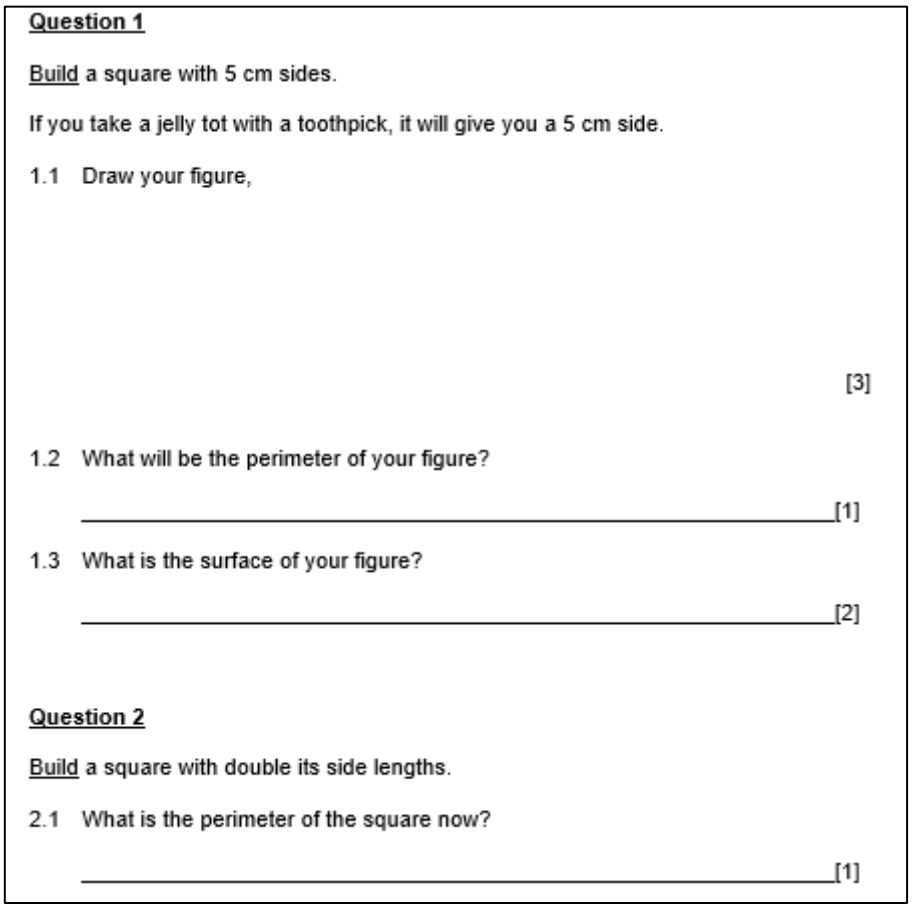
to report on whether the aims and concepts were addressed verbally, or it the teacher deviated from the project design. This also means that I cannot report on how the project was facilitated, and can only make inferences through interviews and the design of the project.

4.4.3.1 Essential and sub-essential questions

Benjamin's summative assessment project did not contain a main essential question. The project followed general instruction where learners used Jelly Tots and toothpicks to build squares and cubes. However, the project did not guide the learners to a final product or conclusion. The use of the Jelly Tots and toothpicks, along with some of the instructions, was very similar to Benjamin's project as a formative assessment. There was no central topic, no relation to a real-life topic, and the questions were closed-ended, as seen in Figure 4.14.

Figure 4.14

Questions 1.1-2.1 from Benjamin's project as a summative assessment



Question 1

Build a square with 5 cm sides.

If you take a jelly tot with a toothpick, it will give you a 5 cm side.

1.1 Draw your figure,

[3]

1.2 What will be the perimeter of your figure?

_____[1]

1.3 What is the surface of your figure?

_____[2]

Question 2

Build a square with double its side lengths.

2.1 What is the perimeter of the square now?

_____[1]

The design of these questions is similar to what Mentzer et al. (2017) found in their study where the teachers did not include main essential questions, and designed projects with closed-ended questions that only had one correct answer. The cognitive levels of the project are presented in Table 4.12.

Table 4.12

Summary of the spread of CAPS cognitive levels in Benjamin's project as a summative assessment

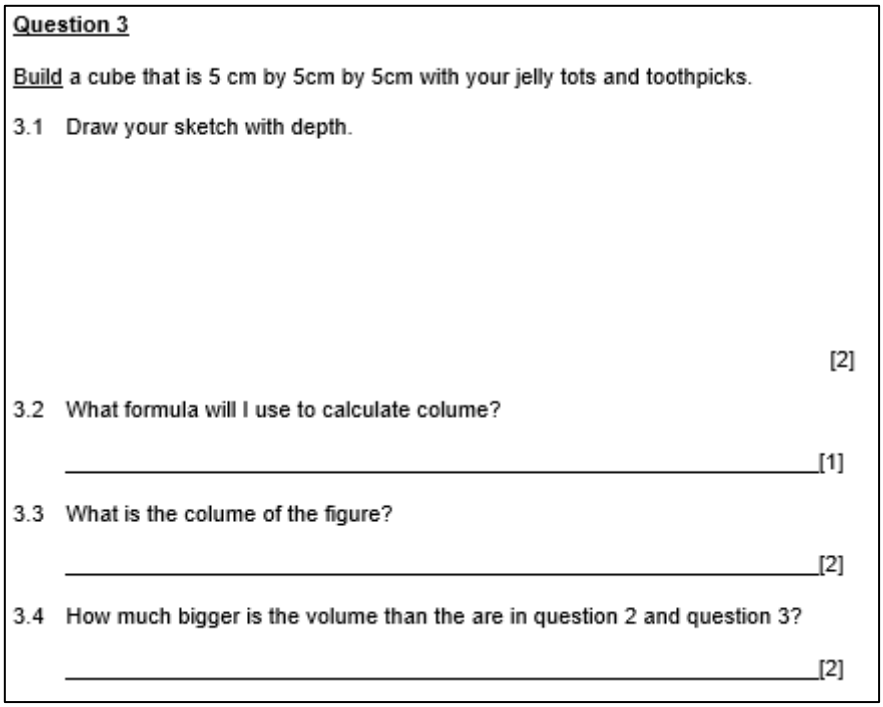
Cognitive Level	Number of questions on the CAPS cognitive level	Percentage of questions on the CAPS cognitive level (rounded off to the first decimal place)	Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines
Knowledge	5	263%	25%
Routine procedures	12	63.1%	45%
Complex procedures	2	10.5%	20%
Problem-solving	0	0%	10%
Total	**19**	**100%**	**100%**

There was a good balance of 'knowledge' questions, but there were too many 'routine procedure' questions, resulting in too few 'complex procedure' questions. The absence of 'problem-solving' questions was brought on by the exclusion of a main essential question. The sub-essential questions built upon each other to an extent. For example, the first four questions of Benjamin's project (Figure 4.15) required the completion and full understanding of the previous questions to adequately understand the next. The first question required learners to draw their Jelly Tots square. The second question asked what the perimeter of that square is.

The project then delved deeper into questions where learners evaluated what would happen to the area and perimeter if the length of the square was doubled. Unfortunately, no follow-up questions were asked, which would have allowed learners to reason and interpret the effect of a change in the length of a cube on the perimeter of the cube. The next set of questions concerned volume (Figure 4.15).

Figure 4.15

Questions 3.1-3.4 from Benjamin's project as a summative assessment



Question 3

Build a cube that is 5 cm by 5cm by 5cm with your jelly tots and toothpicks.

3.1 Draw your sketch with depth.

[2]

3.2 What formula will I use to calculate colume?

_____[1]

3.3 What is the colume of the figure?

_____[2]

3.4 How much bigger is the volume than the are in question 2 and question 3?

_____[2]

The learners had to change their 2D square to a 3D cube; however, no connection was drawn between the previous section and this one. There could have been a question that introduced the idea of the area of one face of the cube, or the total surface area of the whole cube. Question 3 feels disjointed from Questions 1 and 2. The sub-essential questions should build upon each other to help learners form meaning of the content, and to complete the project. These questions did not drive learners towards the larger narrative of a presented scenario of a problem. For Questions 4.1-4.2, the learners had to draw 2D shapes with different lengths. In Queston 4.3, the learners had to calculate the area of the shapes they drew in Questions 4.1-4.2. In Question 4.3, the learners had to state which shape had the largest area, and in the final question, the learners had to state what the largest possible figure is to have a perimeter of 64m. These questions did not relate to the figures that had been built, and therefore functioned completely independent from the rest of the project. None of the sub-essential questions functioned effectively in the project because there was no main essential question to guide them towards a set goal.

4.4.3.2 Design of the project

Benjamin's project centred around the content area of measurement, specifically the area and perimeter of a square and rectangle, and the volume of a cube. The project did not require learners to do research beforehand, nor were they provided notes about the area and

perimeter of a square and rectangle, or the volume of a cube. This correlates with the characteristics of a summative assessment since it needs to take place after the content is taught (DBE, 2011). The absence of any notes or additional research needing to be done indicates that Benjamin had already taught the topic to the learners. His project covered the following CAPS aims:

Table 4.13

Summary of the CAPS aims that Benjamin's project as a summative assessment achieved (DBE, 2011, p. 5.)

CAPS aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	✓
Work effectively as individuals and with others as members of a team.	X
Organise and manage themselves and their activities responsibly and effectively.	✓
Collect, analyse, organise, and critically evaluate information.	✓
Communicate effectively using visual, symbolic and/or language skills in various modes.	✓
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	X

Benjamin's project managed to address four curriculum aims for the following reasons:

- His project allowed learners to use the figures they built to reason and think creatively when solving the problems related to the figures. However, this only applied to Questions 1.1-3.4, since the rest of the project did not use the figures, and the questions appeared as standard textbook questions. Moreover, these questions did not relate to the other questions in the project that used the Jelly Tots and toothpicks.
- Learners had to be responsible enough to bring their own resources and manage them during the project. If they ate all of their Jelly Tots before finishing the project or did not build their figures properly, they would have experienced a problem.
- Learners communicated their understanding of the properties of a cube and a square when they built them according to certain measurements. They were also required to

draw figures and do some calculations. Thus, the learners used various representations to display their understanding.

The reasons why this project did not achieve the other aims were that the project did not:

- Let learners use mathematics in a way that shows responsibility to the environment.
- It did not showcase how the world is a set of related systems. The project did not have a main essential question, which could be why it did not cover these last two aims as they would require the project to stand as a cohesive whole, with each section of the project playing a role in producing a final product. The sections of the project, unfortunately, did not relate to one another and felt disjointed. There was no relation to real life and, overall, the project did not have learners showcase their overall understanding.

Arguably, Benjamin's project should have achieved the last aim in Table 4.13 since it related to a main essential question. The failure to achieve this indicates that Benjamin either chose not to achieve the aim, or he did not know about it. This indicates a problem in the planning process of the project as it would have allowed Benjamin to implement the curriculum's objectives (Li et al., 2009). The project, however, did achieve the following: "Collect, analyse, organise, and critically evaluate information" (DBE, 2011, p. 5), which are relevant skills developed when doing a project. Benjamin's project was thus adequately aligned with the aims of CAPS, but could have been better with the addition of a main essential question.

The project covered the following concepts and skills:

Table 4.14

Summary of the concepts and skills in the RATP that Benjamin's formative assessment addressed (DBE, 2023a, pp. 3-4)

Content Area	Topic	Concepts and Skills
Measurement	**Area, perimeter, and volume**	Measure the perimeter using rulers. Find the areas and perimeters of regular and irregular shapes. Find the volume/capacity of objects.

The project managed to cover most of the concepts and skills as prescribed in the RATP. I excluded that which it did not cover as projects are not obligated to cover every concept and skill in its content area. It is worth mentioning the skills and concepts it could have addressed

given that a project would have been a useful activity to address them. The project did not include the following: investigate the relationship between perimeter and area of rectangles and squares; investigate the relationship between surface area and volume of rectangular prisms (DBE, 2011).

This project would have allowed for learner agency if Benjamin had explained every question, as in his formative assessment, and rather guided learners individually as they progressed through the project. Since none of the sections were related to each other, or built upon each other towards a final product, the learners did not demonstrate their understanding in the form of a final product. This is likely due to the lack of a main essential question and a central topic. However, the learners did develop skills in investigation, analysis, and problem-solving, which should be part of the main outcomes of a project (Fisher et al., 2020; Kokotsaki, 2016).

4.4.3.3 Timeline of the project

The project did not have a set timeline stated on it, which is a requirement of The George Lucas Foundation model (2007). In interviews with Benjamin, he stated that he would provide extra time for learners to finish should they require more time. However, it is not possible to say how much time the learners would have based on the project alone.

4.4.3.4 Assessment of the project

Benjamin stated the following regarding what preferred assessment tool should be used when marking projects:

> Rubrics are always a helpful tool. They are especially useful when a creative answer is required, as they provide specific guidelines for teachers or facilitators to assess responses. By using a rubric, you can ensure that marks are assigned based on certain criteria, helping you determine what students know. For straightforward right or wrong answers, marking is simple, but for questions requiring descriptions or explanations, the rubric helps evaluate more complex responses. For example, in yesterday's lesson involving drawings, it was important to assess whether students understood and could interpret their own drawings. This understanding will also guide future assessments.

Benjamin displayed an adequate understanding of how projects should be assessed. Nonetheless, despite this statement, Benjamin only used a memorandum and not a rubric as well when assessing his project. CAPS (2011) states that appropriate assessment instruments need to be used. For projects, this should include a wide range of assessment instruments, from memorandums to rubrics, as it is meant to assess “a range of skills and competencies” (DBE, 2011, p. 245). When assessing a project, teachers should also provide diagnostic

feedback. A memorandum alone limits the range of feedback that Benjamin could provide to the learners.

4.5 PRESENTATION OF THE DATA COLLECTED FROM SOPHIA

The data collected from Sophia will be presented in three sections: factors influencing the implementation of projects; the project as a formative assessment; and the project as a summative assessment.

4.5.1 Section A: Factors influencing the implementation of projects

The factors covered in this data presentation were those that presented to have the most impact on how PBL and PBA were used.

4.5.1.1 Internal factors

The section discusses the internal factors that can influence the implementation of projects as formative and summative assessments. These discussions focus on formative and summative assessments simultaneously since many of the discussion points overlap.

- **Interpretation of the curriculum**

During the interviews, Sophia pointed out that she used the RATP and not the original curriculum. When I inquired about this, Sophia explained:

> At the moment, we're doing the RATP. I think that was for a three-year basis, but we do follow exactly what's given to us by the department, even though they give it to us very late and the term is usually over already. We do follow what we have currently in front of us and our departmental heads are very good at following up with them to see what is required.

Sophia believed in following the RATP strictly, she even referred to it as her ‘bible’ in another interview. Although she did not use the original curriculum, during other interviews, it became clear that Sophia was aware of the outcomes in CAPS. Sophia believed that mathematics needs to be made relatable to the learners. This speaks to the mathematics-specific aim of fostering a curiosity for mathematics (DBE, 2011), as stated in CAPS. This indicates that she was aware of the original curriculum, and might have used it to guide her teaching alongside the RATP.

- **Pedagogical beliefs**

Sophia described her teaching philosophy as follows:

> So, firstly, the learners have to find a love for the subject. I do spend a lot of the beginning introduction time at the beginning of the year getting to know the learners by working together and getting to know their personal ins and outs. Explaining how fun maths can be. I try and break the perception of maths being boring and I'm always going to fail. As the lessons and the different concepts start, I explained to them all the exciting things we're going to do and how we're going to do this and the minute they've got the love and the happiness and the enjoyment in mathematics, and their attitude changes towards the subject. I definitely do see a lot better results.

Sophia's teaching philosophy can best be described as creating an environment where learners cultivate a love and curiosity for the subject. She did this through building a relationship with the learners and taking her time with each topic to show how 'fun' it can be.

- **Teacher's knowledge of PBL**

Sophia described PBL as follows:

> … working together, sharing ideas, a lot of interaction during the lesson. It's not very formal to the point where there's no talking. You've gotta, you know, work on a particular concept and the process of working it out in discussions, group discussions and sharing ideas. Yeah, I mean putting it together in a final, like a final presentation or a final graph or a 3D model or something like that.

Sophia's explanation of PBL covers many of the key aspects such as collaboration, investigation, and creating an end product. Learners need to work collaboratively, share ideas to build their understanding, and work towards creating a final product that emulates their full comprehension of the topic. All of these are described by Fisher et al. (2020), Kokotsaki et al. (2016), and The Geroge Lucas Foundation (2005). She did not mention investigating a topic or solving a main problem, however, she stated that learners need to create something 'final' together, which indicates that they had to solve a problem. Overall, Sophia's definition indicates that she had a comprehensive understanding of PBL.

- **Teacher's knowledge of projects**

Sophia described projects as:

> Working together, sharing ideas, interacting while the work is being done and work that is to be done by themselves, to see the understanding and the final output on the idea of work, or the final idea of the concept that's being put across.

This definition is similar to Sophia's description of PBL. This assertion indicates that Sophia closely related the purpose of a project to what PBL comprises. The definitions are closely related as PBL is the application of a project and should adhere to the description of what a project is. Sophia's definition of a project concurs with that of Bell (2010) and Jacobs et al. (2016) since it addresses problem-solving. This is seen through her mentioning the creation

of a 'final product'. For learners to do this, they should solve a main essential question based on a central topic. Even though it was not explicitly mentioned in the definition, it was seen in Sophia's design of a project as a formative assessment (Section 4.5.2.2) that she understood that projects should have a main essential question with a central topic, and be based on a real-life context.

- **Teacher's knowledge of summative and formative assessments**

Sophia described formative assessments as:

> Something that gets done on a regular basis throughout the different lessons. To see the understanding of what is going on in that particular section of work. So, if we're doing, for example, fractions, there'll be constant checks during the different lessons on fractions to see if they understand what's going on.

Sophia described formative assessments as a sort of barometer to check if learners understood the work. CAPS describes formative assessments as "short class works during or at the end of each lesson [and] verbal questioning during the lesson" (DBE, 2011, p. 293), which resonates with Sophia's definition. She mentioned doing constant 'checks' after concepts had been taught, referring to oral questioning, mental mathematics test, and marking learners' books. By doing a formative assessment after a lesson, teachers can evaluate learners' understanding of the concept. However, the focus should remain on it being an assessment *for* learning, meaning it needs to be another facet of the teaching and learning process. Sophia defined summative assessments as:

> Summative assessment involves evaluating learners' performance at the conclusion of a term or academic year. This type of assessment measures how well learners have met the learning objectives and outcomes outlined in the curriculum. It typically includes exams, standardised tests, and final projects, providing a comprehensive picture of learners' understanding, knowledge, and skills across one or more subjects.

Sophia's definition is in line with the CAPS statement about summative assessment, namely, that it is an assessment *of* learning. Sophia mentioning 'final projects' implies that there were other projects done before the one for summative assessment. This indicated that she was aware that projects as formative assessments should be done before projects as summative assessments. Overall, Sophia had a well-rounded understanding of formative and summative assessments.

4.5.1.2 External factors

The following section examines all the external factors that can affect the implementation of projects as both formative and summative assessments. These discussions address formative

and summative assessments concurrently as many of the discussion points are relevant to both.

- **Support from HoD and subject heads**

I asked Sophia what kind of support she received from her HoD and subject head in terms of the implementation of PBL, to which she replied:

> So, I do resort to talking to them about ideas. I don't always have the most amazing ideas. I'll come up with something quite simple and they will help me make it better, more enjoyable, more exciting after so many years…

Sophia elaborated on how she consulted her HoD and subject head about ideas for her projects. Thus, to an extent, they helped her in the design of the project. Sophia therefore experienced what Aksela and Haatainen (2019) detail in their study, which is that one of the biggest challenges in setting up projects is finding creative concepts on which to base them.

When I asked her whether they encouraged her to use projects for formative assessment, and how they would if they did, she explained:

> They don't encourage it as it's not actually something that is discussed if it is part of the actual CAPS curriculum. They will check that it's being done and if they see it, if it is in that particular term, they will then obviously check that it pertains to the grade. That I'm teaching and that I cover the necessary concepts.

Sophia's response is quite interesting. She stated that formative assessments were not something that she discussed with her subject head and HoD, and in the few cases that she did, it was only if it formed part of CAPS. This is a misguided statement because formative assessments are part of the curriculum (DBE, 2011), and are mentioned in subject meetings and circulars (DBE, 2023a). However, she stated that they used the RATP, and her subject head and HoD ensured that everything in it was covered. The RATP does not mention formative assessments, so if these individuals followed it without consulting other departmental documents, they would not know about the requirements of formative assessments.

- **Lesson planning and preparation**

I asked Sophia how she approached planning for a project as a formative assessment, and how she prepared for it; her response was as follows:

> So, what is nice is the same concept would obviously have to be taught just in a different way when it comes to project-based. The lesson plan doesn't change much, just the activities and the steps that children would take. But the content and the skills and concepts covered are going to

> be the same with years of teaching. I do have an abundant supply of lesson plans, which I just adjust per year and per term.

Sophia mentioned that planning and preparing for a project did not require a significant amount of effort. However, a teacher must implement changes in the lesson plan to suit the purpose and design of the project. Lazic et al. (2015) state that to plan and prepare for the use of PBL, a teacher needs to adapt curriculum content to fit the teaching approach's purpose, which resonates with Sophia's statement. Guntur and Retnawati's (2020) participants stated that teachers need to have good planning and preparation in place to execute a project. Sophia's statement that an 'everyday' lesson only needs minor adaptations to be suitable as a project is misguided. Projects require extensive planning to be implemented correctly, and differ from what most teachers do every day. Furthermore, although Sophia did not specifically mention aligning the lesson plans with the general aims of CAPS, she did consider them in her lesson plans (DBE, 2011). This can be seen in the analysis of her project's design in Section 4.5.2.2.

- **Experience of a teacher**

When I asked Sophia if she considered the level of experience a teacher has as a factor that influences the use of PBL, she said:

> So, definitely, experience comes into effect. With more experience, you know what sort of projects are user-friendly. What is impossible to work with? You know how to plan them better. As in, do you, yourself collect the tools or the information, or do you allow children to go out and do it? There are projects, for example, where they've got to do something about a famous mathematician. If you do something like that, how are they going to get the information? Where are they going to get the information from? Do they all have resources? So, experience is definitely a positive factor when deciding on what to do with projects.

Sophia highlighted that a teacher's experience significantly influences the effective use of PBL. She explained that experienced teachers are better at selecting manageable and engaging projects, planning them efficiently, and determining the most effective ways for learners to gather the necessary tools and information. She emphasised that experience helps teachers to anticipate potential challenges, such as ensuring that all learners have access to the required resources, thereby making the experience a crucial positive factor in successfully implementing PBL.

4.5.2 Section B: The project as a formative assessment

Sophia's formative assessment was based on the collection, representation, and analysis of data using a tally chart and a bar graph. The project took place over two periods.

4.5.2.1 Essential and sub-essential questions

Sophia's project contained a main essential question. The question (see Figure 4.16) created a scenario where learners needed to find out what their peers wanted to be when they grew up. Learners needed to collect data and present it in a tally chart and bar graph. Although the scenario was not phrased as a question, it provided learners with guidance, instructions, and a central topic to investigate. The scenario provided learners with the opportunity to be agents of learning by allowing them to collect data and interact with their peers. This is in line with Thomas' (2000) finding that this makes for a good project, and adheres to the George Lucas Foundation's (2007) model for the implementation of projects.

Figure 4.16

Sophia's main essential question from her project as a formative assessment

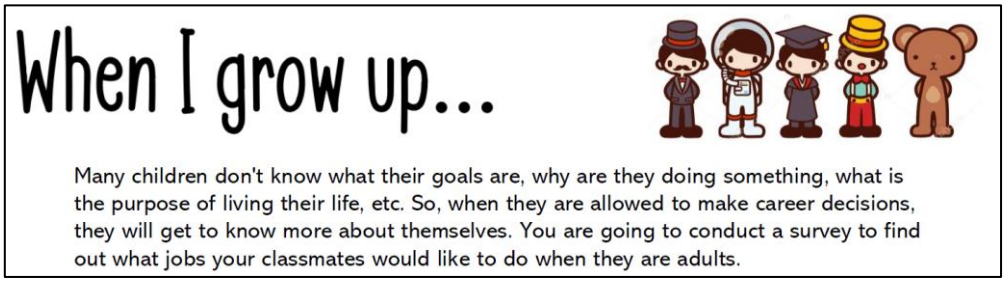


Table 4.15 displays the spread of cognitive levels across the main essential and sub-essential questions in Sophia's project.

Table 4.15

Summary of the spread of CAPS cognitive levels in Sophia's project as a formative assessment

Cognitive Level	Number of questions on the CAPS cognitive level	Percentage of questions on the CAPS cognitive level (rounded off to the first decimal place)	Percentage of questions that is recommended to be on the respective cognitive level according to CAPS guidelines
Knowledge	2	28.6%	25%
Routine procedures	3	42.9%	45%
Complex procedures	1	14.3%	20%
Problem-solving	1	14.3%	10%
Total	**7**	**100%**	**100%**

The distribution of the cognitive levels is almost perfectly balanced. The project had a problem-solving question (Figure 4.16), which was the main essential question. The question thus falls under the cognitive level of problem-solving since it required learners to "break the problem

down into its constituent parts", required "higher order understanding," and was a "non-routine" problem (DBE, 2011, p. 5). The main essential question was open-ended and based on a real-life context that most learners would be interested in as it was part of their lives. During the lesson, every single learner participated, and had an idea of what they wanted to be when they grew up, indicating that it was a relevant topic for them and captured their interests.

When I asked the teacher what makes for a good main essential question, she stated:

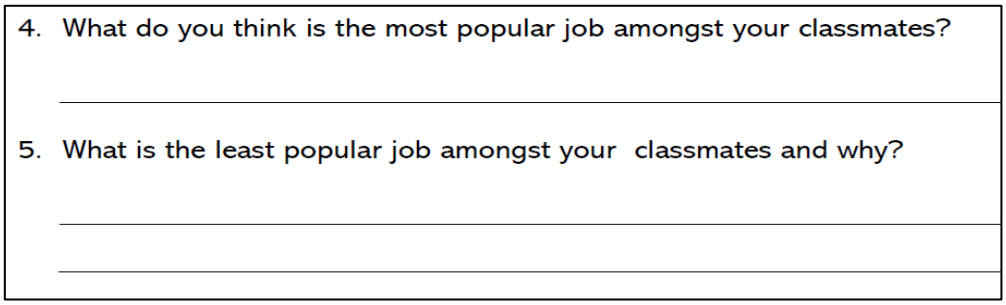
> Definitely a relatable topic to the learners, something they are interested in, and something they can share their own input. I can do something that I'm interested in, but then I would have lost them, so I have to find something that they would be eager and willing to discuss.

This statement indicates that Sophia put a lot of thought into her project, ensuring that it captured learners' attention while also providing meaningful answers and, consequently, developing a better understanding of data handling. The learners were also provided with the opportunity to construct their own knowledge by completing the sub-essential questions. At the end of this project, they would have developed a better understanding of collecting, collecting, analysing, and presenting data using a tally chart and a bar graph. This aligns with the findings of Fisher et al. (2020), Kokotsaki et al. (2016), Lazić et al. (2021), Nasution et al. (2021), and Serin (2019) that projects' purpose is to develop a better understanding of mathematical content.

However, the layout of the project felt incomplete. It ended with a bar graph, which was the end product. However, it felt like there should have been more sub-essential questions that guided learners to interpret their graphs. The learners did discuss their thoughts on the data in two questions before the bar graph, as shown in Figure 4.17. It would have been better if these questions were placed after the bar graph, with other sub-essential questions that summarised their final findings, and asked for their opinions and justification of their findings.

Figure 4.17

Questions 4 and 5 from Sophia's project as a formative assessment



4.5.2.2 Design of the formative assessment project

Sophia designed her project to centre around a topic that is relevant to learners, as revealed through our interviews. When I asked her how she ensured that her project aligned with the requirements of the curriculum, she explained:

> …to look at the ATP. If the ATP says for example, I need to cover something on mean, median, mode and range, I will go and get a variety of questions that are suitable for the particular grade, obviously finding some more challenging ones for those who finish early. But it will be on, for example, goals scored in soccer because they all love soccer or netball – netball goals scored or the amount of websites designed. It would have to be relatable to children in every section of work that I do as much as I can. I find a way to get them to buy into the idea of what we're doing. I don't stand and talk in one tone all day. I make jokes with them. I make lessons fun. So that coming to maths is not a drag.

Sophia again emphasised the importance of making a project relatable to learners. She also mentioned adding questions to her project that would challenge bright learners. These questions would be on the highest cognitive levels (complex procedures and problem-solving), and would challenge these learners. Her statement demonstrates a thorough understanding of curriculum expectations. Reviewing how her project's questions aligned with the prescribed cognitive levels of CAPS (Table 4.16), it is clear that it was well constructed to foster learners' critical thinking.

Table 4.16

Summary of the spread of CAPS cognitive levels in Sophia's project as a formative assessment

CAPS' aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	✓
Work effectively as individuals and with others as members of a team.	✓
Organise and manage themselves and their activities responsibly and effectively.	✓
Collect, analyse, organise, and critically evaluate information.	✓
Communicate effectively using visual, symbolic and/or language skills in various modes.	✓
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X

CAPS' aims achieved through the project	Check
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	✓

Sophia's project achieved most of the CAPS aims for the following reasons:

- The project allowed learners to think critically and creatively while gathering the data and interpreting it into a bar graph. This was also seen in the first two questions when learners had to discuss what career they wanted to pursue when they were older, and were required to describe it. Although these questions were not difficult, the learners' interest was sparked, they became engaged, and they needed to critically evaluate the career they considered for their future lives.
- Learners had to work together in class when they had to indicate whether they would pursue careers that were in the different categories the teacher put on the board.
- Learners had to collect and complete their tally charts on their own. They thus had to ensure that they paid attention and did their tallies correctly.
- Learners had to interpret the data from the tally chart and then present it in a bar graph.
- Learners used three different modes to display their understanding: answering questions, setting up a table, and drawing a bar graph.
- Learners were able to relate mathematics to a real-life context through the project.

One aim that the project did not achieve was using mathematics to show responsibility to the environment and social problems. As stated before, this is not an easy aim to achieve since it is dependent on the central topic of a project.

Sophia's project addressed most of the concepts and skills in data handling, namely, collecting, analysing, and representing data using a tally chart and a bar graph. This is in line with the RATP, as seen in Table 4.17.

Table 4.17

Summary of the concepts and skills in the RATP curriculum that Sophia's formative assessment addressed (DBE, 2023a, p. 4)

Content Area	Topic	Concepts and Skills
Data Handling	**Collecting and organising data**	Collecting and organising data using a tally chart and

Content Area	Topic	Concepts and Skills
		a simple survey with 'yes' and 'no' questions.
	Analysing, interpreting, and reporting data	Represent data using a bar graph. Analysing, interpret and report on data of a bar graph. Analyse data by answering questions related to the data's source and context and its categories. Draw conclusions about the data

Sophia did her formative assessment project at the beginning of Term 4. This meant that she did it after the summative assessment project. I mention this because the RATP prescribes data collection to be done in Term 4, and not Term 3. Furthermore, Sophia's project focused on bar graphs and tally charts. The RATP prescribes the use of other graphs in the 'data handling' content area as well. It also requires learners to describe the data using measures of central tendencies such as mean, median, and mode. Sophia's project did not cover this, but, as mentioned, a project does not have to cover everything in each content area, only that which is most relevant to it.

Sophia's project was designed to foster an active learning environment. The project allowed learners to connect the learnt knowledge with the process of skill development. In other words, learners used their understanding when implementing the project. It also allowed them to share their views on what different careers people can pursue. This is all indicative of active learners (Petress, 2008). It adhered mostly to the qualities of a good project, such as having a central topic, a main essential question, an element of realism, and allowance for learner agency, as mentioned by Thomas (2000), and substantiated an effective PBL approach.

4.5.2.3 Design of the timeline of the project as a formative assessment

Sophia's project did not have a stipulated timeline; she used three lessons to do the project. On the first day, she used a double period, and on the second day, she used one period. She provided a structured environment for the learners to pace themselves in the data collection portion of the project. She did each of the questions with the learners in the first half of the project. The learners did the second portion of the project in their own time, and Sophia waited

for everyone to finish. When I asked Sophia how she decided how much time to give learners to do a project, she replied:

> The [RATP] is my Bible. If it says 6 hours, I plan and break up the sections into what needs more time, what needs less time and, obviously, depending on what my departmental head would like me to assess at the end of the year or at the end of the term, the biggest section she wants assessed is something I would have to put a bit more time into as well. And obviously, if it's something that is not going to be ever covered again in Grade 7, I'm not too worried about it. If it's a big section, I know [the Grade 7 Mathematics teacher] continues working with, I make sure that they've got a good understanding of it.

Sophia's adherence to the RATP indicates that she followed curriculum guidelines, which according to the DBE (2023a) is the RATP. Teachers should follow its termly breakdown of what content to teach instead of what is prescribed in the original CAPS. She, however, also mentioned that she used her discretion in whether a topic would be important in Grade 7 mathematics. This is an interesting way to consider how much time to allocate to a topic.

4.5.2.4 Facilitation of learning

The section is divided into two sub-sections that make up the facilitation process, namely: the teaching approaches and the facilitation of learning.

- **Teaching approaches**

When I asked Sophia whether she used other teaching approaches with PBL, she first needed me to explain the question, ultimately answering:

> When [learners] are learning a new concept, for example, geometry, there is a lot of questioning. I ask them questions, things that they can relate to. For example, if we're doing three-dimensional shapes, I'll ask them what objects look like a sphere. I'll let them bring up their own objects. I'll ask them the different properties of it, so there's a lot of discussion work once we've done the discussion work and the talking, we then sit down and put work into the books which they can then use for studying purposes.

Sophia did not address the project at hand, but rather provided a hypothetical for another lesson. However, she mentioned a questioning approach. Although she did not directly relate it to her use of PBL, it was seen in the lesson observations, along with lengthy discussions. Sophia's mention of a questioning approach is in line with what she did in class. She justified it by saying that when learners encounter a new concept in the year, she would ask probing questions that made learners relate the topic to real life. Her use of a questioning approach was evident at the start of her lesson, as seen in the following excerpt.

> **Sophia**: Okay, so we are collecting what?

Learners raise their hands, the teacher points to one learner to give the answer.

Learner: Information.

Sophia: Collecting information and we are putting it out on what?

Learners raise their hands, the teacher points to one learner to give the answer.

Learner: Different types of charts.

Sophia: Different types of graphs. We have all done this before, so let's wake up our holiday brains. So, we are going to go to describe – explain different types of graphs and I want to explain tally marks to you as well. So, the first thing I want you to underline is the heading 'Tally Marks'. [Learners underline the heading]. Now I want to see, hands up, is tally marks a graph or a chart?

In the next part of the lesson, she used a discussion approach, relating data collection and graphs to real-world examples:

Sophia: …So, I see very often there are people who stand at the side of the road, and they have a clipboard and what they do is, they check the traffic congestion in that particular area. So, they stand with a clipboard, and they are not counting what coloured cars are coming past. They are not counting what type of cars or, uh, if it is motorbikes or trucks. They are counting how much that particular road is being used. What is the usage of that particular road? So, they will stand there, and instead of counting like this [goes to the board to write out '1, 2, 3, 4]) one car, two cars, three cars, four cars, they are going to go fast. Do cars go slow because you want them to go slow? No, they are gonna go pretty fast. So, they are gonna go [writes tally marks on the board], one, two, three, four, five. One two three, four, five. One two three, four, five. One, two, three, four, okay? They are not going to wait for you. What are the multiples going up there [shows to the tally marks]?

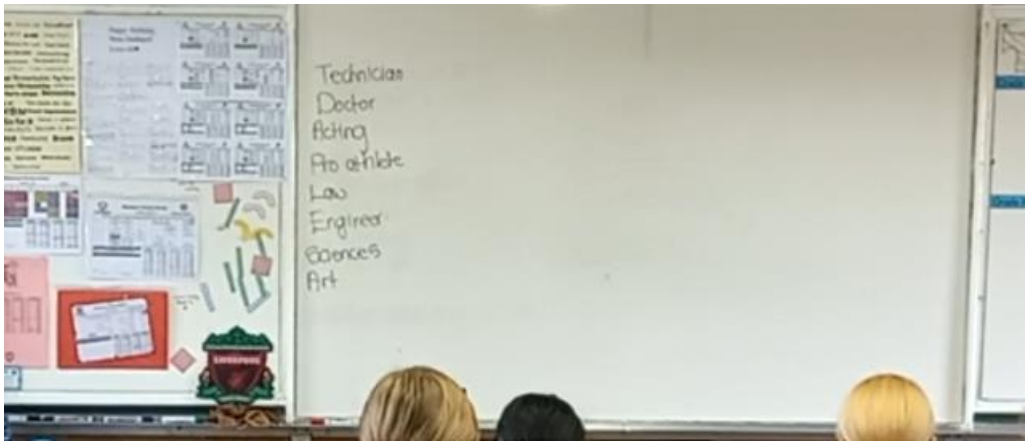
Learners raise their hands, the teacher points to one learner to give the answer.

Learner: Five.

After Sophia explained the work, through questioning and discussion, she started with the project. Sophia guided the learners in the data collection process. She asked each learner to state what career they wanted to pursue one day, and created ten umbrella terms (see Figure 4.18). She then went through each term and asked learners to raise their hands (only once) if they wanted to pursue a career. The learners had to count the number of hands raised and do their tally chart on their own. If the learners had been in a higher grade, one might have been able to leave them entirely alone with the project, however, Grade 6 learners still need structure and guidance. This is why good sub-essential questions are important to help learners complete a project.

Figure 4.18

Image from the first observation of Sophia's project as a formative assessment



Sophia's teaching philosophy was evident in this section as she incorporated real-life contexts, thus making the topic relatable for learners. When I asked her whether she thought relating this topic to real life made it more relevant for learners, she said:

> Yes, definitely. I think they've all heard about data handling. They all know about graphs, but explaining it in a real-life situation, I think makes it more understandable and something they can put into play. For example, counting or tallying or where would different types of graphs come into play.

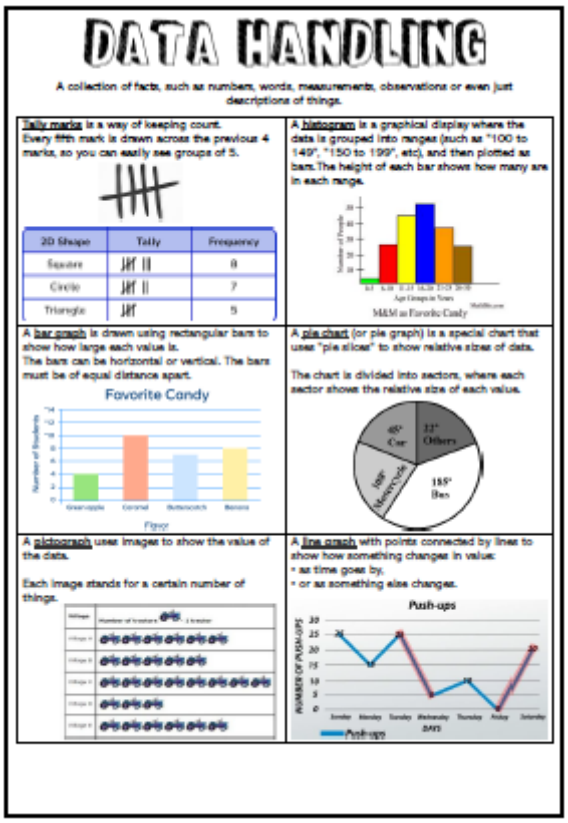
From this section, Sophia appeared to be a constructivist as she guided learners to complete the project, allowing them to independently collect and interpret the data. She facilitated the learning process to ensure that the Grade 6 learners had a set structure within which to work. This is indicative of creating an active learning classroom (Petress, 2008), with Sophia allowing learners to build their own understanding (Lessani et al., 2016).

- **Sophia as a facilitator**

Sophia provided notes to the learners (Figure 4.19). The notes gave detailed definitions of tally charts, bar graphs, histograms, pictographs, and pie charts. The notes also stipulated what data handling comprises. Sophia may be viewed as a provider of knowledge when looking at how she explained tally charts and graphs. However, because of the notes given to the learners, Sophia was not the only source of knowledge, and thus learners were not solely reliant on her to understand the concepts and skills required for the project. Sophia guided the learners through the notes, and established a connection to a real-life context. In the process, she addressed the proposed qualities as stipulated by Botha (2010) and Kokotsaki et al. (2016). Once she finished, she facilitated the data collection process.

Figure 4.19

Notes from Sophia's project as a formative assessment



As mentioned, after working through the notes, Sophia facilitated the data collection process. She worked step-by-step, going through each of the careers that were written on the board, as can be seen in Figure 4.18.

> **Sophia**: Okay, mouths close. Alright, so what we are going to do, is under the different categories who wants to be one and they are going to put up their hands. I am not going to count for you. So, I am going to, for example, say Technician and if you are one of those technicians you are going to put your hand up like this [shows how to properly raise hand], please don't do this [shows how a hand is half-heartedly raised]. People are going to turn around to count. You do this and we are going to miss you and then we have to start all over again. You only get to put your hand up once. Even though you are counting, you must remember to include yourself if that is your category. Okay? We are going to tally it, so for example, let's say there is a teacher at the bottom [Sophia writes the category 'teacher' at the bottom of the list on the board]. Example. And there were six teachers interested in teaching. One, two, three, four, five, six [teacher draws the tally marks on the board]. And the frequency column is the total of tally [Sophia writes a '6' on the board], which would be a total of six.
>
> Learner raises hand.
>
> **Sophia**: Yes?

Learner: Ma'am, what does a professor fall under?

Sophia: Under educator. You still have to study teaching in order to get there. Okay, so I am going to call it out. We are going to do this one, twice in case. You need to be able to turn your body to look at the class. Remember to put your hand up high [shows how to properly raise a hand]. Okay like that, high in the sky. Okay, so if you were interested or if you are interested in being some sort of Technician one day, put up your hand really high.

Learners look around and count the raised hands. Learners tally the data.

Sophia: Okay so did you understand that one? Did you understand what you had to do?

Learners: Yes' ma'am.

Sophia: Okay, so now I am not going step by step, now we are just going to count and total. Okay, any sort of doctor. Head, toe, feet, mind, body parts, you name it.

Learners look around and count the raised hands. Learners tally the data.

Sophia created an active learning environment by enabling learners to function independently, as suggested by Petress (2009). The learners were self-reliant and collaborated to address the main essential question. This aligns with Bell's (2010) assertion that projects foster self-reliance. It also resonates with the views of Fisher et al. (2020) and Kokotsaki et al. (2016), which emphasise the importance of answering essential questions through the creation of an end product. In contrast, the participants in Guntur and Retnawati's (2020) study experienced 'chaos' when given 'free reign'. Sophia, however, balanced independent work with structure and guidance, as highlighted by Aksela and Haatainen (2019) as a challenge in facilitation. She provided clear instructions, ensuring that the learners understood how to collect data, while still supporting their independent efforts. In the second lesson, Sophia guided learners in creating a bar graph.

Sophia: Now, I do apologise, on the left-hand side, there is no line, but you can draw a line on the edge of the worksheet itself. These [Sophia indicates on the board] are going to be the different job… categories. What can we use as a heading over here? It can be one word, literally.

Learners raise their hands to answer. Sophia points to a learner to answer.

Learner: Jobs.

Sophia: Jobs [teacher writes in the heading]. Okay or careers. And then you can underline it nicely in black pen.

Learners write the heading.

Sophia: Please make sure it looks like 'jobs' and not 'tobs', hey. Jobs. J- J-. Okay, over here we are going to write, we are going to start from the bottom. What was our first name in our table?

Learners: Technician.

Sophia: Technician? So, I am going to write Technician at the bottom over here [Sophia writes the word 'technician' on the board]. Write it very small, so that your next word does not go over 'Technician'.

Sophia: Pens and pencils down, please. Eyes forward. Pens and pencils down. How many, friends in your class were interested in technician work?

Learners: Two.

Sophia: Two. [Indicates on the board] do you see where the two is? Coloured pencil of your choice and a ruler. We are going to go up to two [Teacher does the bar on the board] and… then you are going to colour it in beautifully for me. Do you understand the work?

Learners: Yes.

Sophia did one of the bars in the bar graph with the learners. The learners then had to complete the rest of the bar graph on their own. By guiding them, she ensured that they could comfortably do the rest and not complete the rest of the project incorrectly. Overall, Sophia allowed learners to be independent while still supporting them in a way that provided structure and organisation to the process, something Grade 6 learners might not be able to do on their own yet.

Sophia put the memorandum for the first phase of the project on the board. The learners marked the work themselves whilst she explained the memorandum. This was a crucial step since if learners did not do the tally chart correctly, the next phase, which was the bar graph, would have been done incorrectly. This form of diagnostic feedback allowed the learners to fix their mistakes and to learn from them before continuing to the next phase of the project, a very important part of formative assessment (Kokotsaki et al., 2016).

Sophia stated that she allowed learners to mark informal assessments on their own, where after she would check their marking later. I asked Sophia how she ensured that learners understood this diagnostic feedback, or in her case, understood where they made a mistake in the first phase of the project and learnt from it, and she explained:

> So, when work is finished. If it's a particular section that's finished, there's commentary or my comments explaining if the, if the, if the process was wrong or if the exercise was not fully understood. I give them answers. There's comments about 'please come and talk to me tomorrow so I can discuss it further, with you.' Sometimes you can't write it down, but you actually need to sit and practice with the child. If it's a new section of work they come up to me in during the lesson every four or five questions, they come to me so I can check that before they carry on with more challenging questions they have, they understood the basic fundamentals and, and if the work is wrong, the learners have to correct it. Show me before they can move on.

This method of helping learners to understand the work before being able to go on to more difficult parts where fundamental understanding is required is crucial for a project at Grade 6 level.

4.5.3 Section C: The project as a summative assessment

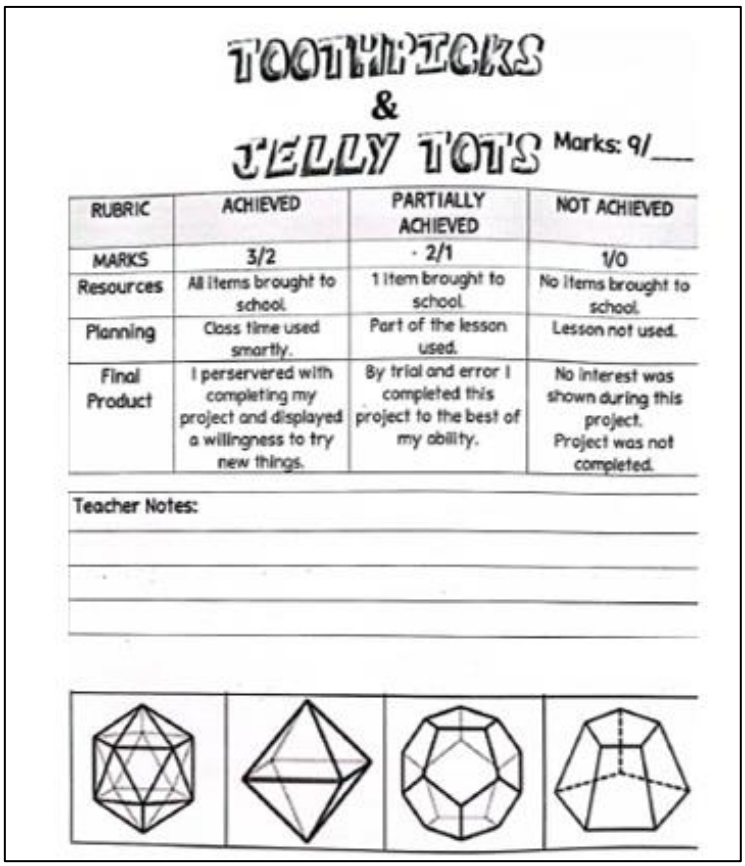
Sophia's summative assessment project was based on the properties of 3D objects. The project counted nine marks for learners' Term 3 report. This project was subject to document analysis only since I did not observe when the project was administered. This means that I can only report on the aims and concepts from the RATP that the project addressed by analysing the project design. I am not able to report on whether the aims and concepts were addressed verbally, or if the teacher deviated from the project design. This also means that I cannot report on how the project was facilitated, and can only make inferences through interviews and the design of the project.

4.5.3.1 Essential and sub-essential questions

Sophia's project did not contain a main essential question or sub-essential questions, which can also be seen in Mentzer et al.'s (2020) study as some of their participants did not have main essential questions, and their projects were not properly set up. Sophia's project consisted of a rubric detailing the marks allocated for each question. The project had the heading 'Toothpicks and Jelly Tots,' and images of 3D objects (see Figure 4.20). From the project title, the images, and the requirements of the rubric, it can be assumed that learners had to build one of the 3D objects that was listed on the page. Thus, it could be argued that the central topic was building 3D objects using Jelly Tots. However, without a main essential question, this cannot be fully confirmed. The teacher might have presented the instructions orally.

Figure 4.20

Sophia's project as a summative assessment



TOOTHPICKS & JELLY TOTS Marks: 9/___

RUBRIC	ACHIEVED	PARTIALLY ACHIEVED	NOT ACHIEVED
MARKS	3/2	2/1	1/0
Resources	All items brought to school.	1 item brought to school.	No items brought to school.
Planning	Class time used smartly.	Part of the lesson used.	Lesson not used.
Final Product	I perservered with completing my project and displayed a willingness to try new things.	By trial and error I completed this project to the best of my ability.	No interest was shown during this project. Project was not completed.

Teacher Notes:

Since there were no main essential question or sub-essential questions, a full evaluation of the cognitive levels was not possible. However, since the learners had to create something, the project can be viewed as a 'routine procedure' type activity. It was not a 'problem-solving' question since it did not relate the 3D objects to a real-life context or present a problem that must be solved.

4.5.3.2 Design of the project

Sophia's project was designed much differently to a 'standard' project since it did not have a main essential question, instructions, or a timeline. The project did, however, require learners to provide an end product, which was the 3D object that the learners were supposed to build. However, the project only comprised a rubric; there were no main or sub-essential questions, or even instructions. This is not to say that there should not be a rubric, only that the project did not include an introduction or conclusion phase. Bearing this in mind, I analysed which of the CAPS aims the project met, which is indicated in Table 4.18.

Table 4.18

Summary of the CAPS aims that Sophia's formative assessment achieved (DBE, 2011, p. 5)

CAPS' aims achieved through the project	Check
Identify and solve problems and make decisions using critical and creative thinking.	X
Work effectively as individuals and with others as members of a team.	✓
Organise and manage themselves and their activities responsibly and effectively.	✓
Collect, analyse, organise, and critically evaluate information.	X
Communicate effectively using visual, symbolic and/or language skills in various modes.	✓
Use science and technology effectively and critically showing responsibility towards the environment and the health of others.	X
Demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation.	X

The project achieved the following aims:

- Learners used their understanding of 3D objects to build the models with their Jelly Tots and toothpicks.
- Learners had to manage themselves in class when they were building their 3D objects. They had to be responsible enough to bring their resources to school, not eat all their Jelly Tots, and build the object correctly.
- Learners had to build the 3D objects; thus, they demonstrated their understanding in a different mode than routine drawings, or questions and answers.

The project did not achieve the following aims:

- Learners did not have a problem to solve. It could be argued that they had to use creative thinking to build the 3D object, but this was not an inherently difficult project.
- Learners did not collect, analyse or evaluate information to do the project.
- The project did not allow learners to use mathematics to address any environmental or social concerns.
- The project was not related to a real-life context; thus, learners could not relate mathematics to real life.

As previously mentioned, I did not observe the implementation of this project. It is likely that the learners might have had discussions about the relevance of the objects in real life, and had to analyse these objects to derive answers about surface area and volume. However, there was no evidence of this in the design of the project. By neglecting to meet some of the CAPS aims, she missed an opportunity to achieve aims such as "[demonstrating] an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation" (DBE, 2011, p. 5), which results in the project not being effective. This corroborates Viro et al.'s (2020) findings that teachers who plan projects with the curriculum in mind enact in-depth teaching, and thus have more effective projects.

Table 4.19 describes the concepts and skills that Sophia's project achieved according to the RATP.

Table 4.19

Summary of the concepts and skills in the RATP that Sophia's formative assessment addressed (DBE, 2023a, p. 3)

Content Area	Topic	Concepts and Skills
Space and Shapes	**Properties of 3D objects**	Make 3D models using drinking straws, toothpicks, and so forth.

Due to the fact that the project did not have any further instructions or information, it is hard to say what other concepts and skills were covered when the learners did this project in class, thus, I only listed the ones that were covered. The teacher could have covered the following concepts and skills during the project:

> Recognize, visualize, and name 3D objects in both environmental and geometric settings, focusing on rectangular prisms, cubes, tetrahedrons, and pyramids. Understand the similarities and differences between tetrahedrons and other pyramids. Describe, sort, and compare 3-D objects based on the number and shape of faces, the number of vertices, and the number of edges (DBE, 2023a, p. 3).

These concepts and skills could have been addressed verbally, but again, I was not there when the project was done. Since no other instructions were provided, I cannot accurately state how much agency learners had during the project. Based on the idea that learners built the 3D objects, this alone is evidence of some amount of learner agency.

4.5.3.3 Timeline of the project

The project did not indicate a set timeline. When I asked her how learners adhered to the provided timeline of a project, she expounded:

> You have to constantly walk around. You have to monitor them. If they're battling you, try to guide them a little bit. You don't do it for them, but you kind of like give little clues or you move little things around on the table. If it was, for example, the Jelly Tots project, the learners are also given a variety of shapes to choose from, and the more the children who do very well academically and seem very clued up, get more challenging objects to build, and those who are a little bit slower get something a little bit more simpler and easier, and obviously, it's constant monitoring in the classroom.

Sophia emphasised the importance of active engagement and continuous monitoring to ensure that her learners adhered to the project's timeline. She described a hands-on approach, which involved walking around the classroom to observe and support learners, as well as offering subtle guidance and scaffolding, without doing the work for them. Sophia adjusted the difficulty of the tasks based on learners' academic abilities, providing more complex challenges to advanced learners and simpler tasks to those who needed more support. This tailored approach, coupled with ongoing supervision, aimed to keep all learners on track, and fostered a supportive learning environment.

4.5.3.4 Assessment of the project

Sophia used a rubric to evaluate her project. To provide optimal feedback and align with the project's design, a rubric was an effective tool for assessing the built 3D objects, unlike a memorandum. However, Sophia's rubric included only three criteria: resources, planning, and final product, without assessing any other areas. Since the project did not have distinct phases, Sophia assessed it only after the learners had completed their work.

4.6 CONCLUSION

This chapter provided the biographical information of the three participants, and discussed the data analysis methodology. In analysing the data, I followed a deductive approach and was guided by the conceptual framework. I furthermore presented the data that were collected through document analyses, observations, and interviews in three sections. Section A addressed the internal and external factors influencing the use of projects as summative and formative assessments. Section B discussed projects as formative assessments, while Section C examined projects as summative assessments. I also provided interpretations of the findings, and related them to the theory utilised in this study, and the findings of other similar studies.

In Chapter 5, I will thoroughly discuss the findings, interpreting the results in the context of existing literature. This chapter will include a detailed analysis of the data, highlighting key themes, patterns, and insights that emerged. I will use these findings to answer the research

questions outlined earlier in the study, discussing any agreements, contradictions, or unexpected results. Additionally, I will explore the implications of these findings for practice, policy, and further research, providing a comprehensive understanding of their significance. I furthermore address the limitations of the study, and suggest areas for future research to build on the findings and insights gained.

CHAPTER 5 DISCUSSION OF FINDINGS AND IMPLICATIONS

5.1 INTRODUCTION

In Chapter 4, the data were presented, interpreted, and related to the literature. This study aimed to explore how Grade 6 Mathematics teachers implement projects. Through the document analysis, observations, and interviews, I came to understand how three teachers implemented projects for summative and formative assessments. In this chapter, I discuss the secondary and main research questions, provide a reflection on the study, discuss the limitations of the study, make recommendations, and suggest future studies.

5.2 FORMATIVE ASSESSMENT OF PROJECTS

The following discussions are centred around the secondary research questions for projects as formative assessments. It is presented in sub-sections that display the most significant findings.

5.2.1 Sub-question 1: What factors influence teachers' implementation of PBL as a teaching approach?

The factors discussed include external and internal factors that influenced the implementation of projects in significant ways.

5.2.1.1 Interpretation of the curriculum

This study reveals variations in teachers' curriculum implementation as each teacher enacted the curriculum differently. Sophia and Benjamin adhered to the RATP as directed by the DBE (2023a, b), while Emily followed the full curriculum (DBE, 2011). Both Benjamin and Emily failed to align their projects with the curriculum's aims and cognitive levels, neglecting suitable content and skills. Their projects did not adhere to the qualities of a good project according to Thomas (2000), who stipulated that projects should have (1) A central topic; (2) An essential question(s); (3) The opportunity for constructive problem solving and investigation; (4) Learner agency; and (5) An element of realism. The way in which they implemented the projects was also a far cry from PBL since they opted for more teacher-centred approaches. This suggests that they did not implement the curriculum as intended since their projects were not designed correctly in nature. This aligns with Viro et al. (2020), who emphasise the importance of curriculum-aligned PBL for effective teaching. Conversely, Sophia's well-designed project,

which considered the curriculum's aims and cognitive levels, demonstrated effective PBL. This highlights how teachers' curriculum interpretation impacts project design.

5.2.1.2 Pedagogical beliefs

This study indicates that teachers' philosophies directly impact project design, and the implementation of projects. Emily and Benjamin created passive learning environments by positioning themselves as knowledge providers, limiting learner autonomy. This mirrors Guntur and Retnawati's (2020) finding that teachers struggle to relinquish control. This also highlights Lazić et al.'s (2021) assertion that for PBL to be implemented correctly, teachers need to subscribe to a constructivist or sociocultural learning theory. Emily and Benjamin's practice contradicted their stated PBL approach, aligning with the finding that teachers often implement methods differently than they claim (Botha et al., 2023). Ultimately, behaviourist teachers resist adapting to learner-centred methods, supporting Aksela and Haatainen's (2019) conclusion that PBL requires a shift in teacher thinking. Conversely, Sophia, a constructivist, allowed students to construct their own understanding. This proves that if a teacher's pedagogical beliefs are aligned to support learner-centred approaches, such as PBL, they will easily implement it, embracing all of its characteristics.

5.2.1.3 Teachers' knowledge of PBL and projects

The results of this study indicate that two of the three teachers could not comprehensively define PBL. Emily and Benjamin overlooked key PBL characteristics, such as learner agency, prompting investigations, and producing an end product that answers the main question. This aligns with Tamim and Grant's (2013) finding that teachers who do not fully understand PBL fail to define it correctly. These participants also omitted key project design elements, showing a lack of consideration for curriculum requirements. Conversely, Sophia accurately defined PBL. She included essential characteristics of a project in her definition, such as learners collaborating, conducting investigations, and creating end products, all of which were evident in her implementation of a project. Mentzer et al. (2017) state that if we want teachers to define and implement PBL as described in the literature, they require training. Similarly, Aksela and Haatainen (2019) conclude that in-service teachers require more PBL training, which should be better addressed in teacher education programmes.

5.2.1.4 Support from subject heads and HoDs

The findings reveal that support from subject heads and HoDs plays a pivotal role in the implementation of PBL. Benjamin suggested that the experience of, and support from HoDs

would influence whether or not a teacher would use PBL. The lack of support from Emily and Sophia's HoDs and subject heads further reaffirms this as these subject heads and HoDs did not understand or know about PBL and the use of formative assessments required by CAPS. Without support from their subject heads and HoDs, teachers do not implement PBL properly, or even at all. Benjamin's statement that teachers need support from experienced teachers when using formative assessments and PBL agrees with the findings from Viro et al.'s (2020) study regarding the importance of support from leadership.

5.2.1.5 Lesson planning and preparation

Two of the participants failed to mention aligning lesson plans and preparation for projects with curriculum aims. This omission points to a critical flaw in their project design approach as adhering to curriculum guidelines is crucial for successful project outcomes, a point accentuated by Bell (2012). The lack of consideration of curriculum requirements affected the overall design of these projects since their projects did not allow learners to "demonstrate an understanding of the world as a set of related systems by recognising that problem-solving contexts do not exist in isolation" (DBE, 2023a, p. 5), which is the CAPS general aim applicable to projects. It consequently also did not allow learners to "investigate, analyse, represent and interpret information" (DBE, 2023a, p. 5), which are mathematics-specific skills stipulated by CAPS that learners should achieve by the end of Grade 6. Alternatively, Sophia's project as a formative assessment demonstrated what would happen if a teacher considered the aims of the curriculum. Sophia achieved multiple aims in her project as a formative assessment, and she considered concepts and skills that lend themselves to being developed into a project. Her project supported Viro et al.'s (2020) conclusion that for in-depth teaching to take place, a project must consider the requirements of the curriculum.

5.2.1.6 Teachers' project experience

Benjamin and Sophia highlighted that experience influences the use of PBL. They noted that experienced teachers are better at managing PBL's complexities and selecting engaging projects, thus creating a learner-centred environment. In contrast, Emily argued that experience does not influence the use of PBL. During the observations, Benjamin, being the most experienced teacher, indicated an adequate understanding of projects and PBL. In his implementation of PBL, I observed how his pedagogical beliefs and knowledge of PBL played out in his practises. Sophia, the teacher with the second most experience, applied PBL the best. Her understanding of it and her projects resonated in her practice. Emily, who was the least experienced in the implementation of projects, had the least effectively designed projects, and did not implement these correctly. Her teaching approach was far from what PBL

is supposed to be as she took on a teacher-centred approach. Overall, it seems that experience does affect the implementation of projects. Moreover, established knowledge plays a role in how teachers approach projects and if they have the understanding and skills to do it well and correctly.

5.2.2 Sub-question 2: How do teachers plan a project by using PBL?

The planning of a project involves setting questions, designing the project, and creating a timeline.

5.2.2.1 Essential and sub-essential questions

Two of the three participants either did not know how to set up main essential questions and sub-essential questions, or did not regard it as an important element that would guide learners to an end product. Benjamin's project lacked a main essential question and had unrelated closed-ended sub-essential questions, leading to a directionless and unconstructive investigation. Similarly, Emily's project lacked a main essential question, consisting of disconnected worksheets and activities, resulting in a lack of focus. Alternatively, Sophia's project featured a main essential question with related sub-questions, guiding learners to an end product and fostering independence – demonstrating an effective project design. This finding corroborates Markula and Aksela (2022) and Mentzer et al.'s (2017) findings, which emphasise the importance of a guiding question for project coherence. These authors have also found that the majority of their participants did not set up projects with a main essential question. This is also an example of the influence that a main essential question has on the overall effectiveness of a project. Without it, the project lacks direction and ultimately does not realise its full potential.

5.2.2.2 Design of the project and its timeline

Two out of the three teachers did not design their projects correctly. Benjamin and Emily's projects did not align with the general aims of CAPS. Their projects did not address the content in CAPS, which lends itself to being used in projects. In Benjamin's case, this was investigating and solving problems with length, area and perimeter. In Emily's case, her project did not allow learners to collect, analyse, or represent data. Because these two teachers did not adhere to the requirements of the curriculum, and were influenced by their pedagogical beliefs, they set up projects that did not allow learners to function independently from the teacher. In contrast, Sophia's project effectively fostered an active learning environment by integrating knowledge with skill development and encouraging the exploration of career paths. This aligns with the principles of effective project design as stipulated by Thomas (2000), and supports a robust

PBL approach. Designing projects is thus an important part of implementing PBL. This is supported by Aksela and Haatainen (2019), and Guntur and Retnawati's (2020), who report that planning a project is a lengthy process that should be carefully considered. However, the findings of this study are congruent with those of Markula and Aksela (2022) where the majority of participants did not design their projects appropriately. In this study, only one participant designed the project correctly, indicating that there is a gap in teachers' understanding of PBL.

As for the timeline of the projects, Benjamin managed the time spent on the project by working through each question with the learners, and not allowing them to continue until he was ready to explain the next question. Benjamin waited for most of the learners to finish before continuing. This delayed those learners who were finished early, which caused the class to become restless as most learners had nothing to do. Emily did not provide a timeline except for a 20-minute timer near the end of the project. This happened only after she explained all of the work, and the learners could do the project on their own. Sophia did not provide a timeline for her project, but guided learners through each question. Unlike Benjamin, she did not hinder the learners from continuing. Overall, the participants did not provide a clear timeline for any of their projects. They managed the timeline on their own by ensuring that they finished the work in a set number of lessons.

5.2.3 Sub-question 3: During the implementation of PBL, how do teachers facilitate learning?

This question considers how the participating teachers facilitated PBL, considering their applied teaching approaches and how they acted as facilitators.

5.2.3.1 Teaching approach

The influence of these teachers' teaching philosophies and learning theories is evident in how they implemented PBL. Only Sophia applied PBL effectively, while Emily and Benjamin made themselves the providers of knowledge, and limited the investigation element of the projects. Although Benjamin could be seen facilitating more than Emily did, he still placed himself in a position where learners were dependent on him. This control over the learners is a common challenge for teachers when implementing PBL as they cannot let go of it (Guntur & Retnawati, 2020). They used questioning approaches, and stated that this was used with PBL, but it dominated over PBL. Sophia was the only participant who successfully integrated the PBL approach into another approach, namely, the discussion and questioning approach. This worked well for her and her learners. This indicates that other teaching approaches can be used in conjunction with PBL, but it should not dominate the PBL approach.

5.2.3.2 The teacher as facilitator

The study's findings reveal that only Sophia facilitated a project correctly, whereas the others deviated from the characteristics of PBL. Benjamin and Emily's method focused heavily on direct instruction, which may hinder learners' independence and active engagement. This contradicts the principles of project-based and active learning where autonomy and problem solving are crucial. They were thus not facilitators of learning, and did not apply PBL effectively. In contrast, Sophia adopted a balanced approach, allowing learners to work independently while providing the necessary guidance, and fostering an active learning environment that is conducive to collaborative problem-solving. However, since the majority of my participants struggled to strike a balance between guiding learners and providing them with information, this concurred with the findings of Aksela and Haatainen (2019), whose participants also struggled to create this balance. Furthermore, in light of the majority of the participants struggling to facilitate PBL, and the fact that most could not coherently define PBL, this finding supports the notion that teachers in South Africa need guidance to improve their skills in implementing PBL. Furthermore, there needs to be an overhaul of teachers' pedagogical belief systems.

5.3 SUMMATIVE ASSESSMENT OF PROJECTS

The following discussions are based on the secondary questions regarding projects as summative assessments. It is presented in sub-sections that display the most significant findings.

5.3.1 Sub-question 4: What is teachers' understanding of a project as a summative assessment, and PBA?

Sophia's definition aligns with the CAPS statement about summative assessment, identifying it as an assessment *of* learning. Her mention of 'final projects' implies that other projects preceded the summative assessment, indicating her awareness that formative assessments should be conducted before summative assessments. Overall, Sophia had a well-rounded understanding of formative and summative assessments. Conversely, Benjamin and Emily demonstrated a limited understanding of summative assessments in their application in project-based evaluations. Benjamin demonstrated confusion between formative and summative assessments, mistaking 'formative' for 'formal', indicating a misunderstanding of their distinct purposes. This is similar to the findings of Ussher and Earl (2010), whose participants confused summative and formative assessments. Emily, although aware that summative assessments are formal evaluations that count toward grades, incorrectly

perceived them as substitutes for formative assessments. This misconception reflects a partial understanding of their complementary roles in educational assessment. Overall, while Sophia demonstrated a solid grasp of formative assessment principles, Benjamin and Emily revealed varying degrees of misunderstanding regarding the purposes and distinctions between formative and summative assessments.

5.3.2 Sub-question 5: How do teachers plan a project by using PBA?

The planning of a project involves setting questions, designing the project, and creating a timeline.

5.3.2.1 Essential and *sub-essential questions*

None of the participants designed their projects to have main essential questions or sub-essential questions that guided learners to create an end product. The projects designed by Benjamin and Emily for summative assessment lacked main essential questions, central topics, and real-life contexts, resulting in close-ended questions that did not foster critical thinking or learner engagement. These questions were also not appropriately set up according to the cognitive levels of CAPS, failing to have problem-solving questions, which would have been the main essential question. Both projects mirrored previous formative assessments without significant improvement or coherence. While there was potential for meaningful discussions and the exploration of these topics, they did not base the project on concepts and skills that lend themselves to being developed into projects. The sub-essential questions also did not guide learners to an end product, and they did not relate entirely to Benjamin's project, and not at all to Emily's project. This aligns with the findings of Mentzer et al. (2020) and Viro et al. (2020), highlighting the necessity of well-planned, curriculum-aligned projects to achieve deeper learning outcomes. Sophia's project did not have questions, and thus it could not be evaluated. However, her project fell into the same bracket as Benjamin and Emily's, which did not have main essential questions and was not related to a real-life context. The project also lacked instructions, thus its design did not reflect the qualities of a good project.

5.3.2.2 Design of the project and its timeline

All of the summative assessment projects' designs were ineffective according to the standards set out by Thomas (2000), Bell (2010), Fisher et al. (2020), Kokotsaki et al. (2016), Lazić et al. (2021), Nasution et al. (2021), and Serin (2019). These authors state that projects should allow for constructive investigation, learner agency, and should lead learners to an end product. The projects also did not fully adhere to the aims of CAPS. All of the above prevented the learners from demonstrating how the world and mathematics are interconnected systems

(CAPS, 2011). Since it did not contain a main essential question or any instructions, Sophia's project could have achieved this aim if it had been discussed orally in class, where I was not present. However, based solely on the design of the project and what the learners were assessed on, it merely required learners to build 3D objects. Benjamin's topic allowed learners to be agents of learning if he allowed them to work through the project on their own, unlike in his project as a formative assessment. Even though the project allowed learners to investigate, and required critical and creative thinking, the learners did not produce an end product, which is inherently a trait of projects. Thus, his project did not fully correspond to the qualities of a good project. Lastly, Emily's project was designed as a summative control test. Learners did not investigate or work independently, and had to answer a myriad of questions based on multiple topics that were not related to each other. Learners were ultimately tested, and no growth was promoted. None of the projects had stipulated timelines. It is also not possible to infer how much time the teacher gave the learners, or if they expressed a timeline verbally as I did not observe the lesson. Nonetheless, projects should have specified timelines to clarify to learners when certain things need to be done, and how much time they have to do the project.

5.3.3 Sub-question 6: What opportunities does a project provide for learners to develop the required knowledge and skills?

Two of the projects could have allowed learners to develop the knowledge and skills from the curriculum that the teachers intended. Sophia's project addressed building 3D objects, and it provided an opportunity for learners to actively engage with the concept. However, this is all that her project addressed. The learners only engaged with one concept and skill from CAPS. This did not prompt a constructive investigation, and thus they were not agents of learning since building a figure does not entail a lot of critical thinking, and does not relate the topic to a real-life problem. As for Benjamin's project, the learners were agents of learning to an extent. They could not present their understanding in a final cumulative answer or end product. Instead, every question was treated separately, and it addressed the skills and concepts it aimed to address, but it did not adhere to the qualities of a good project. Emily's project tested skills, however, the learners did not get an opportunity to further develop their skills. The project was also not structured in a way to support building their understanding of the topic.

5.4 Primary research question: How do South African Grade 6 mathematics teachers implement projects?

The findings reveal that the majority of the participants did not implement projects as formative and summative assessments correctly. The projects lacked main essential questions, central topics, and relation to real-life topics. Learners were not allowed to conduct constructive investigations that allowed them to be independent from the teacher. Aside from one participant, the teachers did not implement PBL correctly, indicating that they did not fully understand the teaching approach and how to implement it. Finally, the teachers did not set up projects as summative assessments correctly. Various factors influenced why these projects were not implemented correctly, such as how they implemented the curriculum, their pedagogical beliefs, support from subject heads and HoDs, and their overall understanding of projects.

5.5 Reflecting on this study

The conceptual framework considered the internal and external factors that influence the implementation of PBL and PBA. The framework does not depict every possible factor that could influence teachers' implementation of projects; however, it does align with those that are most prominent, as seen in the results of this study. The process of implementing projects was informed by the George Lucas Educational Foundation's (2007) six steps for implementing PBL. The model was adapted to suit the circumstances of this study, as well as PBA and PBL. The conceptual framework provided multiple advantages, such as clarifying what factors influence the implementation of projects, and how projects should be designed and facilitated. It allowed me to collect data in a directed manner, drawing focus to that which was essential to the study. However, the conceptual framework did have disadvantages as well, such as separating the steps of the implementation process of projects between those that were applicable to PBL and those of PBA. The process of facilitating the projects (Step 4) should be applicable to PBA as well; however, due to the nature of the study, this was not possible.

The study originally intended to only explore how Grade 6 mathematics teachers implement projects as formative assessments using PBL. However, after lengthy discussions with my supervisor, I decided to expand the study to focus on projects as formative *and* summative assessments. This provided a larger picture of how Grade 6 teachers' projects are designed, and it thus demonstrated their overall understanding of the difference between formative and summative assessments. It also provided more insight into how CAPS was enacted. I am glad I made this diversion from the original intention of the study due to these findings. Although I

acknowledge that had the study originally been designed to focus on both assessments, it would have changed the data collection process to also incorporate the observation of projects as a summative assessment. Moreover, I would have designed the interviews to provide more detailed data on the use of projects as a summative assessment. However, this provides an avenue for future studies.

5.6 LIMITATIONS

Although the study allowed for the collection of in-depth data and the discussion thereof, a limitation was that the study had a small sample of only three teachers from different schools in one area of South Africa. I thus realise that my findings cannot be generalised. However, the study produced an insight into many teachers' lack of ability to implement projects, and provided a clear picture of three teachers who committed themselves to implementing projects in their instruction. Furthermore, with the inclusion of projects as summative assessments at a later stage in the study, I did not do an in-depth observation of the implementation of PBA. Nonetheless, I still collected an adequate amount of data during the course of the interviews due to the two assessments being related. Lastly, this study was bound by time and subjectivity due to my personal experiences and opinions influencing the data interpretation. Although my supervisor scrutinised the study, it could still be influenced by subjectivity, especially in the analysis of the questions' cognitive levels, and the project design.

5.7 RECOMMENDATIONS

From this study, the following recommendations emerged:

- The DBE and teacher-training institutions could offer in-depth training to in- and pre-service teachers on designing, implementing, and assessing projects. This should cover key elements such as setting essential questions, fostering learner autonomy, and aligning projects with curriculum goals.
- Encourage and equip school leaders, including HoDs and Subject Heads, to understand and support the use of PBL and PBA as teaching approaches.
- The ATPs need to be clearer about what the expectations are for projects; this includes what a project is, and how it should be designed.

5.8 FUTURE STUDIES

Future studies in South Africa on the use of projects could include:

- A study with a larger and more diverse sample of teachers from various regions and school types. This could validate the findings and explore regional differences in PBL and PBA implementation.
- A longitudinal study to observe how teachers' understanding and implementation of PBL and PBA evolve with continuous professional development and support.
- An investigation on the impact of well-implemented PBL and PBA on learner outcomes, including academic performance, critical thinking skills, and engagement levels.

5.9 Conclusion

This chapter has explored key findings related to the formative and summative assessment of projects using PBL and PBA. It addressed the research questions to identify crucial factors influencing the implementation of PBL, project planning and design, and the facilitation of learning. Significant variations in teachers' curriculum interpretation, pedagogical beliefs, knowledge of PBL and projects, the support they receive from subject heads and HoDs, lesson planning, and the experiences of teachers play critical roles in how projects are designed and implemented. This study emphasised the need for comprehensive training and ongoing support to align PBL and PBA with curriculum aims. Currently, more effort is being put into ensuring that projects are implemented correctly in Johannesburg East, as I attended subject meetings advising on the proper use of projects. The subject advisor for Grade 6 in the district also sent an example of how a project should not look. However, more should be done to equip teachers than simply providing examples.

The proper formulation of main essential and sub-essential questions is vital for guiding learners toward meaningful end products, with failures in project design leading to a lack of direction and coherence. Effective PBL implementation was demonstrated by only one teacher, who fostered an active, learner-centred environment, while the others struggled to relinquish control. The study also revealed teachers' general misunderstanding of formative and summative assessments, indicating a need for clearer guidelines and support structures for effective project design and implementation. Overall, the study accentuates the necessity for targeted professional development, clearer policy guidelines, and enhanced support systems to bridge the gap between curriculum expectations and classroom practice. The implementation of these will ultimately foster a more effective and engaging learning environment for learners.

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APPENDIX A: DOCUMENT ANALYSIS – PROJECT CHECKLIST

This checklist addresses Steps 1-3 in the conceptual framework: 1) Essential question(s); 2) Design of project; and 3) Design timeline of project. The generated data will enable me to answer the second secondary research question: *How do teachers plan a project using PBL in terms of the essential question(s), design, and timeline of the project?*

Step 1: Essential Question(s)

Checklist for the ESSENTIAL QUESTION(S)			
Criteria	**Checklist**		**Notes**
	YES	**NO**	
SECTION A: MAIN ESSENTIAL QUESTION			
1 Does the project contain an essential question?			
2 Does the essential question guide the rest of the project?			
3 Is the essential question open-ended?			
4 Is the essential question based on a real-life context?			
5 Is the essential question relevant to the learners' lives?			
6 On which cognitive level is the essential question?			

Cognitive Level	Knowledge	Routine Procedures	Complex Procedures	Problem-Solving
Checklist				
Notes				

SECTION B: SUB-ESSENTIAL QUESTION 1 **(Repeat for all sub-essential questions)**

1. Does the project contain an essential question?			
2. Does the essential question guide the rest of the project?			
3. Is the essential question open-ended?			
4. Is the essential question based on a real-life context?			
5. Is the essential question relevant to the learners' life?			
6. On which cognitive level is the essential question?			

Cognitive Level	Knowledge	Routine Procedures	Complex Procedures	Problem-Solving
Checklist				
Notes				

Step 2: Design of the Project

Checklist for the DESIGN OF THE PROJECT			
Criteria	**Checklist**		**Notes**
	YES	**NO**	
1 Does the project provide opportunities through the questions that touch on other topics, thus allowing for the opportunity to delve into those topics deeper as well?			
2 Does the project allow for learner agency?			
3 Does the project allow for a constructive investigation into a topic?			

4	Does the project allow learners to conduct constructive investigations on the central idea/topic?			
5	Does the project require learners to use realistic resources such as textbooks, computers to do research or booklets provided by the teacher, and realistic materials such as basic stationery and paper or worksheets?			
6	Does the project integrate other subjects such as Natural Sciences and Technology or Arts and Culture?			
7	Is the project aligned with the aims of CAPS?			
8	Is the project based on a central idea/topic?			
9	Does the project address the specific concepts and skills related to the project according to CAPS?			
10	Does the project focus on improving certain misconceptions about the topic?			

Step 3: Design the timeline of the project

Checklist for the DESIGN OF THE TIMELINE OF THE PROJECT			
Criteria	**Checklist**		**Notes**
	YES	**NO**	
1 Is there a stipulated allotted timeline to complete the project?			
2 Does the project allow for a flexible amount of time to be completed?			
3 Is the timeline realistic?			

Note: All of these tables are based on the literature from DBE (2011); Kokotsaki et al. (2016); The George Lucas Educational Foundation (2005)

APPENDIX B: OBSERVATION CHECKLIST

The following checklist addresses my data collection during the observations. The checklist is subject to change depending on how many phases of the project there are for each teacher's project. This checklist focuses on Step 4 of the Conceptual Framework. Each of these criteria would indicate how PBL was used and thus help me answer the secondary research question: *During the implementation of PBL, how do teachers facilitate learning?*

OBSERVATION FIELD NOTES

Date: _____

Time of observation: _____

Number of phases in the project: _____

Participant name and surname: _____

ACTIONS TO BE OBSERVED						
How does the teacher facilitate the timeline of the project?	**Evident teaching approach(es)**	**How does the teacher act as a facilitator of learning?**	**How did the teacher ensure learners had access to the required resources and materials and provided suitable guidance?**	**If there was group work, how did the teacher help manage it?**	**How are learners agents of learning?**	**How are learners allowed to construct knowledge?**

OBSERVATION 1 FIELD NOTES						
OBSERVATION 2 FIELD NOTES						
OBSERVATION 3 FIELD NOTES						

THINGS TO BE CONSIDERED ON ACTIONS BEING OBSERVED	
How does the teacher facilitate the timeline of the project? (T)	T1 - How does the teacher set benchmarks? T2 - Did the teacher help learners who struggle to perceive time? T3 - Did the teacher remind the learners of their timeframe? T4 - Did the teacher help learners schedule and prioritise tasks?
Evident teaching approach(es) (TA)	TA1 - Did the teacher use other teaching approaches with PBL such as Inquiry-Based Learning, co-operative learning, or the telling approach? TA2 - Does the teacher combine teacher-centred approaches with learner-centred approaches?
How does the teacher act as a facilitator of learning? (FL)	FL1 - Did the teacher guide learners to answers or provide them? FL2 - Did the teacher let learners discover more about the topic or provide it to them?
How did the teacher ensure learners had access to the required resources and materials and provided suitable guidance? (R)	R1 - How did the teacher help learners set benchmarks? R2 - Was easy access provided to the resources learners needed to do the project?
If there was group work, how did the teacher help manage it? (GW)	GW1 - How did the teacher teach learners to work collaboratively? GW2 - How did the teacher help manage learner groups? GW3 - How did the teacher ensure that all learners understood their roles in the group and their part in the project?
How are learners agents of learning? (AL)	AL1 - Did the project make learners more curious about the topic? AL2 - Did the teacher help them become more curious about the topic and delve deeper into it as their questions and statements arise?
How are learners allowed to construct knowledge? (CK)	CK1 - Were the learners allowed to form connections with prior knowledge and their experiences to understand the topic? CK2 - Were learners allowed to investigate the problem and topic? CK3 - Were learners allowed to collect data, analyse it and draw conclusions?

Note: Based on the literature from Fisher et al. (2020); Nasution et al. (2021); Sahin (2013); The George Lucas Educational Foundation (2005)

APPENDIX C: SEMI-STRUCTURED INTERVIEW SCHEDULES

There are four individual semi-structured interviews. The first interview is conducted before any observations are done. The second interview is conducted after the first observation. A third interview is done once the first phase of the project is done and marked by teachers, i.e. when the first section of the project is done. For example, the first section could be where learners have to provide definitions about key terms and the next section would be where they have to collect data. Then, depending on the number of phases, the third interview is conducted after each phase. A final interview is done once the project is completed.

The following applies to every interview schedule. Next to each question, I specified the part of the Conceptual Framework that the question links to. For example, IF3 refers to *Internal Factors, the third bullet point;* EF1 refers to *External Factors, the first bullet point*; and Step 1 refers to the *Essential question(s)* in the process of implementing PBL.

INTERVIEW 1

This interview needs to be conducted before the first observation. The answers to these questions informed my first secondary research question: *What factors influence teachers' implementation of PBL as a teaching approach?*

GENERAL INFORMATION

Name of school	
Name of researcher	Ms. C. van Loggerenberg
Name of teacher	
Date of interview	
Number of years of experience using PBL	

Firstly, thank you for your willingness to participate in this interview. I will be voice-recoding this interview so that I have an accurate record of this conversation. Your identity will remain anonymous, and this recording will remain strictly private. The file containing the voice-recordings will also be password-protected. No one except myself and my supervisor will listen to this recording. Do you give consent to be interviewed?

Please answer the following questions to the best of your abilities and truthfully. There are no right or wrong answers.

Questions of Interview 1

1. How would you describe your teaching philosophy in mathematics? (IF2)
2. How do you think your teaching philosophy impacts how you do activities in mathematics such as projects? (IF2)
3. In your own words, explain to me what a project is. (IF4)
4. What is your understanding of PBL? (IF3)
5. Do you consider the level of experience a teacher has as a factor that will influence if they use PBL? Why do you say so? (EF5)
6. How long have you been using PBL? (EF5)
7. Why did you decide to use PBL to teach this topic? (EF/IF overall)
8. How do you plan to implement PBL for this topic? (EF/IF overall)
9. Describe what your understanding is of the formative assessments in the CAPS. (IF5)
10. In terms of the type of support you get from your subject head and Head of Department, how do they encourage and help you implement PBL? (EF1)
11. Does your subject head and Head of Department encourage the use of projects as a formative assessment and how do they support you in this if they do? (EF1)
12. Do you think that the type of support you receive from your Subject Head and Head of Department, plays a role in your use of PBL and projects as a formative assessment? Why do you think so? (EF1)
13. What is your approach to lesson planning and preparation for a project? (EF4)
14. How would you describe your ability to manage your time when using PBL? (EF2)
15. Do you think that a lack of time management skills prevents teachers from using PBL? Why do you think so? (EF2)
16. In what way are you prepared to handle disruptions when you administer a project? (EF5)
17. Would disruptions that affect teaching time influence you to adapt your teaching approach? (EF3)
18. Would you say that disruptions to class time can influence your use of PBL? Why do you say so? (EF3)

Thank you for your time. If you have any questions, please feel free to ask. You also have my contact details if you have any concerns later on. Remember that the transcript of this interview is at all times available to you if you wish to verify the content of it.

INTERVIEW 2

This interview should be done after the first observation when the project's first phase has been completed. The answers to these questions informed my second secondary research

question: *How do teachers plan a project using PBL in terms of the essential question(s), design and timeline of the project?*

GENERAL INFORMATION

Name of school	
Name of researcher	Ms. C. van Loggerenberg
Name of teacher	
Date of interview	
Number of years of experience using PBL	

Thank you for your willingness to participate in this interview. I will be voice-recoding this interview so that I have an accurate record of this conversation. Your identity will remain anonymous, and this recording will remain strictly private. The file containing the voice-recordings will also be password-protected. No one except myself and my supervisor will listen to this recording. Do you give consent to be interviewed?

Please answer the following questions to the best of your abilities and truthfully. There are no right or wrong answers.

Questions of Interview 2

1. What do you think are the qualities of a good main question in a project? (Step 1)
2. Explain to me, what your process is for designing a project. (Step 2)
3. What do you think makes for a good project? (Step 2)
4. How do you ensure that your projects are designed and administered according to the requirements of the curriculum? (IF1; Step 2)
5. How do you decide how much time you are going to provide your learners to complete the project? (Step 3)
6. How do you ensure that your learners stick to the provided timeline? (Step 3)
7. At what point, do you decide to extend the deadline of the project? (Step 3)
8. What role does a teacher have when learners are doing a project? (Step 4)
9. Do you think you use PBL with other teaching approaches such as Inquiry-Based Learning? (Step 4)
10. How do you ensure that your learners construct their own learning? (Step 4)

Thank you for your time. If you have any questions, please feel free to ask. You also have my contact details if you have any concerns later on. Remember that the transcript of this interview is at all times available to you if you wish to verify the content of it.

INTERVIEW 3

This interview should be done after the second observation when the project's second phase has been completed. However, it will be repeated after each observation that takes place during the middle part of the project i.e. every other phase except the first and last one. The answers to these questions informed my second secondary research question: *During the implementation of PBL, how do teachers facilitate learning?*

GENERAL INFORMATION

Name of school	
Name of researcher	Ms. C. van Loggerenberg
Name of teacher	
Date of interview	
Number of years of experience using PBL	

Thank you for your willingness to participate in this interview. I will be voice-recoding this interview so that I have an accurate record of this conversation. Your identity will remain anonymous, and this recording will remain strictly private. The file containing the voice-recordings will also be password-protected. No one except myself and my supervisor will listen to this recording. Do you give consent to be interviewed?

Please answer the following questions to the best of your abilities and truthfully. There are no right or wrong answers.

Question of Interview 3

1. Did you use any rubrics, checklists, or other assessment criteria to guide your diagnostic feedback process? If so, how did they inform your feedback to learners? (Step 4)
2. What strategies did you employ to ensure that learners understood the diagnostic feedback provided and were able to apply it to improve their work? (Step 4)
3. In your opinion, are learners still on track according to the timeline you planned for them? (Step 4)
4. Explain how you facilitated learning in the previous phase. (Step 4)
5. How do you plan to facilitate learning in the next phase? (Step 4)
6. Did you use another teaching approach with PBL in the previous phase? (Step 4)
7. How would you explain your use of PBL in the previous phase? (Step 4)

Thank you for your time. If you have any questions, please feel free to ask. You also have my contact details if you have any concerns later on. Remember that the transcript of this interview is at all times available to you if you wish to verify the content of it.

INTERVIEW 4

This interview should be done after the final observation when the project is completed. It focuses on the teachers' reflection on the use of PBL and their experiences during the process. The answers to these questions informed my final secondary research question: *How do teachers' reflections on the project inform the use of PBL?*

GENERAL INFORMATION

Name of school	
Name of researcher	Ms. C. van Loggerenberg
Name of teacher	
Date of interview	
Number of years of experience using PBL	

Thank you for your willingness to participate in this interview. I will be voice-recoding this interview so that I have an accurate record of this conversation. Your identity will remain anonymous, and this recording will remain strictly private. The file containing the voice-recordings will also be password-protected. No one except myself and my supervisor will listen to this recording. Do you give consent to be interviewed?

Please answer the following questions to the best of your abilities and truthfully. There are no right or wrong answers.

Questions for Interview 4

1. Why did you select the topic you did to base the project on? (Step 1; Step 2)
2. Did you involve your learners in selecting the topic of this project? (Step 2)
3. What misconceptions did you aim to address through the use of this project? (Step 2)
4. After the completion of the project, does it seem learners have fewer misconceptions about the topic?
5. In what way did your teaching approach allow learners to construct their own knowledge? (Step 2; Step 4)
6. What challenges have you faced while using projects as formative assessments in your classroom? (EF; IF)

7. What challenges have you faced while using PBL in your classroom? (EF; IF)
8. In your opinion, what are the benefits of using PBL in your classroom? (IF3)
9. Why do you think other teachers might not be using PBL? (EF; IF)
10. Would you change your approach to a project next year? Why do you say so? (IF4)
11. Do you think that through this project, learners are prepared to adequately do a project for assessment in Term 3? (IF1 and 2)

Thank you for your time. If you have any questions, please feel free to ask. You also have my contact details if you have any concerns later on. Remember that the transcript of this interview is at all times available to you if you wish to verify the content of it.

APPENDIX D: LETTERS OF PERMISSION AND CONSENT

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FACULTY OF EDUCATION

Miss Carika van Loggerenberg

Natural Science Building 4-1

Groenkloof campus

LETTER OF CONSENT TO THE GAUTENG DEPARTMENT OF EDUCATION (GDE) TO CONDUCT RESEARCH

Research Title: South African Grade 6 Mathematics teachers' application of project-based learning when using a project

To whom it may concern

I am a Master's degree student at the University of Pretoria and would hereby request permission to use public schools in Gauteng for my research. My research is aimed at learning how mathematics teachers use Project-Based Learning (PBL) when administering projects in a classroom.

I would like to invite three teachers from three schools to participate in this study. These would be Grade 6 teachers who work at public schools that use the Department of Basic Education's CAPS. If consent can be obtained from the GDE, the data will be collected using document analysis of the project design and lesson plans the teachers prepare when using a project, classroom observations and semi-structured interviews.

My data collection process entails the following:

- Two documents will be analysed before the interviews and the observations commence. The two documents are the teachers' planned projects and their lesson plans. Both will be analysed using checklists that were created based on established literature as reflected in the conceptual framework.
- The number of observations will depend on the number of phases of the project. I will observe their lessons where they use PBL. The first observation will be when the project is first given to the learners. The second observation is done when the first phase of the project is completed. At such a point, formative assessment is required, and the teacher should provide feedback to the learners. This will enable the learners to rectify misunderstandings and common errors made before proceeding to the next phase. The last observation is when the learners will hand in their final projects that have been edited by the learners to exclude all mistakes from previous sections that the teacher

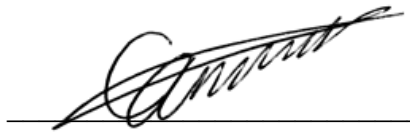
commented on. All observations will be video-recorded, and the camera will be set up to only focus on the teacher and the backs of the learners. If learners' faces appear in the video, they will be blurred.

- The number of interviews will depend on the number of phases of the project. The discussion of the interviews in this letter assumes there are two phases. The interviews will happen at different stages of the data collection process and will last for about 30-45 minutes per interview. The first interview will be before the first observation. This interview will focus on the external and internal factors that influence teachers' choice to use PBL. The second interview will be after the first observation. This interview focuses on how the teacher introduced the project. The third interview will be conducted after the second observation and will focus on the teacher's feedback at the end of Phase 1 of the project. The last interview will take place after the final observation and will focus on teachers' reflections on the project. The interviews will take place after school hours at a place convenient to the teacher and will be voice-recorded and afterwards transcribed verbatim to text data.
- The learners will not be part of this study and I will not teach them in any way. I will also not adjust or ask the teacher to change their lessons and timetable. Everything will happen at their convenience.
- Lastly, I would request that the teachers hand out the consent letters (I will provide them) for the parents of the learners in the classes as well as the assent letters to the learners. I kindly request that the teacher will take responsibility for collecting the letters' reply slips as I will not be on the premises. The reply slips need to be collected before the observations of the lessons commence.

Neither the voice-recordings nor the video-recordings will be seen by anyone else but myself and my supervisor. This study is voluntary, the schools and the teachers are welcome to withdraw from the study at any stage. I will use pseudonyms in the study to protect the teachers' identities and the schools' names will never be mentioned. The data collected will only be used for academic purposes. All data collected with public funding may be made available in an open repository for public and scientific use. After the successful completion of my Master's degree, I will give feedback on my findings to the GDE in the form of a written report or a copy of the dissertation.

I receive no commission through the study and only want the information that will contribute to critical knowledge in South African mathematics.

Yours sincerely,



Researcher: Miss C. van Loggerenberg — **28/05/2023** Date

Supervisor: Dr JJ Botha — **28/05/2023** Date

I,_____, hereby grant consent to Miss C. Van Loggerenberg to conduct her research in Gauteng for her Master's research. I also give consent to Miss C. Van Loggerenberg to video-record the lessons, voice-record the interview(s) and photograph the necessary documentation.

GDE representative's signature: _____

Date: _____

Email address: _____

Contact number: _____

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Miss Carika van Loggerenberg

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LETTER OF CONSENT FOR HAVING YOUR CHILD PRESENT DURING A RESEARCH STUDY

Research Title: South African Grade 6 Mathematics teachers' application of project-based learning when using a project

Dear Parent/Guardian

I am a Master's degree student at the University of Pretoria and will be conducting a study on how your child's teacher uses a project when teaching mathematics. To do this study, I need to observe the teacher during class time while all learners are present. This study focuses on how your child's mathematics teacher uses a specific teaching approach called Project-Based Learning (PBL).

Your child's presence during the lessons is also voluntary. I only want to observe your child's teacher. The study is not focused on how your child performs in the class. I will sit at the back of the class for the duration of the project the learners will do. This project is part of your child's planned school work and by no means was I involved in the lesson planning or the design of this project. This is all according to the teacher's lesson plans that have been done weeks ahead of time.

I will be video recording **only** the teacher and if your child's face appears on the video by chance, it will be blurred. I will in no way publish the videos or use them for anything other than this study. Only my supervisor and I will see them. All the data I get from the study will be stored in locked files in research offices at the University of Pretoria.

This study has been approved by the Ethics Committee of the University of Pretoria as well as the Department of Basic Education. If you have any questions, please feel free to ask me at carika@loggies.co.za.

Yours sincerely,

Researcher: Miss C. van Loggerenberg — 16/08/2023 Date

Supervisor: Dr JJ Botha — 16/08/2023 Date

Deputy Principal: Miss Maivha — Date

I_____(name and surname) hereby confirm that I have been informed about the nature, conduct, risks, and benefits of this study. I have also read or have had someone read to me the above information regarding this study and that I understand the information that has been given to me. I have had sufficient opportunity to ask questions and (of my own free will) declare that the child may be present during this study.

Signature: _____ Date _____

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Miss Carika van Loggerenberg

Natural Science Building 4-1

Groenkloof campus

LETTER OF ASSENT TO THE LEARNERS

Research Title: South African Grade 6 Mathematics teachers' application of project-based learning when using a project

Dear Learner

I am a Master's degree student at the University of Pretoria. I wish to learn more about how teachers teach mathematics to you in what is called a study. I will not be your teacher when I am in your class. When I come to your mathematics lessons, I will be video-recording the lessons to record what your teacher does during the lesson. I will be at the back of your classroom when I record your teacher. The video is focused on your teacher, not you. The video will be used for my study, and no one will see the video but my supervisor and me.

You will not be involved in any way, and you do not have to do anything except what your teacher expects you to do. Your parents and your teacher know about this study, and you will talk to them about this before you sign this letter. If you have any questions, you may contact me at any time.

Yours sincerely,

Researcher: Miss C. van Loggerenberg — 16/08/2023 Date

Supervisor: Dr JJ Botha — 16/08/2023 Date

Deputy Principal: Miss Maivha — Date

I, _____ (name and surname), hereby grant assent to be present during the mathematics lessons where my teacher will be video recorded.

Learner's signature: _____ Date: _____

Grade (e.g., 6E): _____

FACULTY OF EDUCATION

Miss Carika van Loggerenberg

Natural Science Building 4-1

Groenkloof campus

LETTER OF CONSENT FOR HAVING YOUR TEACHER PARTICIPATE IN A RESEARCH STUDY

Research Title: South African Grade 6 Mathematics teachers' application of project-based learning when using a project

Dear Deputy Principal

I am a Master's degree student at the University of Pretoria. I wish to learn more about how your mathematics teacher uses Project-Based Learning when administering projects in your classroom. I hereby request permission to use your school as one of the three schools for my research.

My data collection process entails document analysis, observations and interviews:

- Documents will be analysed before the interviews and the observations commence. The documents are the teacher's planned project and their lesson plan(s).
- The number of observations will depend on the number of phases of the project. I will observe their lessons where they use PBL. The first observation will be when the project is first given to the learners. The second observation is done when the first phase of the project is completed. At such a point, formative assessment is required, and the teacher should provide feedback to the learners. This will enable the learners to rectify misunderstandings and common errors made before proceeding to the next phase. The last observation is when the learners will hand in their final projects that have been edited by the learners to exclude all mistakes from previous sections that the teacher commented on. All observations will be video-recorded, and the camera will be set up to only focus on the teacher and the backs of the learners. If learners' faces appear in the video, they will be blurred.
- The number of interviews will depend on the number of phases of the project. The discussion of the interviews in this letter assumes there are two phases. The interviews will happen at different stages of the data collection process and will last for about 30-45 minutes per interview. The first interview will be before the first observation. This interview will focus on the external and internal factors that influence teachers' choice to use PBL. The second interview will be after the first observation. This interview focuses on how the teacher introduced the project. The third interview will be

conducted after the second observation and will focus on the teacher's feedback at the end of Phase 1 of the project. The last interview will take place after the final observation and will focus on teachers' reflections on the project. The interviews will take place after school hours at a place convenient to the teacher and will be voice-recorded and afterwards transcribed verbatim to text data.

- The learners will not be part of this study and I will not teach them in any way. I will also not adjust or ask the teacher to change their lessons and timetable. Everything will happen at their convenience.
- Lastly, I would request that the teachers hand out the consent letters (I will provide them) for the parents of the learners in the classes as well as the assent letters to the learners. I kindly request that the teacher will take responsibility for collecting the letters' reply slips as I will not be on the premises. The reply slips need to be collected before the observations of the lessons commence.

Neither the voice-recordings nor the video-recordings will be seen by anyone else but myself and my supervisor. This study is voluntary, the schools and the teachers are welcome to withdraw from the study at any stage. I will use pseudonyms in the study to protect the teachers' identities and the schools' names will never be mentioned. The data collected will only be used for academic purposes. All data collected with public funding may be made available in an open repository for public and scientific use. After the successful completion of my Master's degree, I will give feedback on my findings to the school in the form of a written report or a copy of the dissertation.

I receive no commission through the study and only want the information that will contribute to critical knowledge in South African mathematics.

Yours sincerely,

16/08/2023

Researcher: Miss C. van Loggerenberg Date

16/08/2023

Supervisor: Dr JJ Botha Date

I, _____ (name and surname), hereby grant consent to Miss C. van Loggerenberg to conduct her research at this school for her Master's research. I also give consent to Miss C. van Loggerenberg to video-record the lessons, voice-record the interviews and photograph the necessary documentation.

Deputy Principal's signature: _____

Date: _____

Deputy Principal's email1: _____

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Miss Carika van Loggerenberg

Natural Science Building 4-1

Groenkloof campus

LETTER OF CONSENT TO PARTICIPATE IN THE RESEARCH STUDY

Research Title: South African Grade 6 Mathematics teachers' application of project-based learning when using a project

Dear Teacher

I am a Master's degree student at the University of Pretoria. I kindly invite you to participate in this study where three teachers, each from a different school will be involved. I am working under the supervision of Dr JJ Botha from the Department of Science, Mathematics and Technology Education at the University of Pretoria. I wish to learn more about how you use Project-Based Learning when administering projects in your mathematics classroom.

My data collection process entails, document analysis, observations and interviews:

- Documents will be analysed before the interviews and the observations commence. The documents are your planned project and your lesson plan(s).
- The number of observations will depend on the number of phases of the project. I will observe their lessons where you use PBL. The first observation will be when the project is first given to the learners. The second observation is done when the first phase of the project is completed. At such a point, formative assessment is required, and you should provide feedback to the learners. This will enable the learners to rectify misunderstandings and common errors made before proceeding to the next phase. The last observation is when the learners will hand in their final projects that have been edited by the learners to exclude all mistakes from previous sections that the teacher commented on. All observations will be video-recorded, and the camera will be set up to only focus on you and the backs of the learners. If learners' faces appear in the video, they will be blurred.
- The number of interviews will depend on the number of phases of the project. The discussion of the interviews in this letter assumes there are two phases. The interviews will happen at different stages of the data collection process and will last for about 30-45 minutes per interview. The first interview will be before the first observation. This interview will focus on the external and internal factors that influence teachers' choice to use PBL. The second interview will be after the first observation. This interview focuses on how you introduced the project. The third interview will be conducted after the second observation and will focus on your feedback at the end of Phase 1 of the

project. The last interview will take place after the final observation and will focus on your reflection on the project. The interviews will take place after school hours at a place convenient to you and will be voice-recorded and afterwards transcribed verbatim to text data.

- Your learners will not be part of this study and I will not teach them in any way. I will also not adjust or ask you to change your lessons and your timetable. Everything will happen at your convenience.
- Lastly, I would like to request that you hand out the consent letters (I will provide them) for the parents of the learners in the classes as well as the assent letters to the learners. I kindly request that you will take responsibility for collecting the letters' reply slips as I am not on the premises. The reply slips need to be collected before the observation of the lessons.

Should you decide to be a participant in this study, please bear in mind the following: neither the voice-recordings nor the video-recordings will be seen by anyone else but myself and my supervisor. This study is voluntary, the school and you are welcome to withdraw from the study at any stage. I will use pseudonyms in the study to protect your identity and the school's name will never be mentioned. The data collected will only be used for academic purposes. All data collected with public funding may be made available in an open repository for public and scientific use. After the successful completion of my Master's degree, I will give feedback on my findings to the school in the form of a written report or a copy of the dissertation.

You may ask questions before or during the time of participation. If you have any concerns regarding the data collection procedures, please notify me or my supervisor. As a participant, you will have the opportunity to access and verify the recordings and the transcriptions of interviews.

I receive no commission through the study and only want the information that will contribute to critical knowledge in South African mathematics.

Yours sincerely,

16/08/2023

Researcher: Miss C. van Loggerenberg — Date

16/08/2023

Supervisor: Dr JJ Botha — Date

Deputy Principal: Miss Maivha — Date

I,_____ (name and surname), hereby grant consent to Miss C. van Loggerenberg to have access to the project I will give the learners and my lesson plan, observe my mathematics lessons when I am doing the project, and conduct interviews with me for her Master's degree research. I also grant consent to Miss C. van Loggerenberg to analyse the photographs taken of my preparation documents, video-record the lessons and voice-record the interviews.

Teacher's signature: _____ Date: _____

Teacher's email address: _____