Mathematics Teachers' Challenges in Practicing Project-Based Learning in Their Classrooms

By

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Abstract

Project-based learning is viewed as an instructional approach that promotes student engagement and can equip learners with skills for life and work. In this regard, it is very important for teachers to have a clear understanding of project-based learning for them to be able to provide sufficient student support and guidance for its successful implementation. In this study, we explored the challenges and solutions perceived by high school mathematics teachers in Japan in practicing project-based learning approach in their classrooms. Data was collected from an open-ended online questionnaire survey which was administered to 25 high school teachers and semi-structured interviews on 7 high school teachers. Regarding challenges, the study revealed that, teachers have difficulties in creating authentic project-based learning tasks that contain relevant content and fits the learners' level, creating tasks that learners are interested in, securing time to plan and reflect on the practice, balancing students' independence and student support, students' lack of knowledge, collaborative activities in student groups and evaluating learning outcomes. Regarding the solutions to the challenges, the following were revealed, the importance of creating tasks for project-based learning in small scales that can be completed over a short period of time, cooperation, and collaboration among (mathematics teachers, other subject teachers, and experts in mathematics education), involving students in creating evaluation criteria, and investigating previous studies on project-based learning. Based on the study results, the study recommends the need for mandatory inclusion of project-based learning in the mathematics course of study/curriculum among others. The study concludes by giving suggestions for future research on project-based learning in mathematics education.

Declaration

I declare that this study is my own work and has not been submitted, in whole or in part, for another degree in any institution.

I declare that any information cited from published or unpublished work written by others has been acknowledged in the text and a bibliography has been provided.

CHOMUNORWIRA TAFARA

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1.0 CHAPTER ONE: BACKGROUND AND PURPOSE

1.1 Introduction

For teachers to teach learners 21st century competencies, they must move away from traditional modes of teaching to new modes of teaching. One such method is project-based learning. This mode of teaching enables teachers to prepare learners for the high demands of our constantly changing world.

As an educator, I felt it to be the teacher's duty to prepare learners for present and future challenges. To achieve this, I realized that educators must help learners to develop skills that would enable them to be critical thinkers (Alberta Education, 2013). With a desire to establish and develop 21st century competencies in mathematics education, the researcher has already begun to explore ways in which these skills can be fostered in learners. The use of project-based learning within mathematics classroom challenges learners to learn how to learn and encourages them to take on active learning strategies and adopt a self-directed learning stance. Such skills are the once that will promote success when they enter the working world. However, the process of project-based learning implementation has many challenges. It became the researcher's goal to develop a resource that would help teachers when practicing project-based learning in mathematics classrooms to promote learners' success.

Thus, the main aim of this qualitative descriptive case study is to explore the challenges and the solutions perceived by high school mathematics teachers in practicing project-based learning in their mathematics classrooms.

1.2 Background to the study

Our world is continuously and constantly changing, and people are expected to solve so many complex issues that arise daily. As a result of these changes, every sector in our society is looking for individuals that can adapt to new situations and develop innovative solutions to problems that we are currently facing and those that we will be facing in the future. To produce individuals of such caliber, educators have long seen the value of placing learners in real-life problem-solving situations and scenarios to help them gain deeper levels of understanding of learning (Boss, 2012). Likewise, educators have long understood the value of projects to help learners learn new concepts. Markham (2011) described, project-based learning as more than just "doing projects" as much as it is more than a simple "real-life" experiential activity, but rather it is viewed as the means to redirect the instructional approach to teach the skills needed to prepare learners for the modern global economy (Stanley, 2012). Murray and Savin-Badem (2000) homologate that project-based learning is a "powerful means for facilitating learners' attainment of high-level competencies and transferable skills" that are being increasingly "demanded by government, commerce, and industry" (p.108). This is in line with (Licht, 2014) who pointed out that project-based learning is essential in teaching learners "critical thinking, communication, collaboration and creativity" (p.51).

As teachers experiment with project-based learning and implement the practice in their mathematics classrooms, the challenges they face in doing so and ways they employ to overcome the challenges become a topic of some interest.

1.3 What brought us to this study?

The teaching and learning ideas behind project-based learning have followed me for the past 10 years l have been teaching mathematics in Zimbabwe. I had the privilege to participate in several mathematics teachers' workshops and seminars where issues to do with the teaching and learning of mathematics in the country were discussed. Project-based learning as a pedagogy was one of the topical issues. Project-based learning was viewed as a method which helps learners develop their skills and knowledge while investigating a challenge for a period of time. Most teachers agreed that engaging with project-based learning increases learners' understanding of mathematical concepts. Moreover, learners benefit from project-based learning in terms of increasing motivation (Grant, 2002). Zimbabwean teachers were of the view that when learners deal with real-world problems and seek solutions for and by themselves, they develop better attitudes towards mathematics and learning. As a result of these seminars and workshops, I became deeply interested in teaching and learning using project-based learning approach. Later in 2017, l was enrolled as a master student of mathematics education at Bindura University of Science Education where I conducted research on teachers' perceptions of project-based learning at secondary school level in Zimbabwe. The study revealed that teachers perceived project-based learning as an instructional approach that cultivates more positive learning attributes in learners. The results of the study agreed with several researchers like (Mills and Treagut, 2003, p.12) who state that "learners showed a deeper understanding of the application of their knowledge in practice and are able to address the complexities of other issues related to practical application once project-based learning had occurred". Camp (1996) also found corroborating evidence showing that project-based learning helps learners to better transfer concepts to new problems and can retain knowledge much longer than learners taught conventionally. Moreso, studies have

shown that project-based learning has a large impact on developing and creating learners who are skilled in self-directed learning, along with motivation (Camp, 1996). According to William & Shelagh (1993), as learners increase their motivation, they can significantly increase their knowledge base through increasingly self-directed study.

Based on my experiences, research and the view of other teachers, project-based learning appears to be one of the best solutions to satisfying the need to create competent 21st century learners. However, besides the identified benefits of implementing project-based learning approach, I realized that there are still issues to be addressed regarding its practice. As a teacher, I felt it to be my duty to investigate teacher issues particularly in mathematics classroom context. This is what brought me to the idea of exploring challenges and solutions perceived by high school mathematics teachers in practicing project-based learning in their classrooms.

1.4 Statement of the problem

There is literature available to support educators who are interested in implementing project-based learning, as prescribed by Stanley (2012). There is also current literature available that addresses the efficacy of project-based learning compared to other modes of instructional practice (Thomas, 2000). However, there are few studies that explore the experience of teachers in implementing project-based learning. Specifically, there are very few studies exploring the challenges teachers face when implementing project-based learning in mathematics classrooms and how they go about solving the challenges. Studies in this area could be of great help to teachers if, indeed, project-based learning is a teaching and learning approach more suitable to teach concerns of this 21st century era. The research seeks to identify and analyze challenges faced by mathematics teachers in practicing project-based learning method of delivery and

envisage solutions. This will go a long way in improving teaching and learning process, improve mastery of mathematics concepts and learners will have skills required in the 21st century.

1.5 Purpose of the study

The purpose of this study is to explore the challenges that mathematics teachers face in practicing project-based learning in their classrooms, this includes challenges in designing good project-based learning tasks for the learners, challenges in organizing the process of teaching and learning of project-based learning, and challenges in evaluating project-based learning activities and how they respond to all the challenges. It is of importance to explore the difficulties teachers encounter and how they respond to the challenges when practicing the approach in their mathematics classrooms.

1.6 Research questions

The following research questions are designed to guide the exploration of the challenges and solutions perceived by high school mathematics teachers in practicing project-based learning in their classrooms. These questions will also guide the analysis of the results. The research questions are as follows.

Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?

Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

1.7 Significance of the study

The results of this study are expected to contribute to the body of literature by filling in the existing gap of knowledge on the challenges and their solutions perceived by mathematics

teachers in practicing project-based learning. Thus, providing mathematics teachers with common answers to common problems associated with the practice. The study results might help to inspire decisions regarding project-based learning implementation and how to design professional development in project-based learning. Thus, helping researchers and implementers to have a full description and understanding of project-based learning within mathematics classroom context. This study could also act as a base or framework for other researchers who are interested in researching learner-centered mathematics teaching and learning approaches. Thereby promoting successful implementation of these approaches in mathematics classrooms and maximizing the gains associated with them.

1.8 Organization of the thesis

The following sections of this thesis address literature review, the methodology and methods used to conduct the study, findings, or results of the study and, finally, discussions and implications of the study.

[*Chapter 2*] will provide an inclusive discussion of the relevant literature related to the study, it covers issues to do with project-based learning definition, discourse around project-based learning and problem-based learning. The review will also look at the discourse on the theory and historical beginnings of project-based learning, discussion on mathematics and project-based learning and address the success stories of project-based learning in mathematics classroom context.

[*Chapter 3*] provides a clear description of the research methodology used in the study, information on the participant population, ethical consideration of the study, the data collection

procedures through open-ended online questionnaire and semi-structured interviews, and the data analysis procedure.

[*Chapter 4*] presents the findings of the study from the analyzed open-ended questionnaire and semi-structured interview responses, categorizing the challenges and their solutions.

[*Chapter 5*] discussion on how the results relate or contradict the previous related studies and use literature to explain, concludes the thesis with implications of the study and recommendations for further research.

2.0 CHAPTER TWO:
LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1 Introduction

This literature review examined the research on project-based learning and its connection to mathematics classroom practices. Literature searches were limited to peer reviewed publications and during the searches, the following key phrases and words were utilized: Project-based learning, Project-based learning in mathematics classroom, PBL, Mathematics and project-based learning, Problem-based learning, STEM project-based learning, Mathematics learner-centered approaches among others. For the purposes of this research, the literature selected looked at: the discussion on project-based learning definition, discourse around problem-based learning and project-based learning, theoretical framework of the study, history and theory of project-based learning, mathematics and project-based learning, research on project-based learning in mathematics classroom, and the general challenges in implementing project-based learning.

Discussion on these sub-topics is important if one is to understand the context of the research, its results, and its interpretations.

2.2 Discourse on project-based learning definition

Project-based learning has been described by different researchers and authors in several ways. There is no single definition for this term and no common agreement has yet been reached as highlighted by Bas (2011). Newell (2003) defines project-based learning as a process that emphasizes learner interest rather than following a fixed curriculum, a broad interdisciplinary focus rather than narrow, discipled focus. Thomas (2000) states that project-based learning is a model that organizes learning around projects. The tasks can be different with questions and

problems that involve learners in problem solving and investigative activities. Solomon (2003) said project-based learning is all about learning through experiences. Chard (2011) pointed out that project-based learning enables teachers to guide learners through in-depth studies of real-world topics. This is in line with Buck Institute for Education who define project-based learning as a teaching method in which learners gain knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, or challenge. This was further supported by Kubiatko and Vaculova (2009) who believe that "project-based learning is an instructional method centered on the learner" (p.66). Thus, in project-based learning, learners are at the center of learning who are learning actively to improve their competences. Project-based learning gives learners the opportunity to work on a problem and investigate the topic deeply through learning more about it (Harris and Katz, 2007). Erol et al. (2012) emphasize that project-based learning is a constructivist pedagogy which is intent on bringing about deep learning using inquiry-based approach. This was supported by (Kokotaski, 2016) who went on to say, project-based learning is characterized by learners' autonomy, constructive investigations, goal setting, collaboration, communication, and reflection within real world practices. Project-based learning is an instructional method that is focused on the learner who is guided by a teacher during all the steps of the project (Bell, 2010). Project-based learning has been widely recognized as collaborative, progressive, learner-centered, interactive, active and a deep learning approach. According to Doppelt (2003), project-based learning is a method that helps to create a pleasant and flexible learning environment for learners that will improve their skills and instill thinking competencies. This is in line with Barrows (1996) who states that project-based learning is an instructional model that can be used to structure the development in the curriculum level by placing learners in the active role of problem-solver that resemble real-

world problems. It can also be viewed as a strategy that motivates learners to explore something new by integrating knowledge from already existing subjects. Furthermore, project-based learning is considered as an educational strategy that engages and motivates learners in finding answers by themselves as pointed out by Kolmos (2007).

Even though there are differences in how project-based learning is defined and how the models are practiced worldwide, they are founded on the same theoretical basis and thus have the same principles of learning, that is, it's a learner-centered approach, where learners collaboratively work together to solve real world problems with the teacher being the guide. The selected literature supports a theoretical foundation and key elements that form a consistent definition. Reference is often made to constructivist theorists who support the idea that people learn best when they actively construct their own understanding. (Ajai, Imoko, and O'kwu, 2013) argued that constructivists view that the hands-on similar-to-life experiences gained from the classroom activities are an important approach to the further process of motivation and learning. The main idea of project-based learning is that it is a project work learning strategy that motivates learners in their own learning, provides them with the opportunity to work in teams, and helps them gain necessary skills by solving real-world problems. For this study, the definition of project-based learning by Bell (2010) and Thomas (2000) will be used. It states that project-based learning is a learner-centered, teacher-facilitated approach that organizes learning around projects.

2.3 Discourse around Project-based Learning and Problem-based Learning

Besides the discourse around project-based learning definition mentioned above, there is also an unclear distinction between project-based learning and problem-based learning which to some extent become an obstacle in moving forward with project-based learning in the classroom. Several research in this area use project-based learning and problem-based learning

interchangeably. For example, Barron et al. (1998) failed to differentiate the two instructional pedagogies and summarize both problem and project-based learning into one category. They argued that the two terms can be used to describe one thing with little or no distinction between them. Likewise, Kolmos (1996) states that, “it can be very difficult to define and compare project-based learning and problem-based learning as “what one institution practices as problem-based learning may look very much similar to what another institution practices as project-based learning” (p.141). This was further supported by Blumenfeld (1991) who argued that both project-based learning and problem-based learning are organized around driving questions.

Though both project-based learning and problem-based learning are open, authentic, collaborative, and emphasize learner independence and inquiry, what separates the two concepts is the perspectives that the learners take to solve a problem. Project-based learning tends to consist of longer tasks and is often interdisciplinary. Scenarios often drive learner research and solution building. In the process, learners follow a series of general steps that help to provide structure of learning and project development. On the other hand, Problem-based learning often involves a single content area, but it can include other subjects as well. The learning experiences tend to be shorter and follow specific steps that result in the identification of the problem and then working toward a solution or solutions. According to Barron et al. (1998) project-based learning focuses more on the doing of an activity while on the other hand problem-based learning focuses more on the underlying conceptual knowledge of performing such a task. Markham and Ravitz (2003) differentiate project-based learning from problem-based learning by describing project-based learning as an instructional method that uses projects as the central focus of instruction in a variety of disciplines that may unfold in unexpected ways while problem-based learning is an instructional approach where learners move along a more carefully

planned path toward a set of prescribed outcomes. Table 1 summarizes the similarities and differences between project-based learning and problem-based learning.

Table 1
Comparison between Project-based Learning and Problem-based Learning

Similarities	
▪ Both emphasize student independence and inquiry and are student-centered. ▪ Both encourage active learning and critical thinking. ▪ Both provide authentic application of content and skills (Meant to solve real-world problems).	
Differences	
Project-based Learning	**Problem-based Learning**
Learning tends to consist of longer tasks and is often interdisciplinary.	Learning experiences tend to be shorter and often involve a single content area.
Learners follow a series of general steps to provide the structure of learning.	Learning experiences follow specific steps in the identification of the problem.
Focuses more on the doing of the activity.	Focuses more on the conceptual knowledge of performing such a task.

2.4 Theoretical Framework of the study.

Experiential learning theory by Kolb (1984) and the constructivism provided the study's theoretical framework. Kolb (1984) defines experiential learning as the "process whereby knowledge is created through the transformation of experience from the combination of grasping and transforming experience" (p.41). Experiences and experimentation are described as the way people make sense of the world (Kolb et al., 1999). The experiential learning theory by John Dewey and Jean Piaget states that people learn through experience (Kolb and Kolb, 2012). Dewey (1897) believes that education must be conceived as a continuing reconstruction of experience. This experience is gained by active learning, thinking, feeling, and perceiving. Kolb

and Kolb (2012) postulate that experiential learning is considered as the result of the interaction between the human and his or her environment. According to Harrigan (2014), the experiential learning theory served as the basis for the development of the constructivist theory, which states that learners do not acquire knowledge but actively construct it themselves.

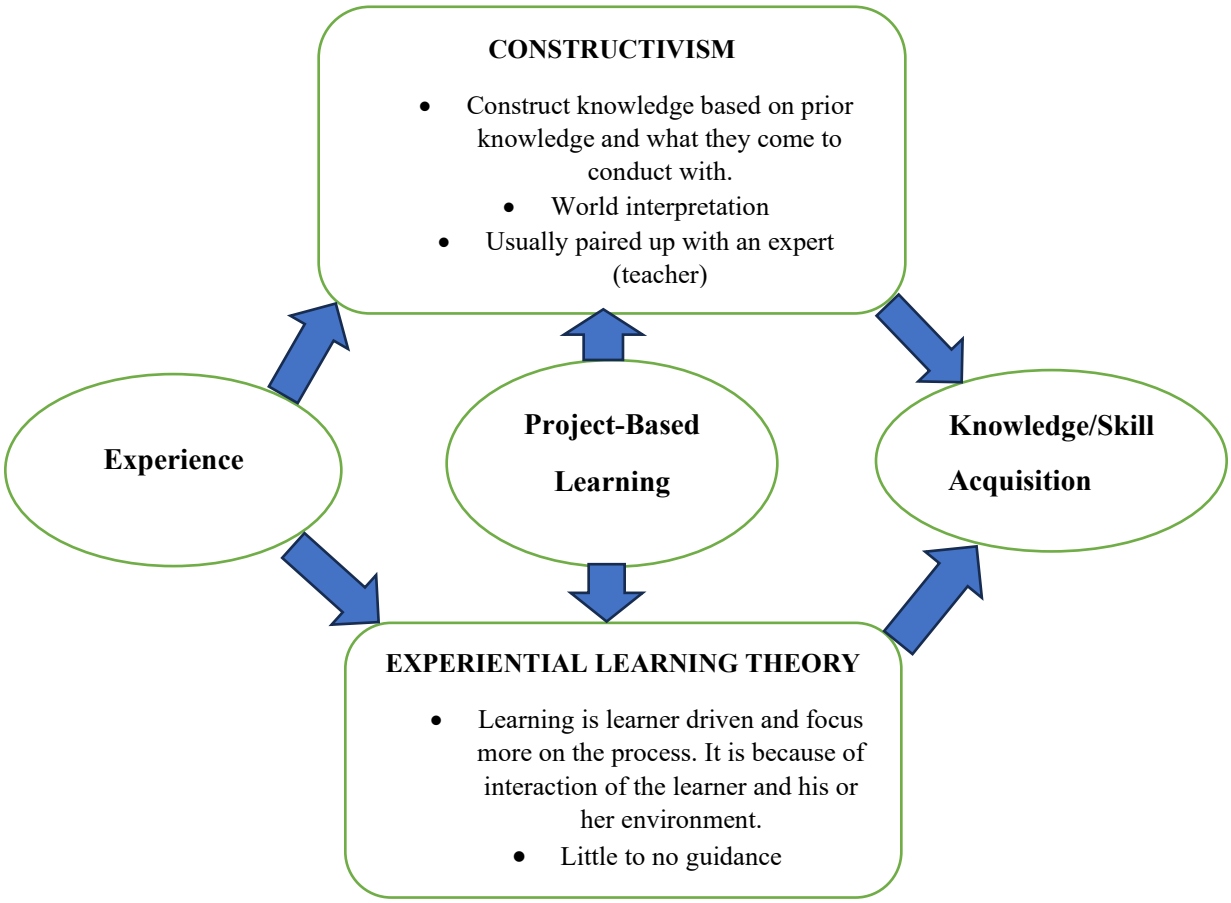
Constructivism is a theory of learning where individuals create their own new understanding based on interaction between what they already know and believe and ideas and knowledge with which they come into contact (Richardson, 2003). Ertmer and Newby (1993) confirm that constructivists claim that learners do not transfer ready knowledge from outside but create their own meaning and interpretation of the world through gained experience. This was supported by Schuman (1996) who postulates that constructivism operates on the premise that perspectives of the world are constructed through individual experiences and schema.

Based on the above definitions, both experiential learning theory and constructivism have a common factor "**experience**" which is because of interactions and active learning. Thus, the acquisition of knowledge or learning emanates from learner's experiences which are very typical of project-based learning.

Figure 1 summarizes the route taken by the two theories in learning.

Figure 1

2.4.1 Summary of the theoretical framework of the study.



2.5 Constructivism

The understanding of constructivism is necessary in the implementation of project-based learning. Constructivism is a theory about how we learn, it suggests that learners must be active participants in the development of their own understanding. (Middleton and Goepfert, 1996) argued that, when teaching mathematics at every grade from a constructivist perspective for example, these principles must be included:

- ✓ making mathematics realistic and interesting,
- ✓ consider learners prior knowledge,

- ✓ making the mathematics curriculum socially interactive.

Constructivist teaching emphasizes that learners must build their own scientific knowledge and understanding. At every stage in learning, they need to interpret new knowledge in the context of what they already understand. Instead of putting formed knowledge in learners' minds, in the constructivist approach, teachers help learners construct scientifically valid interpretations of the world and guide them in altering their scientific misconceptions (Martins et al., 2005). According to Cobb et al. (1992), learning is described as a process in which learners actively construct mathematical knowledge as they strive to make sense of their worlds. It can be argued that the view of learning as active construction implies that learners build on and modify their current ways of knowing mathematical concepts.

In the project-based learning classroom, learners are given the opportunity to construct their own knowledge of mathematics through schematization of the learning process in which previously learned knowledge serves as forerunners and anchors to the new knowledge. In constructivism collaboration is emphasized. Adler (1997) pointed out that collaboration forms the basis of project-based learning. Project-based learning classroom allows learners to collaboratively engage in decision making regarding the solution to a problem at hand with learners not losing their autonomy and control. It is argued that, in constructivism knowledge gained is relatively permanent and project-based learning relies on the heuristics of problem solving in developing and consolidating knowledge in learners.

2.6 History and Theory of project-based learning.

Project-based learning ensures that learners are immersed in their own learning through task-oriented problem solving that incorporates the environment around them. This idea of learn-by-doing has been around since John Dewey in the early 1920s. Dewey's work on the impact of

experience on a child's education is foundational to the formation of project-based learning. Dewey argued that learners should be actively involved in real-world problems to improve their personal skills and abilities. His idea was about active inquiry resulting in a deeper understanding of the problem (Krajcik and Blumenfeld, 2006). Project-based learning is a practical expression of Dewey's philosophy as highlighted in Experience and Education (1938). In this approach, educators and learners work together to design an authentic experience and learners are given an autonomy to build their own understanding while standards and teachers guide them. Dewey (1938) explores the development of experience through interaction as a construct of social control. It can be argued that project-based learning is a structured social interactive experience where learner works collaboratively usually in pre-defined roles to solve a problem or to accomplish a task. Bender (2012) argued that project-based learning provides a process within which a designed social experience takes place.

After John Dewey, Jean Piaget's work on how children build knowledge of the world around them gave more theoretical validation of project-based learning (Piaget, 1973). Piaget postulates that children come to understand their world by going through several developmental stages and do so by being actively engaged with their environment. It can be argued that Piaget's work provides the basis for creating discovery-based curricula where learners learn by doing and skills are discovered rather than taught at the appropriate stage of development (McLeod, 2009).

Lev Vygotsky's study is also another significant theoretical framework for project-based learning. Vygotsky argued that learners learn best through social interaction and there is need to get out of the comfort zone by doing more challenging tasks. According to Vygotsky and Cole (1978, p.86), Vygotsky define the "Zone of Proximal Development" as "the distance between the actual developmental level as determined by independent problem solving and the level of

potential development as determined through problem solving, adult guidance, or collaboration with more capable peers". It can be argued that project-based learning is well designed to place teachers as facilitators and learners in collaborative groups in problem-solving situations. This implies that project-based learning becomes a vehicle through which the "Zone of Proximal Development" is realized.

The experimental learning concepts of Dewey (1938), Piaget (1973) and Vygotsky led to the development of project-based learning. Bass (2011) argued that project-based learning is still in its developmental stage and can have many improvements in the future. However, it is important to recognize that the foundation of project-based learning is based on the learning through experience and interaction with others.

2.7 Mathematics and Project-based learning

Merriam-Webster (2013) defines mathematics as a science of numbers and their operation, interrelation, combination, generalization, and abstraction of space configuration, and their structure, measurement, transformation, and generalization. According to Polya (2000), when teaching learners to understand and solve mathematical problems, there are four main stages to take learners through.

- understanding the math problem,
- devising a plan to solve the problem,
- carrying out a plan to solve the problem, and
- checking the results after solving the problem.

It can be argued that the stages emphasize the connection between the learner's prior knowledge and the concrete understanding of mathematics, which is helpful in solving mathematical

problems. Project-based learning is an effective alternative to take learners through Polya's four important steps because it gives learners more opportunities to think critically, present their own creative ideas, and communicate about mathematics with their peers as highlighted by Erickson (1999). According to Understanding Mathematics (2006), learners in a teacher-centered mathematics education environment learn through exercises, rules, and equations. In this form of learning, learners are drilled on reciting formulas, mathematical rules, and facts. On the other hand, in a project-based learning mathematics education environment, the sharing of mathematical ideas is essential, because it provides learners with the opportunity to analyze and refine others' ideas and understanding of mathematics (Access Group, 2013). This is in line with Lubienski (1999) who postulates that, learners in project-based learning have a greater opportunity to learn mathematical processes associated with communication, representation, modelling, and reasoning in comparison with those learners exposed to teacher centered methods of learning. This was further supported by Artzt and Armour-Thomas (2008) who argued that when learners use project-based learning, they interact and work more cooperatively, develop better mathematical skills, and develop a deeper understanding of mathematical concepts. It can be argued that project-based learning can enhance the effectiveness of teaching and learning of mathematics.

According to Thomas (2000), project-based learning encompasses the essential skills that are needed to support learner learning experiences and provide the central framework upon which the teaching and learning of mathematics concepts are built. The main idea of teaching mathematics through project-based learning is to incorporate learning with real-life problems, achieve a connection between the cognition and professional knowledge of the learner and allow the teacher to help leaners as a facilitator not as an instructor. Chen (2013) pointed out that

project-based learning method can improve mathematics teaching and help learners apply the knowledge they acquired.

As highlighted by Savery (2006), it can be concluded that the use of project-based learning in mathematics teaching is very suitable as it incites learners to actively participate in the learning process. Thus, project-based learning has the potential to facilitate learning in mathematics since engagement in learning is a key factor to increase achievement. Dealing with projects in mathematics and making them relevant to their lives, learners understand mathematical concepts and their achievement also increases. The authentic nature of projects makes it possible for learners to derive their own learning through research, collaborative work, and inquiry.

2.8 Research on project-based learning in mathematics classroom

Much research has been done to shed light on the positive impact that project-based learning has on education. Based on the documented theoretical and actual benefits of project-based learning, this section is going to focus more on the success stories of project-based learning in mathematics teaching and learning context published in Chomunorwira and Koyama (2023):

> One of the well-known, successful, and significant studies of project-based learning in mathematics classroom is that of Boaler in the late 1990s as cited in (Thomas, 2000). In her longitudinal three-year study, Boaler wanted to compare and assess the learners' achievement, attitude, and capabilities in mathematics from two different schools taught in two different methods of instruction that is traditional against project-based learning. To ensure study reliability, the researcher made sure that learners from the two schools were of the same background and that they had experienced similar mathematics instruction before and were of the same mathematics abilities based on performance. The study results found that when it comes to conceptual questions which required creative application and a combination of mathematical rules, learners taught using project-based learning approach performed better that those exposed to the traditional instructions. That

was evidence that learners from the two schools developed different kinds of mathematical knowledge because of the method of instruction they were exposed to. The study also found that most learners from the traditional instructed school perceived mathematics to be a boring and demanding subject whose success is centered on remembering and using rules. However, those learners from the project-based learning instructed school regarded mathematics as an interesting and explorable subject.

According to Thomas (2000), a similar study in Maine concluded that a middle school using project-based learning approach displayed significant increases in all achievement areas on the Maine Educational Assessment Battery after one year. He argued that the gains were ten times higher than the average. This is in line with Bell (2010) who described that learners retain more information when they learn by doing which leads to shaping learners learning with high quality experiences, as well as continuity of experiences. Camp (1996) states that there is evidence that shows that learners that participate in project-based learning can "retain knowledge much longer than learners taught conventionally" (p. 3).

Uyangor (2012) conducted a pre- and post-test of attitudes towards mathematics and found significant increases in high school students' self-reported attitudes towards mathematics learning. Key features of project-based learning, including collaborative learning, engaging with challenging real-world problems, and having choice over the assignment, were cited to be factors that contributed to the students' positive attitudes towards this style of mathematics learning. In the same way, Selmer et al. (2014) examined upper elementary students as they engaged in a project-based learning mathematics unit, and it was found that the authentic nature of the project was highly engaging and enjoyable to students. Project-based learning allows students to understand how mathematics is relevant in the real-world and how they can use mathematics to solve actual problems in their own lives, thus making mathematics highly engaging and relevant for learners (Selmer et al., 2014)

Another study by Han et al. (2016) investigated how science, technology, engineering, and mathematics (STEM) project-based learning affect high-need learners in America in terms of academic achievement. The study revealed that project-based learning approach

in STEM positively influences achievement in mathematics. In the same way, in their study which involved kindergarten learners, He et al. (2021) explored the relationship between project-based learning activities based on STEM education and the development of learners' mathematics ability, the results showed that project-based learning promotes significant improvement in learners.

Holmes and Hwang (2016) investigated the benefits of project-based learning on secondary mathematics learners' academic skill development and motivated strategies for learning. They focused on academic skill development in algebra and geometry assessment scores and other factors in connection to secondary mathematics learning. They used traditional teaching and learning approaches as control groups. The study found out that project-based learning learners were intrinsically motivated and displayed higher critical thinking abilities and appreciate peer learning.

According to Karaca et al. (2016), Ozdemir carried out a study which focused on the effects of project-based learning on the learners' attitudes towards and success in geometry. In this study, learners' and researcher's observations and teachers' responses to the observation scale were examined. The study results showed that the learners' achievements in and attitudes towards geometry were increased with the use of project-based learning method. This study also concluded that learners who lacked attention and were easily distracted were now able to focus easier with the use of project-based learning.

In another study by Ali et al. (2011), 38 eighth-grade learners were assigned to either an experiment group or a control group with 19 learners each. Both groups consisted of high achievers and low achievers. Learners were given a pre-test of eighth-grade mathematics textbook problems. The pre-test results demonstrated that there was no difference in overall ability between groups and then received one month of math instruction delivered through either teacher-centered, lecture-based means [control group] or through authentic, collaborative-based, project-based learning means [experimental group]. At post-test, learners in the experimental group demonstrated greater academic gain than their control group peers. These findings demonstrate that a project-based learning curriculum can be used to foster mathematics achievement of learners at all ability levels.

Another significant study of project-based learning in mathematics is that of Nicholas-Barrer (2013). In this study, the researcher compared the results of reading and mathematics scores. After three years, the researcher observed that there was a movement from 50% to 60% in reading and there was an increase from 56% to 61% in mathematics. The researcher also noted that the results were increasing further the longer the learners stay in the project-based learning program.

Another study by Cross et al. (2012) found that upper elementary learners' understanding of mathematical and statistical concepts and procedures increased after participating in project-based mathematics. Similar results were also found by Uyangor (2012) who found significant differences between pre- and post-tests of high school students' mathematics achievement because of engaging with project-based mathematics. The conclusion was, when considering mathematics performance on standardized and high-stakes tests, the academic performance of learners who engaged with project-based learning is significantly greater than the learners who did not engage with project-based learning in their mathematics learning.

Finally, is a literature review paper analysis of nine research studies on project-based learning/problem-based learning in K-8 Mathematics and Science Education (Merrit, et al., 2017). The review noted the following. (a) Learners in the project-based learning groups outperformed learners in the control groups in terms of academic achievements. (b) When it comes to conceptual development which they defined as the understanding of laws and the ability to apply them, all the nine reviewed studies showed there is significant difference between groups taught using project-based learning instruction and the control groups. To this, the reviewers concluded that project-based learning helps learners in developing reasoning and application as learners develop in understanding math/science concepts. (c) The analysis also found that learners exposed to project-based learning had a better knowledge retention rate and had a positive attitude towards mathematics and science compared to those exposed to traditional methods of instructions.

The review on the implementation of project-based learning in mathematics classrooms showed that learners increase math concepts understanding, they improve in problem-

solving abilities, they improve in collaborative skills and having a positive attitude towards mathematics (Karacalli & Korur, 2014). Thus project-based learning makes mathematics engaging and relevant for learners. More so, learners learn how to organize and present their thoughts, how to make decisions and how to manage time. These are the significant characteristics which enable learners to make noticeable gains in mathematics.

2.9 Challenges in implementing project-based learning.

Despite the identified merits of using project-based learning approach, there are also some general challenges in using the approach highlighted in research. One of the major challenges most teachers need to overcome is their need to teach as much information as possible within a given time frame. Teachers argued that using project-based learning often takes more time than other methods of teaching which may delay the process of covering the lessons scheduled in the syllabus. This is in line with Dahlgren et al. (1999) who states that many teachers assume that project-based learning is time consuming, and they are unable to cover as much material as in using the traditional teaching style. Fox (2013) argued that projects mostly take longer than expected, and teachers may experience problems regarding time management. Bligh (1995) comments on the issue of time in the implementation of project-based learning. He pointed out that "project-based learning is not expected to raise the teaching time but rather to change how this time is spent" (p.342) because teachers implementing project-based learning spend more time working with their learners. It can be argued that teachers need to move from the mind set of being suppliers of legitimate knowledge to seeing themselves as facilitators in knowledge acquisition as highlighted. Teacher centered approaches are challenged when project-based learning is implemented in the classroom and educators are forced to question their educational beliefs. Thus, creating that struggle within teachers to try to adapt to a new way of looking at education while on the other hand trying to meet the educational needs of their learners.

Project definition is also another challenge of project-based learning. According to Krishnan (2011), teachers have difficulties designing project-based learning that meets curricular requirements, choosing real life problems and monitoring the process. This is in line with Fox (2013) who argued that teachers may have difficulties defining projects to solve real life problems and meet the requirements of the curriculum. Besides the issue of project definition, teachers face challenges of meeting the needs of each learner when implementing project-based learning. Thomas (2000) comments that teachers face difficulties responding to the needs of individual learners and they also face challenges in designing assessment tools that help them understand what their learners have learnt.

Another challenge faced by many teachers in implementing project-based learning is the role change from the "knowledge expert" to the "facilitator". Bound and Feletti (1991) pointed out that one of their assistant teachers argued that "I can't handle this. I want to be in total control and project-based learning doesn't allow that" (p.32). This was supported by Dahlgren et al. (1998) who commented that teachers experienced a lot of struggles when they felt like their expertise was not fully utilized because of not using the traditional teaching styles. While teachers believe that the learners need to create their own meanings, they mostly try to check the information flow, and this may cause problems (Thomas, 2000). Novak (1990) comments that it is challenging for teachers who have been accustomed to teaching using traditional methods to implement new learning methodologies that they never experienced personally. Fox (2013) put the challenges teachers experience in implementing project-based learning into six main points which are as follows:

- Ensuring necessary conditions to develop good projects.
- Constructing problems as an opportunity to learn.

- Cooperate with other teachers to develop interdisciplinary tasks.
- Managing the learning process.
- Integrating appropriate technology.
- Developing authentic evaluation.

Thus, many challenges teachers face in implementing project-based learning are in terms of planning, managing, and evaluating.

The issue of the learner pedagogical shift is another problem. Project-based learning force learners to take on a new responsibility for their learning. His (2000) postulates that self-directed learning can prove to be difficult for learners when it comes to applying metacognitive strategies. Many learners have been raised in a teacher centered classroom and have been recipients of knowledge not generators of knowledge. Blumenfeld et al. (1991) comments that learners need to have sufficient knowledge of the content and specific skills to explore information to be successful in a project-based learning environment. According to Greening (1998), most learners wonder why they are not simply being told the information which their teachers want them to know, and they struggle to connect what they need to know with what they already know.

2.10 Conclusion

The literature review offers an understanding of a project-based learning approach. Although many aspects of project-based learning have been researched, the literature review of this study focused on, the discourse on project-based learning definition, discourse around project-based learning and problem-based learning, history and theory of project-based learning, mathematics and project-based learning, success stories of project-based learning and challenges in implementing project-based learning.

The discussion on these issues and the consistence in the previous studies about the advantages of implementing project-based learning in mathematics classes left the researcher with the need to investigate on the challenges that mathematics teachers perceive they face when practicing the approach and their possible solutions to provide mathematics project-based learning educators and implementers with answers to common challenges associated with practicing project-based learning approach thus promoting positive teaching and learning of mathematics.

The chapter to follow will provide a clear description of the research methodology used in the study, the background of the setting, information on the participant population, the data collection procedures, and the methods for data analysis.

3.0. CHAPTER THREE:
METHODOLOGY AND DATA ANALYSIS

3.1 Methodology

In this chapter, the methodology of this study is presented. It includes the summary of the purpose of the study, the research design, participant selection, instrumentation, data collection procedure, data analysis procedure and ethical considerations of the study.

The purpose of this study was to explore the challenges and solutions perceived by high school mathematics teachers in practicing project-based learning in their classrooms.

The study was guided by the following two main research questions:

Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?

Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

3.2 Research Paradigm

The study followed a qualitative descriptive case study research paradigm. There is a range of definitions of qualitative research given by qualitative researchers. Strauss and Corbin (1990) define qualitative research as "any kind of research that produces findings that are not arrived at by means of statistical procedures or other means of quantification" (p.17). According to Bogdan and Taylor (1975), qualitative research is "research procedures which produce descriptive data: people's own written or spoken words and observable behavior" (p.2). This agrees with Hatch (2000) who comments that, one of the characteristics of qualitative research is that it "seeks to

understand the world from the perspectives of those living in it. In addition, Best and Kahn (1998) emphasize that qualitative data are useful within the research setting because participants will freely express their thoughts, perceptions, and experiences in more detail relation to the research topic. Based on the definitions and characteristics mentioned, qualitative research is best suited for this study as the research's objective is to explore teachers' perceived challenges in practicing project-based learning in their mathematics classrooms and how they respond to these challenges. According to Creswell (2014), qualitative research methods provide the opportunity to gain valuable information from participants on the phenomenon when very little is known about it. Since little is known about teacher's perceived challenges and solutions when practicing project-based learning in mathematics classroom, therefore the researcher used qualitative research design.

3.3 Participant teacher selection

Participant teachers for this research were selected using purposive sampling technique. Purposive sampling refers to an intentional selection of individuals based on the understanding that they are information rich on the topic of interest (Creswell, 2003; Patton, 1990). Thus, the participant teachers for this study were selected based on the following judgement.

i. They had to be high school mathematics teachers in Japan.
ii. They had to be experienced in practicing project-based learning in their mathematics classrooms.
iii. They had to be willing to participate.

3.4 Research instruments

In this study, the researcher used two data collection instruments: open-ended online questionnaire and semi-structured interviews to collect the data from the participant teachers on the challenges they perceived they face in practicing project-based learning in their mathematics classrooms and how they respond to these challenges. This was done to ensure credibility and validity of the study as well as to have a balanced explanation of the study results.

3.4.1 Phase 1: The first phase was the use of an online questionnaire from 15 July to 31 August 2022. The online questionnaire was designed to give answers to the following research sub-questions.

1. What are the challenges in practicing project-based learning?
    i. *What are the challenges in preparing and designing tasks for project-based learning?*
    ii. *What are the challenges in the project-based learning implementation process stage?*
    iii. *What are the challenges in evaluating project-based learning*?
2. What are the solutions to the challenges mentioned above?
    i. *What are the solutions to the challenges in the preparation and task designing phase of project-based learning?*
    ii. *What are the possible solutions to the challenges in the implementation processes phase of project-based learning?*
    iii. *What are the possible solutions to the challenges in the evaluation phase of project-based learning?*

Literature review proved that for a questionnaire to be standard and good to obtain accurate information and relevant information, it must contain questions which are easy for the respondent to provide the necessary answers and information to make it easy for the researcher to record the gotten data. In designing the questionnaire, the researcher followed Sudman and

Bradburn (1973)'s idea that questionnaire should not include abbreviations, acronyms and terminologies which are unfamiliar to the respondent. The researcher made sure that questions are simple, to the point and easy to understand. The research also used statements which are interpreted in the same way by the respondent teachers. Thus, the questionnaire used was well thought out and laid out in a chronological manner where one question leads to another. This helped the researcher to obtain comprehensive results on challenges teachers face in practicing project-based learning in their mathematics classrooms and the possible solutions.

The online questionnaire was made up of 10 questions. The intention of the first five questions from the questionnaire guide was to enable participant teachers to contextualize their responses to questions 6 and 7 which were the main objective of the study (Ling and Jee, 2007). The intention of question 6 and 7 was to allow participant teachers to specify the challenges they perceived to face in the implementation of project-based learning in their classrooms in all the three main stages of project-based learning as well as specifying on how they respond to these challenges. The last three questions were mainly to allow participant teachers to give their suggestions and recommendations on areas that they think needs improvement when it comes to implementation of project-based learning approach in mathematics classrooms (**see Appendix 3**).

3.4.2 Phase 2: The second phase involved the use of semi-structured interviews done from July to September 2023. The semi-structured interviews aimed to seek for clarifications based on the open-ended online questionnaire and to gain a deeper understanding of how high school mathematics teachers perceive project-based learning (**primarily task-based learning that mathematically solves real-world problems**) and how they practice it in the classroom. The interviews were based on a semi-structured protocol (**see Appendix 4**). The interviews were guided by the following two sub-questions.

i. *How do high school mathematics teachers understand project-based learning (mainly task learning that mathematically solves real-world problems)?*

ii. *How do high school mathematics teachers choose to practice project-based learning (primarily task-based learning that mathematically solves real-world problems)?*

The researcher used an interview protocol (**see Appendix 4**) which consisted of 14 questions, the first two questions were just to collect the demographic information of the participants. Questions 3 to 7 were meant to give answers to sub-question one and the other questions were meant to give answers to sub-question two.

3.5 Measures taken to ensure ethical protection of participant teachers

In this study, ethical issues were carefully considered. Prior to data collection, an ethics application including the informed consent and the questionnaire guide was made and submitted to Hiroshima University ethics committee (**Application number: HR-ES-000344**) and the application was approved (**see Appendix 2**). For the purposes of this research's open-ended online questionnaire and semi-structured interviews, the following ethical considerations were made (**see Appendix 1**):

1. Participant teachers were aware and notified that the responses they were to give were of their own will, and they had all the right to withdraw at any point in time.
2. Participant teachers for this research were informed that no personal information was going to be included in the questionnaire guide and the interview protocol, its analysis as well as the results.

3.6 Data analysis

Data collected from the open-ended online questionnaire and the semi-structured interviews were analyzed using qualitative relational content analysis method. Content analysis is one of the common qualitative data analysis methods. First the collected data is conceptualized then the

resulting concepts are put in order in a rational way, and themes that explain the data are determined (Yildirim and Simsek, 2013). Below is the summary of content analysis steps that were applied to the data collected on teachers' challenges in practicing project-based learning in their mathematics classroom and their solutions.

- The data or participant teacher's responses was read several times.
- Initial codes were determined.
- Then codes were rechecked and revised, then categorized to create themes.
- The researcher then identified quotations that illustrated each theme and wrote the findings in an engaging narrative to describe the themes.
- Finally in the discussion section, the researcher showed how these themes are similar or different from previous related studies and used the literature to explain**.**

3.7 Conclusion

Chapter 3 has presented the methodology for the collection of data for the study. Chapter 4 is going to focus on analyzing and presenting the findings from the data collected from the respondent mathematics teachers.

4.0. CHAPTER FOUR:
RESULTS AND DISCUSSION

4.1 Introduction.

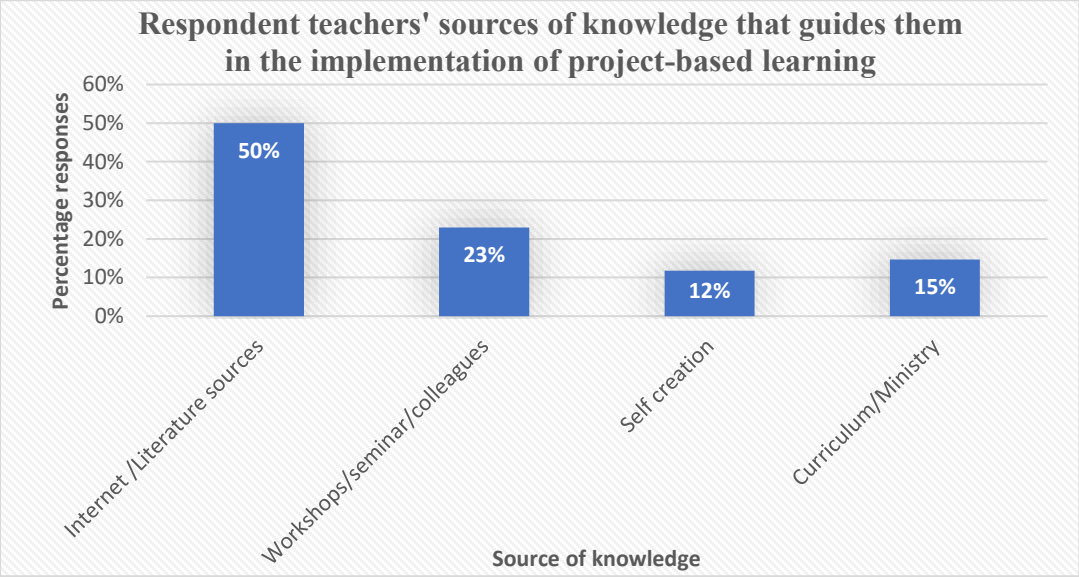
Based on the research questions presented in chapter one, this chapter will describe and summarize the results from open-ended online questionnaire responses and semi-structured interview responses from the 25 and 7 high school mathematics teacher participants respectively. The chapter is organized based on the findings of each main question from the research instruments. The results are discussed according to the main ideas that have emerged from the participant teachers' responses. Exemplified quotations from the teachers' responses were used in the presentation of the identified themes.

4.2 Questionnaire analysis

Out of the 25 teachers who responded to the questionnaire, 10 were from junior high school, 6 from senior high school and 9 from secondary high school. Also, of the 25 teachers, 16 had teaching experience of over 15 years, 6 teachers had 5 to 15 years of experience and 3 teachers had experience of below 5 years.

4.2.1 Fig 2 below shows the response analysis to question 4: Where do you get relevant knowledge to guide you in the teaching using project-based learning approaches?

Figure 2

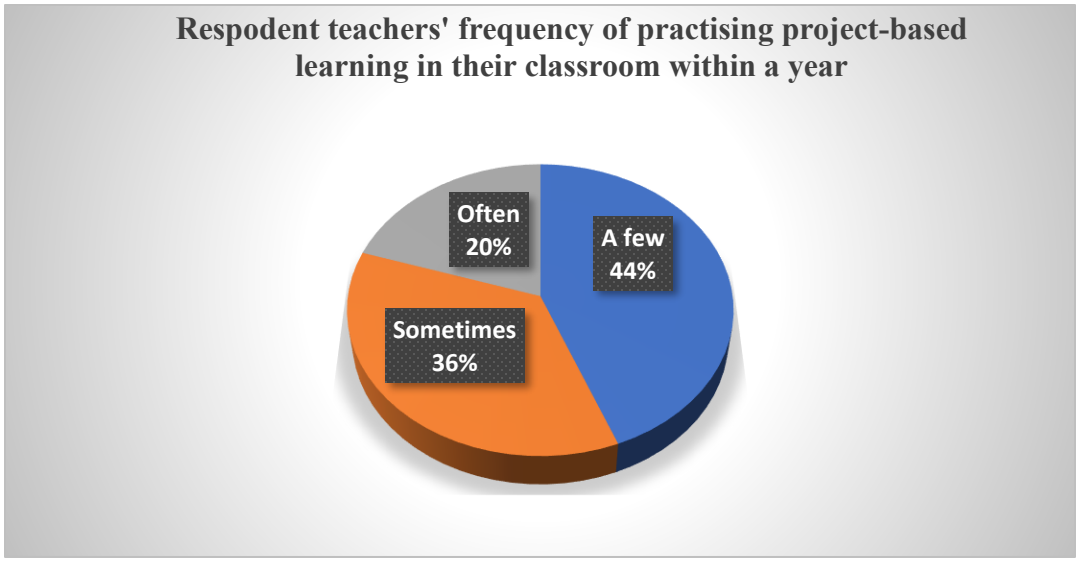


The chart above (***Figure 2***) shows the participant teachers' responses to the question "Where do you get relevant knowledge that guides you in teaching using project-based learning approaches?". 50% of the teachers' responses showed that they get relevant knowledge from the internet and other literature sources like mathematics textbooks, journals, and academic papers. 23% said they get relevant knowledge from colleagues through mathematics workshops and seminars. One of the mentioned workshops is that of "*methodology workshop on teaching statistics, Borland Math*". 12% of the teachers' responses highlighted that they do self-creation. For example, one teacher said, "*I sometimes develop such teaching materials in joint research, so I use what I have learned as a foundation*" The other respondent also explained "*Observing daily lives and taking notes…. Conversations with teachers from other subject areas* ...". This shows that they get the knowledge from their daily experiences as well as interacting with other teachers. The other

15% pointed out that they get guidance from the curriculum and the ministry through their mathematics course of study as well as materials from universities.

4.2.2 Figure 3 below shows the teachers' responses to question 5: How often do you practice project-based learning in a year?

Figure 3



The results showed that within a year, 11 respondent teachers (44%) practice project-based learning a few times, 9 teachers (36%) use project-based learning sometimes and 5 of them (20%) practice the approach regularly. From the teachers' responses, it can be concluded that project-based learning is not often or regularly practiced by most of the respondent teachers, probably due to the challenges they encounter during its implementation. The responses might also mean that project-based learning approach is not encouraged or promoted within the schools where these teachers are coming from resulting in very few teachers regularly practicing the approach.

4.2.3 Question (6): What are the challenges in practicing project-based learning?
i. What are the challenges in preparing and designing tasks for project-based learning?

(Published in **Chomunorwira and Koyama (2023)**):

> The analysis of the 25 teachers' responses to this question identified challenges teachers perceived they face in preparing and designing project-based learning mathematics tasks for the learners. These were the three themes identified: c***reating authentic project-based learning mathematics task***, ***learner interest***, *and* ***time availability***.
>
> The first challenge is Creating Authentic Project-based Learning Mathematics Task. Participant teachers mentioned that creating tasks that make authentic connections or link between mathematics concepts and real life at the same time matching the level of the learner is a big challenge for them. One of the responded teachers indicated, "*The challenge is that it is difficult to find real world problems that can be discussed and resolved within what learners have already learned or are currently learning*". Teachers find it difficult to organize real world learner mathematics activities that enable learners to achieve their learning objectives that is to obtain mathematical knowledge and understanding, as well as having a sense of accomplishment and progress in the subject. Another teacher explained, "*It is difficult to prepare a task that makes it easy to feel the need for advanced mathematics*". Thus, teachers have difficulties in constructing mathematics tasks to solve real world problems at the same time giving learners an opportunity to learn and meet the requirements of their mathematics curriculum.
>
> The second challenge is Learner Interest**,** coming up with mathematics tasks or assignments that learners are willing to work on or are interested in is another challenge that responded teachers mentioned. Learner interest becomes a challenge because it is a component that is emphasized in project-based learning approach. Below are sample descriptions of what respondent teachers said about learner interest.
>
> "*Next, even if a subject is found, the next difficult question is whether or not it is a subject that learners want to solve*".
> "*Searching for topics that learners want to work on is a challenge*".
> "*It is a challenge to set up tasks that are just right for learners to want to work on*".
>
> Third one is Time Availability. Responded teachers also mentioned time availability as another challenge they face when they try to prepare and design project-based learning tasks that are engaging to learners. Some of the responses with respect to the issue of time are.
>
> "*It takes time to create an issue*".
> "*When dealing with things introduced by others at academic conferences, etc., I spend time arranging them so that they suit the learners at my school*".

From the above teachers' responses, teachers suggest that it takes a lot of time for them to create project-based learning tasks that are authentic or as they try to modify the given tasks from colleagues and experts to suit their own mathematics classes. This could be because of inexperience or lack of knowledge on task creation.

4.2.4 ii. What are the challenges in implementing project-based learning?

The analysis of participant 25 teachers' responses to this question identified four main themes which are ***the extent of learner support***, ***time availability***, ***learner group collaboration***, *and* ***resources/technology***.

The first theme is the Extent of Learner Support. Teachers faced challenges in finding specific guidelines on how to support learners and the extent to which that support must be taken to leaving room for learners to be free and overseeing their learning.

One teacher had this to say, *"Drawing a line between how far the teacher guides learners and how far the learners are allowed to be free. This is the most difficult thing*".
Another teacher also explained, "*When learners try to solve problems with elementary school mathematics skills, I do not have a clear answer as to how I should intervene as a teacher*. *Forcing learners to use secondary mathematics skills seems to undermine the significance of project-based learning*".

Thus, it is difficult for teachers to know how much support they should give so as not to interfere with learners' freedom to self-study. The data shows that teachers are not sure of whether they are giving their learners inadequate support or excess support which either way nullifies the real purpose using project-based learning in their mathematics classes. This challenge can be attributed to teachers' lake of scaffolding instruction skill.

The second theme is Time Availability. Responded teachers mentioned time as another challenge they face in the implementation of project-based learning in their mathematics classes. These are some of the participant teachers' responses to the time issue.

"*In the yearly syllabus, we consider the available time and implement it. In the case of high school, there is a strong tendency to consider the progress of learning. So, depending on the unit, it may not be possible to take time*".

"*Number of hours, especially in high schools, is difficult to implement project-based learning that takes several hours*".
"*Not enough class time*".

This suggests that project-based learning is time consuming to teachers making it difficult for them to implement the approach and at the same time trying to meet the demands or the requirements of their mathematics syllabus.

The third theme is Learner Group Collaboration. Most responded teachers perceived project-based learning as an approach that is implemented in group format and each individual member is expected to collaborate and contribute to the task at hand. But they found it challenging to develop and foster that meaningful collaboration among learners' groups. Below is a sample of what teachers said about group collaboration challenge, "*It is difficult to handle differences such as differences in academic ability between groups*".
"*Problem-solving and sharing are done through discussion and collaboration based on actual problems. But it is difficult to make individuals in the group set their own goals and aware of them*".
"*Steering the group discussion so that it does not diverge in the process of resolution and become too much of a social and moral debate is a challenge*".

This data revealed that teachers find it difficult to manage learner groups and to create a collaborative environment to ensure that all learners are actively involved and are learning from the project-based learning mathematics activities being done. This challenge can be attributed to teachers' lack of skills needed to monitor and manage learners.

The fourth theme is Lack of Resources. The analysis results also noted that responded teachers have challenges in incorporating technology in their project-based learning classes. Some of the teachers had this to say, "*Some high school learners do not have PCs…*".
"*The is no environment in which learners can freely use PCs in mathematics classes*".

From the teachers' responses, one can conclude that either teachers lack skills to allow learners to use their PCs or they lack time to monitor them, or the rooms are not designed to allow learners to freely use PCs in their mathematics classes.

4.2.5 iii. What are the challenges in evaluating project-based learning?

The analysis of this question's responses identified two main themes which are ***general evaluation*** *and* ***individual evaluation***.

The first theme is General Evaluation. Learner evaluation emerged to be a challenge for teachers as they implement the project-based learning approach in their mathematics classes. As project-based learning is a multifaceted approach, respondent teachers find it difficult to come up with evaluation criteria that can cater for all aspects. Some responded teachers had this say,
"*Needless to say, it would be unrealistic to set the evaluation criteria for such task-based learning in too much detail. …, I think that [what part to evaluate and what criteria to evaluate] is always a difficult problem*".

"*It is expected that various methods of expression will be used to draw conclusions. So, it is difficult to create an all-encompassing standard*".

"*I feel the difficulty in setting criteria and criteria for evaluation*".

The data suggests that the issue of evaluation is unclear to most respondent teachers. They found it difficult to develop authentic evaluation to understand what their learners have learnt. Some attributed this challenge to lack of mathematics project-based learning evaluation cases in the literature to guide them, some attributed it to their lack of skills to develop evaluation tools aligning project-based learning goals, and others attributed it to lack of mathematics content mastery on the learners, as one of the respondents explained, "*Depending on the problem, the evaluation may be unstable, because learners do not understand the content of mathematics or because they do not understand the problem setting*".

The second theme is Individual Evaluation. As project-based learning being a group format approach, teachers pointed out that it is a challenge to assess individual performance for individuals working in a group. Below are some sample explanations from the respondent teachers on the individual evaluation challenge; "*It is difficult to evaluate each person working in a group*".
"*In PBL, it is difficult to comprehensively evaluate individual results and the individual learners' efforts within the group. I sometimes find it difficult to check with colleague teachers, to prepare and implement measures for evaluation every time*".
"*Since the evaluation is for the entire group, some groups were created on the opinions of one learner…, I wonder if it's okay to give the same evaluation to those who depend on the opinion of one learner and just listened"*.

Though some teachers mentioned about the recently established rubric evaluation, they still found it difficult to come up with standard criteria to evaluate individual performance and group performance in their project-based learning mathematics classrooms.

4.2.6 Question (7): What are the teachers' solutions to the challenges in all the stages of project-based learning implementation?

i. What are the solutions to the challenges in the preparation and design phase of project-based learning?

When responding to what they do to overcome the challenges they face in designing authentic tasks that connects learner's daily life and mathematics concepts, participant teachers pointed out the importance of collaboration among teachers when designing tasks, consulting experts in the field of mathematics education as well as keeping on practicing the approach in their teaching. This form of collaboration equips them with the knowledge and expertise in designing authentic tasks. Some respondent teachers had this

to say, "*Go through it once and fix it. Do this repeatedly. By doing it, learners' thinking processes and difficulties become clear*".
"*Repeat class practice. Share with colleagues to improve*".
"*In addition to reading literature, consult with other faculty members (not limited to those in the mathematics department). If I have the opportunity, I also ask teachers and researchers at other schools*".
"*The faculty of mathematics should strive to have a wealth of knowledge other than mathematics*".

From the above sample responses, teachers emphasized collaboration among mathematics teachers and those from other learning areas as a solution to designing authentic tasks that are multi-disciplinary. They also suggested practice and reading through a lot of literature on designing project-based learning tasks as another solution since they get information that will equip them with the required task designing skills.

4.2.7 ii. What are the possible solutions to the challenges in implementing project-based learning?

When responding to the question on the possible solution to the implementation challenge, teachers highlighted the need for project-based learning to be a school-based approach rather than an individual teacher practice. One teacher said, "*In particular, the principal and vice principal should understand the significance of project-based learning so that it can be positioned as a curriculum for the entire school, rather than the individual teachers working to understand its significance*". This suggests the need for collaboration within the whole school, through to staff development sessions addressing implementation issues among teachers. Still emphasizing on the need for working as a team on the part of the teacher, some teachers explained, "we *may ask other teachers to observe the class or read the record of the class outline and ask for their opinions*".
"*Talk to other teachers*".

Regarding time challenge, respondent teachers pointed out that project-based learning must not be implemented in a random way, but there is need to allocate specific time for the practice when creating the course of study and stick to it during its implementation. They also suggested the need for implementing project-based learning tasks that can be completed within a short time. For example, one of the teachers said, *"I think it would be good to plan something like project-based learning on a small scale and for a short time*".

4.2.8 iii. What are the possible solutions to the challenges in the evaluation phase of project-based learning?

When responding to how they go about resolving the challenges they face during evaluation phase, participant teachers mentioned the importance of involving learners when creating evaluation criteria. For example, one teacher explained, "*Create a rubric with your learners before working on the assignment. By jointly creating a rubric, it is*

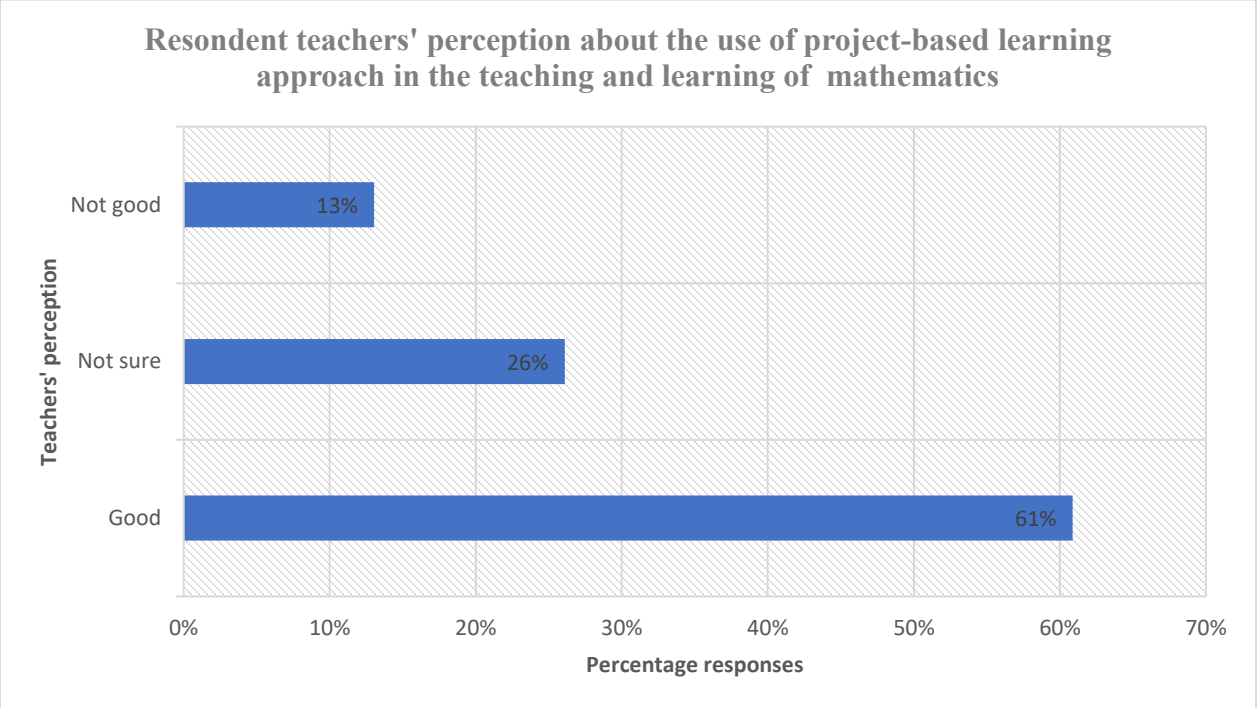
possible to have a common understanding of what we should aim for and ensure the validity of the evaluation. Also, by sharing a vision of what to aim, it becomes easier to come up with a policy on what to do, and it can also serve as a means of facilitating group activities".

Besides the issue of creating evaluation criteria with learners, respondent teachers also mentioned collaborating with other teachers to solve the evaluation challenges. One teacher commented, "*There are situations where it is necessary to coordinate evaluations with other colleague teachers*". Respondent teachers also mentioned the issue of reviewing past efforts on evaluation to get some knowledge and skills as a way of solving their current evaluation challenges.

Collaboration emerged to be the common way of solving all the challenges teachers face in all the three stages of project-based learning implementation, that is the planning and designing stage, the implementation process stage, and the evaluation stage. This is consistent with Mentzer et al. (2017) and Kokotsaki et al. (2016) who describe collaboration as essential in project-based learning. Besides collaboration, reviewing past efforts proved to be another common way in which teachers solve the challenges they encounter in all the stages of project-based implementation. They mention that they always refer to project-based learning articles, literature, and textbooks for ideas.

4.2.9 Figure 4 shows the teachers' responses to question 9, "Do you think project-based learning is a good approach to teaching mathematical concepts? Please explain your answer.

Figure 4



The analysis of this question showed that most of the respondent teachers perceived project-based learning as a good approach to teaching and learning of mathematics. They associated the approach with its benefits for the learners. For example, some teachers had this to say,

"*I think it helps to promote learners' motivation and understanding of learning*."

"*PBL is a very good approach to promote understanding…*"

"*Yes, this is because it makes learners feel the need to acquire mathematical concepts and skills*."

However, even though 61% of the teachers' responses showed that they perceived project-based learning to be a good approach, they had some reservations. Some of the teachers perceived project-based learning as an approach that is only good at equipping learners with the knowledge on how to apply already learned mathematics concepts in their daily lives and in the future at workplaces but not applicable for learners to acquire new mathematical concepts. This is evidenced by the sample responses below,

"*I think it's a good approach from the perspective of making use of what you've already learned. If l were to ask whether it would be compatible with the scene of gaining unknown mathematical knowledge, l would not be confident that it would*."

"*In high school mathematics, l think it is good from the viewpoint of utilization of mathematics*."

"*Rather, I believe that it is a good approach to give learners the opportunity to learn how mathematics can be applied to a given task*."

26% of the teachers' responses showed that some teachers were caught in between. They were not sure whether to classify the approach as good or not good. Some teachers explained,

"I don't know whether it's a good approach to teaching concepts or not. But, if learners say like "what l learned in math class is helping me to solve everyday problems like this", it

helps to promote learners' motivation and understanding of learning. In that sense, it may be said to be "a good approach to teaching concepts."

"*Ideally, I think it's a very good approach. Realistically speaking, it would be difficult to implement it in all classes, so l would like to implement it by ascertaining in what situations and on what topics it would be effective.*"

"*We believe that a good effect can be expected by combing it with conventional learning*."

From the above sample responses, one can conclude that some teachers lack some confidence with the approach, and they do not believe that it can be independently applied to teach mathematics concepts but rather can be used together with other approaches. This might be the reason why very few regularly practice the approach in their teaching and learning (***Figure 3 above***).

Of the teachers' responses, 13% perceived project-based learning as an approach that is not good for teaching and learning of mathematics. They perceived project-based learning to be time consuming, especially during preparation and implementation making it difficult to cover concepts as prescribed in their course of study. One teacher explained, "*I do not think it's a good approach. When trying to teach mathematical concepts in project-based learning, it takes a long time to prepare, but it is not possible to teach so many concepts.*" They also perceived project-based learning as an approach that is not appropriate for high school learners who are still in the process of mastering mathematical concepts. For example, one teacher said, "*I think that junior and senior high schools are the stages where learners acquire tools for solving mathematical problems, so l think it is not good to put too much emphasis on project-based learning*".

4.3 Semi-structured interview analysis

Table 2
Interviewed teachers' demographic information

Respondent Teacher, (T_i)	Level of students taught	Years of teaching experience
T_1	Both Junior and Senior high School students.	17
T_2		17
T_3		16
T_4		13
T_5		23
T_6		9
T_7	Junior high school students.	6

When responding to the question (**Q3**) on how they understand project-based learning, five of the teachers emphasize the issue of using mathematics to solve real-life problems in their explanations. For example, the following teachers had this to say:

T_3 "*I think project-based learning is like using mathematics to solve a practical problem".*

T_2 *" .... I have an image of real world problem-solving learning".*

T_4 *"Well, when you say project-based learning, you give the students a task and basically solve something..., you bring something realistic, interpret it mathematically and solve it".*

Two of the respondent teachers pointed out the issue of learner independence in their explanation. For instance, T_6 said, "*Project-based learning is the student activities by themselves with teacher support, in these activities students must ask their own question and build their researching plans".*

Thus, interviewed teachers understood project-based learning as a teaching approach that is learner centered and allows learners to use mathematics concepts to solve real-word challenges.

In response to the question (**Q6**) on challenges they face in implementing project-based learning, the following challenges emerged from the teachers' responses.

Task design challenge: Teachers find it difficult to come up with mathematics tasks that contain the relevant content under study, fits the learners' level and that learners are willing to work on. For example, T_3 had this to say; "*I think it is difficult to find content that is good material, easy to handle, and that is suitable for the content studied, and that students are interested in".*

Time challenge: They mention that project-based learning is a time-consuming approach, for instance T_6 explained "*when doing project-based learning, it takes a lot of time…".* Respondent teachers perceived project-based to be time consuming in terms of handling activities in all the stages and trying to foster cooperation and collaborate with subject areas.

The teachers also mentioned learners' lack of knowledge as one of the challenges they encounter. For example, T_6 said, "*The main difficulty in supporting students is the lack of knowledge in students, they have difficulties in building researchable questions"*.

This may suggest the need for students to be exposed to the approach from lower grades for them to be equipped with enough knowledge to handle such tasks at high school level.

The teachers also mentioned that the other challenge is project-based learning approach usually leads to change of class discussions from mathematics to non-mathematics, making them fail to achieve the intended objectives. T_2 explained, "*The more realistic the problem is, the more*

non-math stories come up, and l feel that it is a little difficult to answer when asked if it was really a math class".

Evaluation challenge: Since project-based learning involves giving learners some independence and work on a task over a period, teachers find it difficult to evaluate such tasks. For instance,T_1 said, "*it has not yet been clear how to evaluate what has been done over time.*"

Responding to (**Q7**), regarding solving the time challenge, the idea of incorporating project-based learning in the mathematics curriculum at the start of the academic year emerged. This implies that mathematics teachers should plan for the project-based learning approach well on time to avoid unplanned or short time planning which will make it difficult to secure enough time.T_6 explained, *"... teachers gather at the begging of the year to discuss annual curriculum*".

In addition, the idea of cooperation and collaboration among math teachers to share ideas also emerged to be another way to address the difficulties faced in implementing the approach. For example, when T_1 was commenting about the issue of evaluation and said, "*well, l think that expanding the idea of what should be done during evaluation is necessary not only for students but also for teachers who creates the materials*."

Regarding the challenge of students' lack of knowledge and interest, the idea of encouraging and motivating students to read many books emerged to be the way to solve this challenge. T_7 had this to say, "*In addressing the issue of lack of knowledge in my students, l try to promote students to read many books…, though it depends on student motivation*".

Response to (**Q8**), when the respondent teachers were asked when they chose to practice a project-based learning approach in their classroom, the idea that emerged was at the beginning of the topic as well as at the end of the unit. This is the sample teachers' responses: T_8 said "*In my*

case, l think l usually do it towards the end of the unit".

T_1 explained "*l often present assignments/tasks at the beginning of the new topic and sometimes at the end*". This implies that at the begging of the unit, they want their students to master concepts and at the end of the unit/topic they want learners to apply learned concepts to solve real-life problems.

On **(Q9)**, when asked about the skills they will be aiming for in their students as they implement project-based learning, respondent teachers mention the ability to logically communicate mathematical ideas as one of the skills. They also mentioned problem solving skills which they described as the ability to solve designed as well as real problems. For example, T_5 had this to say, "*I am aiming for skills on how to apply the knowledge learnt on real-world situations*". Multitasking was also another skill that emerged where students solve problems, communicating with others, while at the same time mastering math concepts.

4.4 Conclusion

Overall, the analysis of both the open-ended online questionnaire and the semi-structured interview revealed the same challenges that teachers face including, the challenge of designing authentic tasks for project-based learning that contains relevant content and fits the learner level, creating tasks that learners are willing to work on, and the issue of securing time and class group discussion. However, analysis of semi-structured interview revealed clear explanations on some challenges, for example on the issue of time, teachers clarified that they do not have enough time not only to plan and implement the tasks for project-based learning but also to reflect on the whole process to improve on the practice. Regarding the evaluation challenge, interviewed teachers pointed out that there is no clear and well-defined way to evaluate project-based

learning tasks. In addition, on the issue of learner group collaboration and class discussion challenges, interviewed teachers revealed that project-based learning approach usually leads to change of class discussions from mathematics to non-mathematics, making them fail to achieve the intended class objectives. Interview analysis also brought out a new challenge of learners' lack of knowledge where teachers pointed out that their students have difficulties in building researchable questions because they are not exposed to the approach from the lower grades. However, the analysis of online questionnaire also clarified two challenges which did not emerge from the interviews, these include, the extent of learner support challenge where teachers clarified that it is difficult for them to balance between teacher support and learner independence as well as the resource challenge where they mention the issue of lack of PCs on their learners.

When it comes to addressing the challenges, analysis of both the open-ended online questionnaire and the semi-structured interviews emphasize on the importance of incorporating project-based learning in the math curriculum or course of study at the beginning of the academic year to avoid unplanned or rashly planned implementation. They also agree on the importance of collaboration among teachers to share ideas, the importance of going through previous studies as solutions to the challenges. However, the questionnaire analysis clarified the importance of creating tasks for project-based learning in small scales that can be completed in a short period of time to address the time, student interest/motivation and evaluation challenges.

The following chapter is going to summarize the whole study and give recommendations and suggestions for further studies.

5.0 CHAPTER FIVE:
SUMMARY AND RECOMMENDATIONS

5.1 Introduction.

The purpose of this research was to explore the challenges and solutions perceived by high school mathematics teachers in practicing project-based learning in their classrooms. To achieve this, the research used two research questions to guide the exploration. Below are the research questions.

Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?

Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

The chapter is divided into five sections. The first section presents the summary of the findings based on the research questions, the second part includes the comparison of the findings to the existing literature, the third section provides recommendations for professional practice as well as study limitations and suggestions for future research. The fourth section includes the chapter conclusion, and the final section provides the researcher's self-reflection.

5.2 Summary of the research findings.

Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?

As a result of analyzing an open-ended online questionnaire and semi structured interview responses from high school mathematics teachers in Japan, this study revealed the challenges that teachers face in all the three stages of project-based learning implementation in their

mathematics classrooms which include, in the first stage of preparation and designing of project-based learning, they have difficulties in creating authentic tasks that connects students' daily lives and mathematics concepts, creating tasks that learners are interested in, and securing time. In the second stage of implementation processes, they have difficulties in managing student group collaboration, incorporating technology, managing time as well as understanding the extent to which they must support their students. Lastly, in the evaluation stage, they have challenges in developing authentic evaluation criteria that cater for all aspects of project-based learning and they also have difficulties in creating criteria to evaluate individual performance for students working in a group.

Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

Regarding overcoming the challenges of securing time, arousing student interest and that of evaluation, participant teachers mention the importance of creating mathematics project-based learning tasks in small scales that can be completed in a short time as one of the solutions to these challenges. The study also revealed that teachers perceived collaboration (with other math teachers, teachers from other subjects, experts in the field of mathematics education, and students themselves especially in designing clear evaluation description) as a chief way of overcoming their challenges. Reviewing of literature on previous studies on project-based learning in mathematics teaching and learning was also viewed as another way to solve some of the challenges encountered. However, we also noted that teachers do not have solutions to all the challenges they encounter especially in the implementation process stage, that's why they opt to give suggestions like the need for project-based learning to be a school-based approach and the

need for it to be included in the mathematics course of study as solutions to some of the challenges which is a cause for concern.

5.3 Similarities and Differences of the findings to the previous studies

This study found that respondent teachers perceived project-based learning to be time consuming especially during preparation and designing of mathematics tasks for project-based learning as well as in the implementation processes stage. This finding agrees with various research studies like that of Horpyniuk (2015), Mentezer et al. (2017), Yuen (2009), and Cherney (2008) who also found that teachers perceived that it takes more time and effort to plan, implement, and asses project-based learning activities. These research studies agreed that teachers have a difficult time incorporating project-based learning into the curriculum because its process is very time consuming. The argument is that successfully utilizing project-based learning in the classroom requires teachers to have large responsibilities of making sure that the project-based learning tasks that are being incorporated into their classrooms are connected to the curriculum appropriately in terms of content to be covered and learner level among others which requires great commitment on the part of teacher. However, this research finding on time as a challenge contradicts with other research studies like that of Marx, Blumefled, Krajick and Soloway (1997) who perceived that time is not a project-based learning challenge but rather a sign that the teacher is inexperienced in practicing the approach. This suggests that the more experienced the teacher is in practicing project-based learning, the less time it takes to prepare, design, implement and evaluate project-based learning activities.

The study also revealed that teachers have challenges in knowing how to support their learners and the extent to which that support must be taken to leaving room for learners to be free and overseeing their learning. This research finding corresponds with that of Mentezer, Zerniak and

Books (2017) who concluded that teachers do not understand what it entails to give learners sufficient autonomy when it comes to project-based learning implementation. Horpyniuk (2015) also noted that, for teachers, it is not easy for them to see their learners struggling and consistently get incorrect answers, this causes teachers to assist learners a little more than they should. In the same vein, Thomas (2000) also mentions that teachers have difficulty scaffolding learners' activities, sometimes giving them too much independence. The challenge here is of either giving learners excess support or inadequate support which either way violets the true purpose of project-based learning as a learning strategy from happening.

Respondent teachers also revealed that it is difficult to manage learner groups and to create a collaborative environment to ensure that all learners are actively involved and are learning from the project-based learning mathematics activities being done. This challenge was attributed to teachers' lack of skills needed to monitor and manage learners. The findings concurred with that of Kolodner et al. (2003) who concluded that teachers are overwhelmed by challenges like managing learner group, maintain the engagement of all learners and maintain the balance between the investigative aspect of project-based learning and its interpretation. According to Tamim and Grant (2013), teachers often lack the skills and confidence in creating collaborative environments for project-based learning.

Another teacher challenge that this study revealed is that of designing authentic mathematics tasks for project-based learning that connects learners' daily life and mathematics concepts. This finding is the same as that of Akinoghu (2008), Kart and Chad (1992), and Tamim and Grant (2013) who noted that teachers usually find it hard to choose topics for project-based learning, which should allow the integration of a range of disciplines, having sufficient potential for exploration and investigation, allowing for the opportunity for problem-solving, collaboration,

knowledge construction, and cover the prescribed curriculum. Snyder and Snynder (2008) attributed the challenge to teachers' inexperience in designing project-based learning activities.

The study also revealed that teachers have challenges in incorporating technology in their mathematics classrooms even though technology is perceived to be very essential in the implementation of project-based learning. They mentioned lack of resources particularly on the issue of PCs where they said some of their learners do not have PCs and the environment does not allow learners to freely use PCs in their mathematics classes. This implies that their mathematics classrooms set up does not promote the effective use of technology as a cognitive tool as well as an instructional aid in the teaching and learning of mathematics. This finding concurs with the research by Giri (2016) who later suggested that successful implementation of project-based learning in general requires spacious rooms with adequate resources, modern technologies, and trained as well as experienced teachers to guide the learners through the project-based learning tasks being investigated. However, according to Nyai et al. (2019), this challenge of lack of resources can be solved if teachers can develop project-based learning tasks according to the situation and modify tools and materials for project-based learning. This also agrees with Buck Institute of Education (2003) who also noted that projects can be done without technology.

Participant teachers of this study also revealed that coming up with mathematics tasks or assignments for project-based learning that learners are willing to work on or are interested in is another challenge for them. This finding concurs with that of Han, Yalvac, Capraro and Capraro (2015) who also found that teachers had difficulties in effectively implementing project-based learning with learners who are not academically ready. Participant teachers in their study indicated that learner's readiness was a crucial factor in implementing project-based learning.

Some previous studies like that of Han, Capraro and Capraro (2014) perceived project-based learning as an approach that is more effective when used on low achieving learners, however according to the study by Han, Yalvac, Capraro and Capraro (2015), low achieving learners lack familiarity on learner-driven learning environment like that of project-based learning leading to learners becoming unwilling or not interested in project-based learning activities which is a major challenge for teachers.

As project-based learning is a multifaceted approach, respondent teachers for this study find it difficult to come up with evaluation criteria that can cater for all aspects. They find it difficult to develop authentic evaluation to understand what their learners have learnt. They also mentioned that creating standard criteria to evaluate individual performance and group performance in their project-based learning mathematics classrooms is always a challenge. This finding agrees with Amissah (2019) who concluded that, in project-based learning, learners are mostly engaged in groups to work, and there is a range of intertwined activities to work on, thus assessment requires combing the evaluation of the outcome of the whole process and reviewing the quality of individual participation and that of the whole group which is often a challenge. Frank and Barzili (2004) and Ward and Lee (2000) also highlighted that evaluating group work and process-oriented skills proved to be challenging. This is consistent with Lee, Blackwell, Drack and Moran (2014) who also mentioned that assessment remains teachers' area of great struggle in project-based implementation in terms of reaching agreement on what to assess, how to assess and whether teachers have skills and the know-how to develop assessment tools aligning project-based learning goals. Thus, what participant teachers perceived about project-based learning evaluation is very much like what several other previous research said about project-based learning evaluation.

In this study, collaboration emerged to be the common way in which teachers address all the difficulties they face in all the three stages of project-based learning implementation, that is the planning and designing stage, the implementation process stage, and the evaluation stage. This is consistent with Mentzer et al. (2017) and Kokotsaki et al. (2016) who describe collaboration as essential in project-based learning. It also agrees with Aksela-Haatainen (2019) who suggested that to address all the challenges in project-based learning, there is need to develop continuous and collaborative models for teacher training for them to get used to the approach. The argument is that teachers have a better chance of success when implementing project-based learning, if they have others to collaborate with and share ideas, while addressing challenges they face (Gay, 2022).

More so, respondent teachers pointed out going through previous studies as a way of solving the challenges of designing authentic mathematics tasks. The idea agrees with researchers like Nyai (2018) who said teachers should learn the theory of project-based learning from various sources to equip themselves with the capacity to design quality project-based learning tasks.

5.4 Recommendations

The following recommendations are hereby made:

There is need to provide teachers with sample examples of mathematics tasks for project-based learning that are designed according to specific learner levels, specifying the exact skills expected and with a clearly defined evaluation criterion for them to refer when designing their own tasks.

Collaboration among mathematics teachers within the same school on how to practice project-based learning should be encouraged. There is a need for regular mathematics teacher support on

how to apply project-based learning through in-service training, regular networking, and other professional development opportunities on project-based learning. Thus, we recommend the development of long term, continuous and collaborative models for teacher training. We also recommend the provision of project-based learning experiences in teacher education programs rather than waiting for staff development sessions only.

Textbook writers and publishers should consider incorporating project-based learning and its examples in their write-ups for teachers to have access to reviewed and tested models for project-based learning for the benefit of both teachers and learners. We also recommend schools to construct mathematics laboratories where learners will have free access to computer devices to use when practicing project-based learning.

Project-based learning implementation across the entire curriculum should be encouraged to promote the culture of using project-based learning among schools. There is also a need for high school mathematics curriculum to be originally designed to be taught using a project-based learning approach. Learner support and guidance especially on the issue of self-directed learning, time management as well as the proper and correct use of technology should be encouraged. We also recommend that project-based learning should be taught together with other 21st century approaches like inquiry-based learning and problem-based learning.

5.5 Limitations of the study.

The study was limited to 25 high school mathematics teachers in Hiroshima prefecture, Japan who managed to respond to the questionnaire and 7 teachers who participated in the semi-structured interviews, therefore the results may not be generalized. In this study, data were collected by online open-ended questionnaire and semi-structured interviews. Other data sources like observation and document analysis which could have been better data sources for this

research were not used. Study length might also be a limitation because complex issues like that of project-based learning may require more time to carry out some continuous investigation since results that may come later might be more valuable. There is also a possibility that respondent teachers were giving answers based on what they think was required not necessarily based on their experiences and perceptions. Lastly, just like any other qualitative research, data analysis is subject to researcher bias.

5.6 Suggestions for further studies

In view of the limitations of this study, suggestions are made for further studies.

It may be a worthwhile effort for future researchers to engage in a longitudinal study on the challenges and solutions perceived by high school mathematics teachers in practicing project-based learning. The study could therefore be replicated in other prefectures to further give credence to the generalizability of the findings of this study.

It would also be valuable to conduct a study on what learners perceived to be their challenges when practicing project-based learning in the mathematics classroom and how they also try to overcome them. Viewing it from both the teachers' side and the students' side will help us to have a clear understanding of the approach in the teaching and learning of mathematics.

5.7 Conclusion

Project-based learning proved to be a mathematics teaching and learning approach that demands a lot from the teacher. The demands include a lot of time required to create meaningful project-based learning tasks that are leaner-centered, that make authentic connection between mathematics and real-world problems, that are interdisciplinary, and that are collaborative. Despite all the difficulties that teachers perceived they face including designing of mathematics

project-based learning tasks, challenges in the implementation process phase and that of evaluation of project-based learning tasks, they professed to have some solutions to the challenges. Thus, the results of this research have a great potential to guide on the design of a mathematics teacher professional development plan for the successful implementation of project-based learning in math classrooms.

5.8 Self-reflection

Conducting this research, especially during the covid-19 pandemic period helped me to learn and improve my Information and Technology (IT) skills. For example, I learned how to analyze qualitative data using excel, how to create logical google forms among many other skills. Writing this thesis also helped me to develop my research skills. I learned more on how to find authentic and necessary literature from various sources, how to professionally collect data from participants, how to critically analyze the data and present it to the public. More importantly, carrying out this study also helped me to realize and understand the need to involve teachers when designing a curriculum since they are the ones to work with the learners and know best what happens in the classroom including their challenges and their learners' challenges and possible ways to overcome the challenges. Involving teachers will make the curriculum easily implementable resulting in improving the quality of any educational system.

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APPENDIX 1

[PARTICIPANT TEACHER] Informed Consent

こんにちは!

My name is Chomunorwira Tafara, a Mathematics Education student at Hiroshima University. I am kindly requesting you to participate in the research entitled **CHALLENGES AND SOLUTIONS PERCEIVED BY HIGH SCHOOL MATHEMATICS TEACHERS IN PRACTICING PROJECTING PROJECT-BASED LEARNING IN THEIR CLASSROMS** by responding to the questionnaire that will be send to you after your consent.

If you decide to participate in this research, you will be mainly asked questions to give answers to the two main research questions:

Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?

Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

The potential benefit for your participation in this study is that it gives you the opportunity to contribute towards the development of the teaching and learning of mathematics through a project-based learning approach.

Your decision to participate in this research is completely voluntary. This implies that you may not agree to participate or withdraw your participation at any time with entirely no penalty. Moreover, be assured of your confidentiality, no personal information will be included in the questionnaires, its analysis, and the study results.

If you have any questions or if you need any information, please feel free to contact the following:

Research Supervisor: Professor Koyama Masataka; mkoyama@hiroshima-u.ac.jp

The researcher: Chomunorwira Tafara; tchomus@gmail.com

These contact details will be available for you to ask for any information with regards to the research even after its completion.

You are also free to contact the Research Ethics Review Board, Graduate School of Humanities and Social Sciences, Hiroshima University at ed-ken-zai@office.hiroshima-u.ac.jp for any information that you may not want the Study Supervisor and the Researcher to know about and there is no disadvantage in any way in doing so.

I read through and understood this consent form and I voluntarily agree to participate in responding to the research questionnaires.

NAME OF PARTICIPANT……

SIGNATURE…….DATE……

先生へ

質問紙調査についての十分な説明に基づく同意書（インフォームドコンセント）

私は Chomunorwira Tafara（チョムノウイラ　タファラ）と申します。私は、広島大学大学院人間社会科学研究科数学教育学専攻の院生です。現在、「数学授業でプロジェクトベース学習を実践する際の教師にとっての難題」について研究しています。本研究での**「プロジェクトベース学習」**は、**「主として現実場面の問題を数学的に解決する課題学習」**を意味しています。つきましては、この質問紙調査についての説明を読んで同意し、インターネット形式の質問紙調査に参加してくださいますようお願いします。

本質問紙調査へご参加くださる場合、主として次の２つの質問に回答していただきます。

１．先生が数学授業でプロジェクトベース学習を実践する際に直面する課題は何か。

・学習者にとって適切なプロジェクトをいかにデザインするか。

・プロジェクトベース学習を用いた学習指導の過程をいかに組織化するか。

２．先生はこれらの直面する課題にいかに対処するか、その解決策は何か。

先生が本質問紙調査へ参加するかどうかの判断は任意です。本調査への参加・不参加で先生が不利益を被ることは一切ありません。また、本質問紙調査への回答、その分析及び結果の公表において、先生の個人情報は保護されることを約束します。

本質問紙調査について不明な点があれば、次の連絡先に遠慮なくお問い合わせください。

指導教員：小山正孝（広島大学大学院教授） mkoyama@hiroshima-u.ac.jp

調査者：Chomunorwira Tafara tchomus@gmail.com

これらの問い合わせ先は、本質問紙調査の終了後も対応できます。

もし本質問紙調査の調査者や指導教員に知られたくない質問等がありましたら、次の連絡先に遠慮なくお問い合わせください。

広島大学大学院人間社会科学研究科・研究倫理審査委員会

Ｅメールアドレス ed-ken-zai@office.hiroshima-u.ac.jp

研究倫理審査委員会承認（申請番号 HR-ES-000344、2022 年 7 月 14 日承認）

質問紙調査の URL

次の URL から質問紙調査へ回答してください。

Ctrl キーを押しながらクリックしてリンク先を表示してください。

https://forms.gle/mhocmUnPnA9MXFjX7

質問紙調査に参加することについての同意書

本質問紙調査への参加に同意いただける場合は、以下の四角枠内の下線部に入力し、そのファイルをメールに添付して、次の調査者と指導教員宛に送信してください。

調査者：Chomunorwira Tafara tchomus@gmail.com

指導教員：小山正孝（広島大学大学院教授）mkoyama@hiroshima-u.ac.jp

私はこの質問紙調査についての十分な説明に基づく同意書を読んでその内容を理解し、本質問紙調査に参加することに同意します。

氏　名　……

メールアドレス　……

年月日　……年……月……日

APPENDIX 2

[Data Collection approved and authorized form]

(Research Ethics Review Board, Graduate School of Humanities and Social Sciences, Hiroshima University)

Application Number: HR-ES-000344

審査結果通知書

通知年月日

2022 年 7 月 14 日

Chomunorwira Tafara　殿

広島大学大学院人間社会科学研究科長

小林　信一

研究タイトル

Teachers' challenges in implementing project-based learning in mathematics classrooms.

申請年月日

2022 年 7 月 1 日

判定結果(Judgment results)

承認 (Approval)

判定理由又は勧告

別紙参照

APPENDIX 3

TEACHER QUESTIONNAIRE

Dear Colleague

Colleague, I am kindly requesting you to participate in the mathematics education research entitled "***Teachers' challenges in implementing project-based learning in mathematics classrooms***" by answering the questions attached below. In the context of this research, project-based learning refers to task-based learning [**TBL**]. I am interested in understanding the challenges you face when implementing project-based learning in your mathematics classrooms and how you respond to these challenges. From your responses, the researcher is hoping to come up with a detailed description of how project-based learning can be successfully implemented in mathematics classes, addressing the challenges in using the approach to minimize their negative impact.

You may be assured of complete confidentiality. No personal identifying information will be included in the questionnaire, its analysis and in the research results.

QUESTIONS

1. What is your gender? [**male, female]**
2. What is your school? [**lower secondary school, upper secondary school, secondary school]**
3. How long have you been teaching mathematics? **[0 to 5 years,5 to 15 years,15 and above]**
4. Where do you get the appropriate knowledge that guides you in teaching using a project-based learning approach?
5. How often do you use project-based learning in your mathematics class a year? **[often, sometimes, a few]**
6. What are the challenges of using project-based learning?
    i. What challenges do you face when preparing and designing project-based learning (**TBL**) tasks?
    ii. What challenges do you face in the implementation processes?
    iii. What challenges do you face in the assessment stage?

7. Considering the challenges you mentioned above, how do you go about trying to overcome these challenges?
    i. What are the solutions to the challenges you face when preparing and designing project-based leaning tasks?
    ii. What are the possible solutions to the challenges you face in the implementation process?
    iii. What are the solutions to the challenges you face in the assessment phase?
8. When facing challenges in the implementation of project-based learning, whom do you consult? **[ministry, colleagues, literature, curriculum experts]**
9. Do you think that project-based learning is a good approach in teaching mathematical concepts? Please explain your answer.
10. Which area/s do you think needs improvement in the teaching and learning using project-based learning approach?

Thank you for your participation. Your input will be valuable for this research and will help to improve the teaching and learning of mathematics using project-based learning approach.

質問紙　数学科の先生へ

先生には、私が取り組んでいる「数学授業でプロジェクトベース学習を実践する際の教師にとっての難題」というタイトルの数学教育研究に、ご参加いただき、以下の質問にお答えくださいますようお願いします。本研究での**「プロジェクトベース学習」**は、**「現実場面の問題を数学的に解決する課題学習」**を意味しています。私は、数学授業でプロジェクトベース学習を実践する際に教師が直面する難題と、それらにどのように対処するかを理解することに興味があります。

私は、この質問紙への回答から、プロジェクトベース学習が数学授業でどのようにしたらうまく実践できるかについての詳細な説明を考え、その負の影響を最小限に抑えてプロジェクトベース学習のアプローチを使用する際の難題に対処したいと思っています。

あなたの機密性は完全に保証されます。この質問紙への回答やその分析、研究結果には個人を特定できる情報は一切含まれません。以下の質問に回答してください。

質問

1. あなたの性別は何ですか?［**男性、女性**］

2. あなたの勤務校は何ですか?［**中学校、高等学校、中等教育学校**］

3. あなたは数学を教えて何年になりますか?［**0~5 年未満、5~15 年未満、15 年以上**］

4. あなたはプロジェクトベース学習のアプローチを使用して教える際の指針となる適切な知識はどこで得ますか?

5. あなたは 1 年間の数学授業でどのくらいの頻度でプロジェクトベース学習を行いますか?［**たびたび、ときどき、たまに**］

6. あなたがプロジェクトベース学習を行う際の難題は何ですか?

i. プロジェクトベース学習で用いる課題を準備したり設計したりする際に直面する難題は何ですか?
ii. プロジェクトベース学習を実施する際に直面する難題は何ですか?
iii. プロジェクトベース学習の評価をする段階で直面する難題は何ですか?

7. 上で答えた難題について、あなたはこれらの難題をどのように克服していこうとしますか?

i. プロジェクトベース学習の準備と設計段階で直面する難題に対する解決策は何ですか?
ii. プロジェクトベース学習の実施過程で直面する難題に対して可能な解決策は何ですか?
iii. プロジェクトベース学習の評価段階で直面する難題に対する解決策は何ですか?

8. プロジェクトベース学習の実践において難題に直面したとき、あなたは誰に相談しますか?［**行政、同僚、文献、カリキュラムの専門家**］

9. プロジェクトベース学習は数学的概念を指導する上で良いアプローチだと思いますか? あなたの答えを説明してください。

10. あなたがプロジェクトベース学習のアプローチを使用して学習指導を改善する必要があると考える数学科の領域はどれですか?

この質問紙へ回答していただきありがとうございました。あなたの回答は、この研究にとって大変貴重なもので、プロジェクトベース学習のアプローチを使用して数学の学習指導を改善するのに役立ちます。

APPENDIX 4

Interview protocol

Hello

Thank you for agreeing to participate in this study.

The purpose of this research is to gain a deeper understanding of how high school mathematics teachers perceive project-based learning (**primarily task-based learning that mathematically solves real-world problems**) and how they practice it in the classroom. That's it. Also included are the difficulties high school math teachers encounter and how they are resolved.

This research is guided by two main questions:

I. *How do high school mathematics teachers understand project-based learning (mainly task learning that mathematically solves real-world problems)?*
II. *How do high school mathematics teachers decide or choose to practice project-based learning (primarily task-based learning that mathematically solves real-world problems)?*

This interview consists of a series of in-depth questions that will help me to gather the data l need for this research. I will also record our interview and take notes to ensure data accuracy.

Any questions before we start?

First, l will ask you for the basic information l need to describe the survey sample.

Q1. What kind of school do you teach?

Q2. How long have you been teaching?

Next, I would like to ask you how you understand project-based learning.

Q3. What does project-based learning mean to you?

Q4. Can you give an example of a project-based learning assignment you have implemented?

Q5. Please explain how you present project-based learning tasks to your students and how you proceed.

Q6. What challenges do you face in implementing project-based learning?

Q7. How do you solve the challenge?

Next, l will ask how you decide or choose to practice project-based learning.

Q8. When do you choose to practice project-based learning tasks with your students?

Q9. What skills are you aiming for?

Q10. Are there any specific topics in your math study course that made you choose project-based learning? Give an example.

Q11. Is it mandatory for you to include project-based learning in your annual mathematics teaching plan?

Q12. How would you describe the success of project-based learning?

Q13. What challenges do you face in choosing to practice project-based learning?

Q14. How do you solve the problems?

インタビュープロトコル

こんにちは

この研究への参加を受け入れていただき、誠にありがとうございます。

この研究の目的は、高校の数学教師がプロジェクト型学習（主として現実場面の問題を数学的に解決する課題学習）をどのように認識し、教室でどのように実践しているかをより深く理解することです。また、高校の数学教師が遭遇する困難と、それらをどのように解決するかも含まれています。

この研究は、次の２つの主要な問いによって導かれます。

I. 高校の数学教師は、プロジェクト型学習（主として現実場面の問題を数学的に解決する課題学習）をどのように理解しているか。

II. 高校の数学教師は、プロジェクト型学習（主として現実場面の問題を数学的に解決する課題学習）を実践することをどのように決定または選択するか。

このインタビューは、調査に必要なデータを収集するのに役立つ一連の詳細な質問で構成されます。データの正確さを期すためにインタビューを記録し、メモも取ります。

始める前に質問はありますか？

まず、調査のサンプルを説明するのに必要なあなたの基本情報をお尋ねします。

Q１．あなたの学校の種類は？

Q２．あなたの教職年数は？

次に、あなたがプロジェクト型学習をどのように理解しているかお尋ねします。

Q３．あなたにとって、プロジェクト型学習は何を意味しますか?

Q４．あなたが実施したプロジェクト型学習の課題の例を教えてください。

Q５．あなたは生徒にプロジェクト型学習の課題をどのように提示し、どのように進めているかを説明してください.

Q６．あなたがプロジェクト型学習を実施する際に直面する難題は何ですか?

Q７．あなたはその難題をどのようにして解決しますか?

次に、あなたがプロジェクト型学習を実践することをどのように決定または選択するかお尋ねします。

Q８．あなたはプロジェクト型学習の課題を生徒に実践することをいつ選択しますか?

Q９．あなたが目指すスキルは？

Ｑ１０．あなたがプロジェクト型学習を選択するきっかけとなった、数学学習コースの特定のトピックはありますか? 例を挙げてください。

Ｑ１１．あなたは、数学の年間指導計画にプロジェクト型学習を含めることは必須ですか?

Ｑ１２．あなたは、プロジェクト型学習の成功をどのように説明しますか?

Ｑ１３．あなたがプロジェクト型学習を実践することを選択する際に直面する難題は何ですか?

Ｑ１４．あなたはその難題をどのように解決しますか？