

Exploring Challenges and Solutions Perceived by High School Mathematics Teachers in Practicing Project-Based Learning: Analysis of an Open-Ended Online Questionnaire in Japan

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Abstract: The purpose of this study was to clarify the challenges faced by junior and senior high school mathematics teachers in practicing project-based learning (mainly task-based learning that mathematically solves real-world problems) in the classroom and their solutions to the challenges. Therefore, with the approval of the Research Ethics Review Committee, we conducted an open-ended online questionnaire survey (July 15 to August 31, 2022) of high school mathematics teachers in Japan about the issues they face and the solutions in the three stages of project-based learning: the design and preparation stage of the learning tasks to be handled in project-based learning, the implementation process, and the evaluation stage. In this paper, we analyzed the data from 25 high school mathematics teachers who agreed and responded to the purpose of this survey using a qualitative content analysis method. As a result, it was clarified that mathematics teachers face six challenges when practicing project-based learning in the classroom: designing authentic mathematical tasks, arousing students' interest, the degree of learning support for students, collaborative activities in groups, securing time, and evaluating learning outcomes. Second, it was clarified that mathematics teachers are trying to solve these problems by creating project-based learning tasks in small scale and for a short time, collaborating with mathematics teachers at the same school, collaborating with teachers of other subjects at the same school, collaborating with students, collaborating with experts in mathematics education, and investigating previous studies on project-based learning. Finally, based on these research results, we suggest research issues that need to be addressed in future research on the practice of project-based learning in mathematics education.

Keywords: Project-Based Learning, Teachers' Challenges, Teachers' Solutions, Mathematics Classroom

1. Introduction

Teacher-centered mathematics teaching and learning practices are found to be unable to guarantee the much needed 21st century skills in learners. This leads to current research in mathematics education to focus more on learner-centered teaching approaches like project-based learning which engage learners in real-life problem-solving context. The engagement of learners in real-life issues and collaborative approach to teaching and learning of mathematics has proved to be essential for the development

of a variety of skills such as critical thinking, creativity, collaboration among others [3]. Several studies in project-based learning classes addresses different issues including the effectiveness of project-based learning as a teaching and learning method, teachers and students' perceptions about project-based learning, the role of the teacher and that of the student, and advantages of project-based learning in math classes among many other issues.

However, there is little research on the challenges that teachers face as they implement the project-based learning approach particularly in mathematics classroom context. To

fill in this gap in literature, this study aims to explore the challenges that teachers face when implementing project-based learning in their mathematics classes and ways in which they try to overcome these challenges. Research questions of this study are.

- 1) What are mathematics teachers' challenges in practicing project-based learning?
- 2) What are the teachers' solutions to the challenges in implementing project-based learning?

The results of this study are expected to contribute to the body of literature by providing knowledge for 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.

2. Theoretical Background

2.1. Project-Based Learning

Project-based learning is perceived to reflect constructivism in learning theory which most researchers say to be the modern face of learning paradigms and forms the basis for self-directed and self-regulated learning [16]. Under constructivism theory, learning is a process of knowledge construction based on experience often described as authentic learning activity [7] and this is typical of project-based learning.

Different researchers define project-based learning differently. However, the common view is that project-based learning is a teaching and learning model that engages learners in problem-solving activities and provides students with the opportunity to work independently to construct their own learning and at the end produce valuable and realistic result [2]. The main idea in project-based learning centered on developing tasks or assignments in which learners plan, implement, and evaluate projects that have real world implication beyond the classroom. In project-based learning, learners are required to take an active role in understanding concepts and context, and it allows learners to develop the skills which foster curiosity and hunger for knowledge [1].

In mathematics classroom context, project-based learning enables learners to build mathematical knowledge solving mathematical problems and solve problems that arise in mathematics and other context [13]. The approach also enables learners to develop better mathematical skills, develop a deeper understanding of mathematical concepts, making mathematics relevant and engaging to learners. Thus, project-based learning allows learners to develop their own mathematical ideas and understanding, connecting their mathematical experiences to the real world [10].

2.2. Literature Review on the Successful Project-Based Learning in Mathematics Classrooms

This literature review focuses on the success stories of project-based learning in mathematics teaching and learning

context.

One of the well-known, successful, and significant studies of project-based learning in mathematics is that of Boaler in the late 1990s as cited [15]. In her longitudinal three-year study, Boaler wanted to compare and access the students' achievement, attitude, and capabilities in mathematics from two different schools taught in two different methods of instruction that is traditional (passive learning where learners just sit and take notes and work on assignments while the teacher dictates the learning) against project-based learning. To ensure study reliability, the researcher made sure that students 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, students taught using project-based learning approach performed better than those exposed to the traditional instructions. That was evidence that students 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 students 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 students from the project-based learning instructed school regarded mathematics as an interesting and explorable subject.

Another study [4] investigated how science, technology, engineering, and mathematics (STEM) project-based learning affect high-need students 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 students, [5] explored the relationship between project-based learning activities based on STEM education and the development of students' mathematics ability, the results showed that project-based learning promotes significant improvement in learners.

A study [6] investigated the benefits of project-based learning on secondary mathematics students' 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 students were intrinsically motivated and displayed higher critical thinking abilities and appreciate peer learning.

According to the research [8], Ozdemir carried out a study which focused on the effects of project-based learning on the students' attitudes towards and success in geometry. In this study, students' 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 students who lacked attention and were easily distracted were now able to focus easier with the use of project-based learning.

Another significant study of project-based learning in mathematics is that of the research [14]. 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 students stay in the project-based learning program.

Finally, it is a literature review paper analysis of nine research studies on project-based learning/problem-based learning in K-8 Mathematics and Science Education [12]. The review noted the following. (a) Students in the project-based learning groups outperformed students 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 that 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 students in developing reasoning and application as students develop in understanding math/science concepts. (c) The analysis also found that students 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 instruction.

Thus, research findings about the implementation of project-based learning in mathematics showed that students increase math concepts understanding, they improve in problem-solving abilities, they improve in collaborative skills and having a positive attitude towards mathematics [9].

3. Methodology

3.1. Research Questions of This Study

Given the consistence in the previous studies about the advantages of implementing project-based learning in mathematics classes, this left us with the need to investigate on the challenges that teachers perceive they face when implementing the approach and their possible solutions to provide mathematics project-based learning educators in general with answers to common challenges associated with implementing project-based learning approach. Therefore, research questions of this study are as follows.

- 1) Research Question (1): What are mathematics teachers' challenges in practicing project-based learning?
- 2) Research Question (2): What are the teachers' solutions to the challenges in implementing project-based learning?

3.2. Open-Ended Online Questionnaire and Participant Selection

The purpose of this study is to explore the challenges that

teachers perceive they face when implementing project-based learning approach in their mathematics classes and how they try to overcome the challenges. To get maximum responses from the participant teachers, questions about the challenges that teachers face were split into three categories: Challenges in the task designing and preparation stage, in the implementation process phase, and those in the evaluation stage. Data collection was approved and authorized by the Research Ethics Review Board at the Graduate School of Humanities and Social Sciences, Hiroshima University [Application Number: HR-ES-000344]. Data was collected through an open-ended online questionnaire which was administered to high school mathematics teachers in Japan from 15 July to 31 August 2022. The participant teachers were selected according to a purposeful sampling method. They had to be high school mathematics teachers with project-based learning teaching experience, and they were willing to participate in this study. Before responding to the open-ended online questionnaire, teachers were given an explanation that for this study, project-based learning refers to task-based learning that mathematically solve problems in real situations as interpreted in Japan.

- 1) The open-ended online questionnaire asked the participant teachers to give answers to the following questions in Japanese:
 - i. What are the challenges in practicing project-based learning?
 - ii. What are the challenges in preparing and designing tasks for project-based learning?
 - iii. What are the challenges in the project-based learning implementation process stage?
 - iv. 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?

3.3. Data 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. Data from the participant teachers' responses were analyzed using qualitative content analysis as prescribed by Yildirim, A. and Simsek, H. [17] who state that the basic process in content analysis is to gather similar data within the framework of certain concepts and themes and to interpret them by shaping them in a way that the reader can understand. Thus, the data was conceptualized first and then

themes that explain the data were determined. Exemplified quotations from the teachers' responses were used in the presentation of the identified themes.

4. Results and Discussion

4.1. Question (1): What Are the Challenges in Practicing Project-Based Learning

i. *What are the challenges in preparing and designing tasks for project-based learning?*

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: *creating 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 students have already learned or are currently learning"*. Teachers find it difficult to organize real world student mathematics activities that enable students 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 students 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 students want to solve".

"Searching for topics that students 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 students. 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 students 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.

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 student support, time availability, student group collaboration, and resources/technology*.

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

One teacher had this to say, *"Drawing a line between how far the teacher guides students and how far the students are allowed to be free. This is the most difficult thing"*.

Another teacher also explained, *"When students 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 students 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' lack 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 Student 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 students' 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 student groups and to create a collaborative environment to ensure that all students 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 students.

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 students do not have PCs..."*.

"There is no environment in which students can freely use PCs in mathematics classes".

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

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. Student 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 students 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 students, as one of the respondents explained, *"Depending on the problem, the evaluation may be unstable, because students 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 students' 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 student..., I wonder if it's okay to give the same evaluation to those who depend on the opinion of one student 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. Question (2): 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 student'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, students' 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.

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”*.

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 students when creating evaluation criteria. For example, one teacher explained, *“Create a rubric with your students 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 students, 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 the authors [10,

11] 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.

5. Conclusion and Recommendations

As a results of analyzing an open-ended online questionnaire 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 time availability. 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.

This study also revealed how teachers overcome these challenges chief among them being able to create project-based learning tasks in small scale and for a short time, 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) and reviewing past literature on project-based learning. 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. Knowledge about these challenges and their solutions will provide teachers with common answers to common problems in practicing project-based learning in mathematics classrooms. Thus, promoting successful implementation of the approach in mathematics classes and maximize on the gains that the approach brings about.

Even though it's quite impressive that this study revealed the challenges that teachers face when implementing project-based learning in their mathematics classrooms and how they overcome the challenges, facing such several challenges might make the approach unfavorable for many teachers to want to implement it since it might require a lot of effort for teachers to have the experience and become fully comfortable with the approach. As a result, we recommend

the need for future research to investigate ways to motivate and encourage mathematics teachers to implement project-based learning in their classrooms. We also recommend further studies to give examples when they do research on project-based learning in mathematics classroom context, since it helps teachers with knowledge and ideas when dealing with the approach. Lastly, there is also a need for researchers to explore project-based learning challenges from the student standpoint. 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.

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