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Research Article

PROJECT-BASED LEARNING IN THE CONTEXT OF MATHEMATICS TEACHING AND LEARNING: TEACHER STANDPOINT

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Abstract

For real mathematics learning to take place, teachers must identify, develop, and implement strategies that are effective in a social context. Teaching must be centered on teaching and learning approaches that promote high content retention and promote creativity in learners such as project-based learning. In this literature review, the researcher uses various sources such as articles, journals and publications that are relevant to the topic to define project-based learning in the context of mathematics teaching and learning. The researcher also reviews how mathematics teachers perceive project-based learning, giving an example of a project-based learning task in mathematics in senior high school grade. The paper then discusses the role of the teacher in project-based learning steps. The paper concludes with an explanation about the contributions of this review to the general body of mathematics education.

Keywords: Project-based learning, Mathematics teaching and learning, 21st century skills.

INTRODUCTION

Project-based learning in mathematics is a teaching and learning approach that brings down the abstract mathematical concepts to the learners' level of concrete understanding by inciting learners to actively participate in the learning processes (Savery, 2006). Intel corporation (2007) postulates that given an opportunity to learn using project-based learning, learners become motivated and directly involved in the learning process and this leads to academic gains. Project-based learning is designed around student centeredness (Harris and Katz, 2001) that allows each learner to draw from their previous knowledge, and to develop new knowledge. Project-based learning as an instructional approach in mathematics classroom focuses on including problems involving the learners' problem-solving, decision making and investigative skills. It supports the notion that learners construct learning for themselves through a driving question that encourages them to discover central concepts and principles of a subject through hands on learning, thus project-based learning fuse knowing and doing (Markham, 2011). The focus of project-based learning is to allow learners to develop their own mathematical ideas and understanding, connecting their mathematical experiences to the real world. Successful implementation of project-based learning leads to students being critical thinkers, connecting real world problems to mathematics classroom context and motivate, encourage learners to apply new knowledge in a problem-solving context. The approach also helps learners to transfer their mathematical skills to other disciplines (NCTM, 2000). Uyangor (2012) cement the idea by saying project-based learning allows learners to explore learning processes, discover new ideas through creative processes, develop high level of thinking through self-discovery. From the above definitions and descriptions of project-based learning in mathematics classroom context, it can be concluded that when learners learn using this approach, they have an opportunity to develop better mathematical skills, and develop a deeper understanding of mathematical concepts (Artzt and Armour-Thomas, 2008). This creates an environment where learners participate actively and are helped to reflect on what they learn. Project-based learning proved to be a learning model in mathematics that enables learners to provide solutions to problems that occur through an innovative learning model. Thus, the use of project-based learning makes mathematics relevant and engaging to learners.

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METHODS

This review used google scholar and academic search complete to identify articles and studies addressing project-based learning in mathematics classroom. Out of the searched articles, only those addressing project-based learning in mathematics classrooms from the teacher standpoint were included. The articles were mainly analyzed for teachers' definition of project-based learning in mathematics classroom context, teacher perception of project-based learning, project-based learning math tasks and teacher role in a project-based learning class.

Teachers' perceptions of project-based learning

Research has shown that teachers perceive project-based learning as a strategy that involves students in doing the work by themselves and providing more space and freedom for self-learning. Project-based learning provides learners with opportunities to do the work by themselves, which helps them get involved in their own learning. Teacher researchers emphasize the importance of hands-on approach to content (Holm, 2011) and learning by doing in project-based learning, which results in a deeper learning and understanding (Thomas, 2000). Teachers perceive project-based learning as an approach that engages learners and takes into consideration their areas of interest. Regarding this issue Krajcik and Blumenfeld (2006) argued that project-based learning became a great tool to engage learners and raise their motivation.

Teachers are key figures in motivating students and creating a pleasant collaborative atmosphere in the classroom (Yam and Rossini, 2010). Teachers perceive that project-based learning provides learners with the opportunity to practice theoretical knowledge gained during lessons and fully understand mathematical concepts. Literature supports this understanding, confirming that project-based learning provides learners with opportunities to deeply investigate topics (Bell, 2010). Research has shown that teachers perceive project-based learning as an approach that helps learners to realize the much needed 21st century competences such as critical thinking, creativity, effective communication, and collaboration which are critically important for student success. This agrees with Bell (2010) who described project-based learning as an approach that has a great potential to enhance 21st century skills and engages learners in real-world tasks. Capraro and Slough (2008) also argued that project-based learning leads to additional outcomes including thinking skills, collaboration, communication, and problem solving.

The figure below summarizes the 21st century skills which teachers perceive that project-based learning brings about to learners if properly implemented.

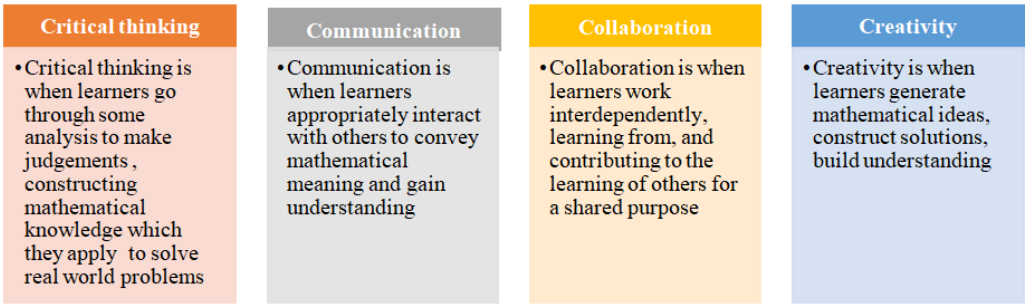

Figure 1. A summary of skills gained from project-based learning implementation

Thus, teachers perceived project-based learning as a strategy to help learners get involved and motivated. Project-based learning appears to be focused on self-learning, providing learners with more freedom and space, which makes them more responsible for the work they are doing and helps them to understand mathematics topics deeper. Teachers also perceive that their ability to properly execute project-based learning in practice determines the effectiveness of the approach to teaching and learning of mathematics. Scholars like (Han, Yalvac, Capraro 2015; Kokotsaki, Menzies, Wiggins 2016) concluded that how teachers implement project-based learning greatly affects learners' content understanding and skill development. Thus, teachers perceive that their understanding and implementation of project-based learning has a great effect on students' mathematical understanding and skill development.

Example of a project-based learning task

Literature review found that there are a wide variety of project-based learning tasks that mathematics teachers can use in their classes. One of them is that they can look for suitable project tasks that engage learners in real life problem solving where they solve a problem in their community or solve a designed problem. Mathematics teachers may also present a scenario for the project and have learners take the role of a person at workplace (NCTM, 2000). The following is an example of a designed project-based learning task in mathematics on differentiation application.

Differentiation Application in senior high school grade

Concepts/skills:

Critical thinking, Calculation, Modelling the situation mathematically, Creativity, Knowledge and understanding (Zimsec, 2017)

Dimensions:

- Develop an appreciation of the applicability, creativity, and power of Pure Mathematics in solving a broad range of Mathematical problems.
- Understand the nature of Pure Math and its relationship to other branches of Mathematics.
- Develop the abilities to reason logically and learn independently.

Objectives:

- Construct and use appropriate mathematical models for a given situation.
- Use appropriate formulae, algorithms, and strategies to solve routine and non-routine problems in Pure Mathematics
- Apply Mathematical reasoning and communicate Mathematical ideas clearly.

Task content:

Learners will calculate the areas of the different plane shapes given and then compare their findings.
Learners are to identify a suitable area that may give maximum utilization of land.
Learners are to use a specific value of Q of their own choice. (Q length of fence in meters)

Background for learners:

At a school the agriculture department wants to raise funds by growing vegetables. The department has a bundle of mesh wire of length Q meters to be used to fence the garden. They would want to use the maximum area available for the Qmeters of wire available. The department thinks of three plans:

- PLAN A: To fence an area which is circular in shape.
- PLAN B: To fence an area which is rectangular in shape.
- PLAN C: To fence an area which is square shape.

The task

To help the department with advice on the best plan to use, do the following items using your knowledge of calculus or otherwise, to determine the plan which gives the biggest area.

Table 1. Comparison of answers from the three plans

Shape Plan	Perimeter (Q)	Dimensions	Maximum area	Number of standards beds	Number of perimeter poles
Plan A					
Plan B					
Plan C					

Table 2. Achievement standards

OBEJECTIVE	*26-30*	*21-25*	*16-20*	*10-15*	*0-9*
Construct and use appropriate mathematical models for the given situation. calculation of the areas of the 3different plans compare the areas and determine the maximum one	Excellent use of length of wire and correct calculations of the areas of all the 3 shapes to determine the maximum possible area with creative thinking	Very good use of the length of wire and correct calculation of the areas of all the 3 shapes to determine the maximum possible area.	Good use of the length of wire and comparison of two areas.	Satisfactory use of the length of wire and correct calculation of the areas of two shapes	Below average calculation of all the three areas
Use appropriate formulae, algorithms, and strategies to solve routine and non-routine problems in Pure Mathematics	Excellent use of differential calculus to obtain maximum areas. Justification of maximum/minimum using second derivative	Very good differential calculus to obtain maximum area	Good use of differential calculus to obtain maximum area from two calculated areas with justification	Satisfactory use of differential calculus to obtain maximum area from two calculated areas with no justification	Below average use of differential calculus to obtain area of one shape
Apply mathematical reasoning and communicate mathematical ideas clearly. Write a report advising on which plan to consider based on the results.	Excellent application of mathematical reasoning to give a well detailed recommendation on the shape, and size of the garden	Very good Application of mathematical reasoning to give recommendation on 2 of either shape or size	Good application of mathematical reasoning to give recommendation on 1 of either shape or size	Satisfactory application of mathematical reasoning and give recommendation without highlighting any shape or size	Below average application of mathematical reasoning

Table 3. Teachers' marking guide

ITEM	*EXPECTED SOLUTION*	*MARK*	*NOTES*
A	Correct solution with expected dimensions for all the plans.	15	There should be evidence of use of differentiation to find the maximum area.
B	There should be a comparison of the three areas. The greatest area will be chosen.	5	Considerations should be given to the area that uses the maximum area.
C	A correctly completed table with reasonable measurements.	5	
D	The report should include all the relevant details like ▪ Dimensions of the garden ▪ Maximum length of wire used. ▪ Maximum area realized. ▪ Any relevant detail for the chosen plan.	5	Learners may include details like the gate, number of perimeter poles, number of standards vegetable beds

In each of the three cases state the dimensions that give the maximum area, number of standard vegetable beds and perimeter fence poles.

Calculate the

1. Maximum area of each Plan using your chosen value of Q,
2. Number of standard vegetable beds,
3. Number of perimeter fence poles.
4. Compare your answers that you got in all the three Plans by completing the table below.

Write a brief report to the agriculture department advising them on which plan to consider. In your report you may consider the following:

- Plan that uses maximum length of wire
- Plan that uses maximum area
- Plan that contains maximum number of beds
- Plan that uses a minimum number of poles

How you will be assessed

Your answers and working on all the items will be assessed. Achievement standards specific to this task will be provided so that you are aware of the assessment criteria.

Task tips

Remember that you are trying to show your teacher your highest level of understanding of this topic, so give clear answers and show your working when requested.

From the above project-based learning task on Differentiation application, some of the things to consider when designing project task in mathematics is to make sure that learners are aware of the skills that are expected of them. The project task objectives must be clear to learners. Teachers need also to make sure that the project-based learning tasks are detailed so that they are well understood by the learners at the same time giving learners room to be creative. For example, by giving learners the chance to write a report based on the results of the three plans, gives them a chance to think critically, making their mathematical judgements and ideas real. Another important issue is that learners must be aware of how they are going to be assessed through giving them the achievement standards. Teachers must also have a making guide for the tasks to ensure uniformity in learner assessment. A properly designed project-based learning task must also allow students to give feedback either in terms of report writing or group presentation.

The role of the teacher in a project-based learning class

Previous studies have identified various factors that facilitate project-based learning implementation. In project-based learning, mathematics teachers must be able to identify and structure project tasks that present the necessary opportunities for mathematical learning (Lee and Breitenberg, 2010). Teachers need not only to understand the relevant mathematical content but also how learners develop understanding of specific mathematical content and how that can be represented and made accessible to learners (Chick, 2007). Another aspect to facilitate implementation is that of teachers knowing their expected roles at every stage in project-based learning. Several researchers agree that in project-based learning, the teacher become more of a guide, adviser, motivator, facilitator. Kubiatko and Vaculova (2011) pointed out that project-based learning focuses on a real-world problem, learners must assume responsibility for their own learning, the teacher's role becomes that of a guide or facilitator, and the deliverable must relate the learner's life. The following is a summary of the expected role of the teacher in the three main stages of project-based learning.

Initial stage in project-based learning

In this stage, the teacher's role is to design and plan for authentic learning experiences. At this stage, mathematics teachers seek out relevant activities or projects that engage students in real-life problem solving. They will be creating opportunities for learning by providing access to information (Blumenfeld *et al.,* 1991). The teacher's role in this stage is to think of project-based learning mathematics tasks that are likely to sustain learner interest, increase student motivation and ensure student meaningful engagement. The teacher plays a role of a knower, helping students select a topic, generate ideas through the brainstorming, guiding students to formulate their project objectives and developing a proposal for groups. It is also at this stage where teachers make sure that learners understand their learning goals and why they matter, ensuring that students develop a sense of ownership in the project-based learning tasks they will be doing.

Implementation process stage

In the implementation process stage, the teacher's role is to support learning by scaffolding instruction and guiding the learners to make tasks more manageable (Blumenfeld *et al.,* 1991). The teacher becomes a consultant, a facilitator, or a co-learner, helping students gather ideas. This view is supported by Vernon and Blake (1993) who postulate that the instructor's role becomes one of resource guide and the task and group consultant. It is at this stage where teachers focus on strategies for improving teamwork, time management and integrating tools for inquiry and creativity. Teachers intervene and offer suggestions to solve problems and respond to requests from students. Teachers also act as collaborators collaborating with teaching colleagues as well as with students. They will be making connections between mathematics and other disciplines, as project-based learning is an interdisciplinary approach. Teachers need to collaborate in designing project-based learning tasks which are interdisciplinary (Maxwell et al, 2001). Thus, the facilitator's role allows the teacher to become a content and procedural resource person, a facilitator of group processes, a guide to additional resources and a learner him/herself.

Assessment stage

The teacher plays the role of a commentator and appraiser. Blumenfeld *et al.* (1991) state that, at post-project stage the role of the teacher is to "assess progress, diagnose problems, provide feedback and evaluate overall results" (p.381). It is at this stage where the teacher implements an assessment plan to evaluate the learning process of the students' project. Teachers will come up with a guide listing specific criteria for grading mathematics tasks (rubrics). The assessment plan and implementation of project -based learning serves as an important tool, used to determine how much the students have learnt, and how to help the learners reach their educational goals. Teacher pays attention to what students learnt during the project, shares the reflection, provides a balanced picture of strengths and weaknesses, offers suggestions for improvement. Thus, the role of the teacher in mathematics project-based learning is to be able to identify the mathematics coherent in a range of contexts and applications and bring learners' attention to that mathematics in ways that are authentic. Teachers must also be able to identify and structure project-based learning tasks that present the necessary opportunities for mathematical learning (Lee and Breitenberg, 2010). They must encourage learners to pursue their own interests and guide them as they explore mathematics tasks of their own choosing.

Conclusion

This review found that learning mathematics using project-based learning approach is beneficial to learners as the strategy allow learners to convert abstract mathematical ideas to reality by allowing them to transfer their mathematical knowledge to scenarios and situations outside the classroom. The approach increases students' mathematical knowledge retention rate, they become independent and creative in solving real life problems. Project-based learning increases students' interest in learning mathematics. Teachers perceive the approach as a useful practice to teaching and learning of mathematics considering the benefits that the approach brings about. The review on project-based learning definition in mathematics teaching and learning context, how mathematics teachers perceived project-based learning, mathematics teachers' roles in project-based learning stages and atypical example of project-based learning task in mathematics will help mathematics teachers to understand the approach and develop

on how to effectively use it in their classes. It will also help researchers and mathematics teachers to identify some areas within the topic that need attention and research to improve teaching and learning using the approach.

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