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Impact of project-based learning on student's mathematical higher order thinking with learning aids

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ABSTRACT :Project-based learning allows students to create learning material that engaging students for deeper meaningful learning. It requires teachers to implement various activities for students to work with peers and share with others. The article investigated a project-based learning mathematics class in an elementary in China. Explorative case study research design consisted of classroom observation, teachers' interviews, and lesson plans for data generation. The results show that teachers tried to implement project-based learning into their course, but with hesitations of time-consuming for preparation and classroom management. However, we observed that students were engaging and highly motivated during the project-based learning process.

Keywords –*John Dewey, learning material, mathematics, project-based learning*

I. INTRODUCTION

Project-based learning (PjBL) has been studied for quite a long time across different disciplines. In Chinese, "Elementary School Mechanistic Standards" but depicted in descriptions of how children can learn through problem-solving in different grades. For example, experiencing the process of working with others to solve problems is promoted from the first grade to the third grade. From the fourth grade to the sixth grade, children are expected to explain their thinking process in addition to their cooperative problem-solving experience. (Jones & Brader-Araje, 2002)However, the term "Project-based learning" is not specifically stated in the standard. In regular classes, elementary school mathematics teachers are still trying to make the class learning activities interesting and energetic. As a result, we are trying to investigate how Project-based learning affects student's mathematical reasoning of higher-order thinking for deeper learning with the mediation of Learning aids.

According to the "Compulsory Education Primary School Mathematics Curriculum Standard," it is suggested that mathematics teachers should be able to utilize all sorts of course resources for meaningful designed and objectively developed instructional activities according to the standard.(Department of Education, 2011) As depicted by the standard, teachers should make full use of information related to mathematics in daily life environments and develop them into teaching resources. Teachers should strive to develop and produce simple and practical teaching aids and learning tools. Schools with conditions can establish "mathematics laboratories" for students to broaden their learning fields, cultivate their practical abilities, develop their personal qualities and innovative spirit, and promote different developments in mathematics.

II. LITERATURE REVIEW

Theoretical Origin of Project-based Learning

The origin of the term "project-based learning,"PBL, or PjBL in short, was an idea derivedfrom Dewey's "learning by doing." It is promoting actively in classroom learning experiences.(Beier et al., 2018; Varga, 2017)Dewey believed that learners should have worked on their own learning artifacts for manipulating meaningful real-world problems.(Krajcik & Blumenfeld, 2006, p. 318)When building around this teaching and learning method, the student actively works on knowledge building for deeper and more meaningful learning. As Dewey noted, "to develop an orientation to children conditioned by ongoing reflection on the pedagogical meaning and significance of experiences in their lives," which is authentic to those children for more meaningful concept development.(Van Manen, 2016, p. 10) From a pedagogical perspective, the operational practice in teaching and learning in a classroom for deep learning and higher-order thinking can be a challenge for in-service teachers. There are also means for mediating concept formation to be considered in the process of

project-based learning. (Dewey, 1938, p. 89)In other words, a learning experience is progress of learning, the means for learning, and the goal. Dewey also explained that:

The way is, first, the teacher to be intelligently aware of the capacities, needs, and past experiences of those under instruction, and, secondly, to allow the suggestion made to develop into a plan and project by means of the further suggestions contributed and organized into a whole by the members of the group.(Dewey, 1938, pp. 71-72)

Therefore, the project progresses suggestions input for group creation, among students and between teachers.The nature of the experience was explained by Dewey that "it includes an active and a passive element peculiarly combined. On the active hand … a meaning which is made explicit in the connected term experiment." (Dewey, 1923, p. 87)The idea of passive and active perspectives of students' learning experiences

Experiences as means of education

Dewey linked students' learning experience with is progressive and new education. He depicted that "the educational system must move one way or another … forward to ever greater utilization of scientific method in the development of possibilities of growing, expanding experience."(Dewey, 1923, p. 87)He concluded that Experience is not merely a cognitive activity but a combination of active and passive events. Experience is also evaluated in its meaning of perceptional relationships for further developments.(p. 87)

Problem-solving as higher-order thinking and Learning Phases

Vygotsky (1978) suggested that mediation is the basis of higher psychological processes and explained that "every function in the child's cultural development appears twice, on two levels. First, on the social, and later on the psychological level; first, between people as an inner psychological category, and then inside the child, as an intrapsychological category… the actual relations between human individuals underlie all the higher functions." (p. 128) The cultural mediation from the classroom brings the students' stimulus from peers and the teacher, including classroom activities and instructional materials. Those instructional materials are usually provided to those students from the school or the teacher, but if the material can also be created and manipulated by the student influenced with social stimulation, the learning material created by the student may develop concepts further to deal with more complex problems in real-world.

According to Bloom's taxonomy and mastery learning, Demonstrations is on the top of the competency hierarchy for assessment of performance. In Bloom's taxonomy, six levels of structure classify objects and skills required for achieving meaningful learning. The levels from the bottom up remember, understand, apply, analyze, evaluate, and create. Since "create" is on the top of Bloom's taxonomy, it gathers a learner's priorexperience and knowledge for newly formed concepts. It is combing parts prior knowledge for creating something new.Thephases of a lesson are depicted by Bill and Jamar(2010)from an authentic scenario.

According to Bill and Jamar (2010) from Ms. Scott's classroom in their article, there are four phases: set up, explore, share and discuss, and presenting.First, in the set-up phase, students should understand their learning expectations and be evaluated by explaining the expectations by themselves. Second, in the explore phase, students begin their learning process and cooperate with their classmates for problem-solving tasks. The teacher should keep assessing student's concept formation and knowledge construction by using questioning-and-answering strategies for formative assessments. Because students are in small groups, one student's performance can be assisted and shared by others, and the explanation and presentation can be helpful. Third, in the share-and-discuss phase, the student's discussion is based on the mathematical goals that have been planned for instruction in the signs of progress. There can be different solutions for problems presented; new concepts are discussed and manipulated for students' engagement.

Learning Aids is a meaningful tool for students to learning in a classroom setting. As mediation of artifacts, learning aids can bring students better learning experiences that ultimately convert their classroom experiences into authentic ones that facilitate further knowledge construction.(Krajcik & Blumenfeld, 2006, p. 325)

III. METHODOLOGY

Research Design

This study wasanexploratory case study design for researching a certain topic with an in-depth, specified, and comprehensive understanding.AsGriffee(2012)described Yin (2000) described, a case study should investigate subjects in real life, generate data from multiple sources, and use theory for data generalization.(p. 87)We conducted our study in an authentic classroom. Multiple methods of data collection of observation, interviews, and lesson plans were utilized. Theories of Dewey that are linked with project-based learning are used for data generalization.

Participants

This study was done with an elementary school in Xuzhou, one of the metro areas in northern Jiangsu Province in Mainland China. Forty-five second-grade mathematics studentsparticipated.The purpose of this study was to investigate how project-based learning affects student's mathematical reasoning of higher-order thinking for deeper learning with the mediation of Learning aids.Meetings with the teacher had been conducted for the math classes for instructional design and teaching models. The learning influences of project-based learning in the research project were observed and evaluated by analyzing the creation of meaning performed by students mediated by learning aids created by students and interacted with classmates in a classroom setting. The instruments chosen for this research included observation notes, teacher interviews, and lesson plans created by teachers. Data were generated throughout the Spring semester of 2021.

The preservice teacher was trained in the participating elementary for one full semester with their mentor experienced in-service teachers. In the Spring 2021 semester, they are expected to teach full mathematics classes. The objective of the preservice teachers was to provide them with authentic teaching experiences in a real-world teaching environment to deal with practical teaching problems. Tactics of teaching with project-based learning were utilized for students' higher-order thinking. Other than Bloom's taxonomy, the learning syntaxes developed by Bill and Jamar (2010) are used. In the learning syntaxes of project-based learning, there are four major phases as described earlier: set up, explore, share and discuss, and presenting. (Abidin, Utomo, Pratiwi, & Farokhah, 2020, p. 43) Data from this project will be discussed accordingly.

IV. METHODS

Methods of observation, interviews, and lesson plans were utilized for this study.

The observation was done in an elementary school mathematics class and was specifically taken during the angle subject. The researchersits in the back of the classroom and observes students'learning performance with observation notes. Observation notes were used for guiding and recording observation data. The purpose of observation is to gain insights into students' participation in the process of project-based learning mathematics class. The notes are divided into four sections accordingly with Bill and Jamar (2010) four phases of setting up, exploring, sharing, discussing, and presenting.

The interview was conducted in a semi-structured format with preservice teachers and consisted of the following four themes question stems.

1. What are the teachers' concepts of project-based learning?
2. How is project-based learning designed in their classrooms?
3. What are the deficits that project-based learning may cause?
4. What are the advantages of project-based learning in a mathematics classroom?

This interview was conducted to assess teacher's concepts on project-based learning and the meaning of their teaching practices. Five preservice teachers were interviewedwith interview protocolin their office.Follow-up questions were asked for more detailed insights.

Lesson plans of teachers were collected from contrasting the instructional design and actual performance.Lesson plans are important artifacts for understanding how teachers prepare their class teaching before the actual class time. Element of project-based learning was examined for further discussion with data generated from observation and interview.

The Project

Learning can happen in different places and settings. In this study, classroom settings were discussed and investigated—constructs of teacher's responsibility, restrictions, learning flexibilities, procedures, and learning content. In a project-based learning classroom, the teacher's responsibility is to assist students in designing and creating their learning material, the angle ruler, and allow the student to manipulate during the class instruction and present their creation to the rest of the class while solving mathematics problems.

This study was done with an angle ruler-making projectassociated with the elementaryschool"getting familiar with angles" objectives in the second-grade elementary mathematics standard of the People's Republic of China. The procedures are as follows:

First, students have explained a bigger concept of angle. Before students are asked to produce their own "angle ruler," teachers provide prior knowledge of making the angle ruler. The angle ruler is made of hard paper that joins.

Second, a project was assigned for making learning aids, the angle ruler.

Third, problem-solving trying with learning aids.

Fourth, presenting how problems are solved by using learning aids.

Data was generated by the three classroom observation methods, interviews, and lesson plans before, during, and after the courses associated with the "angle ruler making" project.

V. RESULTS AND DISCUSSION

Observation

Students were told to make their angle rulers for their learning aids in a mathematics class. Teachers presented material to be used, such as paper, paper clips.

The mathematics teacher hadanopeningwith asking students to search for samples of angles in students' daily lives for later implementation into learning and teaching tasks.Studentswere actively raising their hands and sharing what they found with the teacher and other classmates. After the opening, the teacher usedsome teaching materials used were set squares,documentenvelopes, and an analog clock with the hour hand and minute hand. Next, the teacher drew anglefiguressuch as right, acute, obtuse, and straight angles. Parts of an angle are arms, vertex, and angle. The teacher was repeatedly asking students about the names of parts of an angle. Students raised their hands for opportunities of answering.

After introducing the basic concept of an angle, a project was implemented for students to complete for further classroom activities. Students were asked to create angle rulers. An angle ruler is aruler with two arms that has a joint on one end. Students used simple materials such as regular rulers, hardboard papers, tapes, and others. Most materials were prepared and brought from home. When students created their angle rulers, they could use a color of their own in any style. The creativities of students manifest in this project and make the class lively. Students were able to see how other students work on theirs and chatting with others. Some students who progressed faster would help other slower students with their angle ruler-making project.The teacher later assigned students into groups of 5 and said:

> "I have prepared some materials for you as well as materials you prepared from home (two sticks, two hard paper strips, a piece of wool, a round piece of paper). Please use the materials provided to create an angle according to your needs. How can you make it? Let us see who has the most ideas." (Observation Note 210420)

The teacher encouraged students to explore all kinds of possibilities making different kinds of angles by producing their angle rulers.Students made angle rulers for the purpose of learning aids.While different purposes of demonstration of teaching aids, learning aids are more mediational functions for problem-solving activities during a classroom meeting in this study.During the observations, students used their angle rulers for varieties of tasks.For example, fivestudents in a group were asked to make different angles with their angle rulers; in addition, comparing the wideness of the angles was performed.

The teacher first assigned students into groups of five and explained to the students that "different kinds of angles can be seen everywhere in our daily lives. Do you want to make anangle with your angle ruler? Give it a try!" (Observation Note 210420)

The presentation of students was lively.The teacher gave a problem to the groups:

"As a group unit, who will introduce your solutions?" (Observation Note 210420)

Groups of students are asked to show their hand-made angle rulers and their solutions to problems on the stage. Their projectswerealsocaptured with a real-object camera projectorand displayed on a big screen in front of the classroom. The teacher went on asking:

> "You all have a pair of delicate hands making all kinds of angles. Can you make this angle larger or smaller? Please use the angles you made within your groupsand show them to each other. How to make the angles bigger or smaller?"(Observation Note 210430)

Studentswere encouraged to turn the angle ruler and make adjustments to compare different types of angles and finally make sense of angles. The teacher elicited that:

> "From this activity, we can learn that what is needed to make the angle larger or smaller. What if you want to make the angle larger or smaller? Howdoesthe angle have to do with its arms?" (Observation Note 210430)

This part of the class perfectly matches Dewey's "learning by doing" in a project-based learning setting. If students hear what the teacher said, they might forget, but after they have tried many other methods, such as reading, manipulation by hand for a project, students can master the content. They gain experiences by doing and explore all possibilities of solving problems. Students also cooperate and communicate with other classmates. They realized that there were many other solution possibilities and experienced the diversity of problem-solving strategies.In this case, students gain their own experience making their angle and presenting it to the class. Because of the participation and engagement, students have meaningful learning.

After students' presentation on making their own angles, the teacher kept on asking follow-up questions to guide students' deeper understanding. The teacher insisted on students for direct observation and company. The teacher also used an analog clock as teaching material for guiding student's thinking and learning.

"Can you compare the wideness of the angles now?" (Observation Note 210430)

After the guidance, the teacher implemented small group discussions for other practical ways of angle comparisons.

Other events observed were some unpredicted events from students, including one girl who had a stomachache, and the teacher asked the class monitor/leader to take her to the school health center. The other even was related to the angle ruler-making project as one male student was asked to manipulate a right angle on his angle ruler and show it to the class. While the student was working on the problem solving, a student from his behind shouted that the angle ruler was his and claimed that the first student gave it as a gift. The two students were fighting over the angle rulers.The teacher went to them and asked them to learn the content knowledge first and deal with the ownership of the angle ruler later. The teacher also assigned them different tasks, so they were busy problem-solving.

Interview

The interview was done after the teacher was done with their teaching of the unit of understanding angles.Five participants were interviewed to gain more insights. From the interview data, those teachers presented their understanding of project-based learning in their mathematics teaching of the understanding angle unit; however, the complexity of project-based learning made the teacher compromised with practical classroom teaching.The teachers showed their understanding of project-based learning in great depth; however, struggling with making it possible for a meaningful experience for their students. According to the questions from the interview protocol, teachers' responses are similar.

1. What are the teachers' concepts of project-based learning?

"Based on the meaningful exploration environment and factors of the real world, a logical organization project is constructed." (Interview A)
"Students are required to actively study and explore, and use group cooperation to carry out specific practical operations, and complete the understanding and construction of the meaning of knowledge in the form of making the final work." (Interview B)
"The knowledge generated by the students and the ability cultivated is the goal." (Interview C)
"Making students work on a project and teaching around it." (Interview D)

“Project derived from the textbook and let the students work the problem with others.”(Interview F)

2. How is project-based learning designed in their classrooms?

“(1) Determine the theme; (2) Make a plan; (3) Activity exploration; (4) Production of works; (5) Results from exchange; (6) Summary evaluation."

3. What are the deficits that project-based learning may cause?

(1) Time-consuming and labor-intensive, classroom efficiency is low, and it is difficult to guarantee the high-quality completion of classroom teaching tasks

Teachers explained that, First of all, because some students realize that project-based learning does not take exams, and the atmosphere is more autonomous, they naturally relax the learning of this course, thus forming a free and undisciplined attitude. The efficiency of practical operation and autonomous construction tasks is greatly reduced, and theoretical knowledge is not absorbed. The teaching quality of courses is difficult to guarantee. Secondly, the design of logically organized project-based learning requires high quality and ability of teachers, time-consuming and labor-intensive. Teachers are required to use appropriate language and methods in the classroom to arouse students' curiosity, and teachers are needed in the process of students' autonomous exploration. Effective guidance and timely comments, but in actual operation, teachers tend to emphasize "autonomy one-sidedly."

(2) It is difficult to effectively supervise and control the individual activities of students in the classroom

Discussion and operation in the form of group cooperation do not guarantee that each group member can actively and actively participate in it. Some students may completely stay out of the matter, play their own, and not participate in the project, affecting other students. Only a small number of students participate in discussions, mutual assistance, and cooperation. Project-based learning cannot guarantee that all students participate, and effective supervision and control of teachers are difficult to achieve, and the efficiency of feedback is low.

(3) Project-based learning is not suitable for all knowledge in mathematics

Although the knowledge of mathematics is generally logical and organized, it can form a large unit of teaching and then develop students' basic knowledge and basic skills through design projects, but it does not contain all the knowledge. Through project-based learning, students' knowledge structure and system through self-inquiry cannot fully contain all mathematical knowledge. On the one hand, just as Bruner's discovery method cannot cover the knowledge points learned, there is some simple and easy-to-understand knowledge and abilities. Use the teacher's meaningful teaching directly; it will appear to be overkill if you use project-based learning. On the other hand, some knowledge points are very delicate and complicated. The project-based learning designed in this way will lose the students' interest due to difficulties and give up feeling despair, which is not conducive to the harmonious and healthy development of the students' body and mind. Project-based learning is Lost its original value and became a formality.

4. What are the advantages of project-based learning in a mathematics classroom?

(1) Improve students' problem-solving skills

The core concept of project-based learning comes from the famous educator Dewey's "learning by doing" and constructivist ideas. Dewey's pragmatic education theory, Bruner's discovery learning theory, and constructivist learning theory are its theoretical foundations, and learning methods such as contextual teaching have gradually formed. In the process of project-based learning, a real learning situation is particularly important, and many of the problems are the most important and difficult points for students to breakthrough in the entire project-based learning. In the context of a problem-driven project, students explore and discover according to the problem, make full use of known conditions, dig out hidden conditions, and finally conclude to solve the problem. During the project learning, the knowledge points with internal logic are linked together into units so that students no longer memorize by rote and use their own ability to solve problems in the situation to master the knowledge and remember more firmly. Therefore, in mathematics education, teachers can develop students' math problem-solving ability through project-time learning.

(2) Cultivate students' core skills in the 21st century

In the current era, the 21st century is a new century full of hopes and challenges. The era puts forward new requirements for people's core skills and qualities, such as the requirements for the 21st century. In 2007, "How to Train 21st Century Students" was promulgated. It believes that students must learn not only traditional

subjects, but also have 21st-century skills, namely, to understand the whole world and be a global citizen: to be able to think beyond the limits of thinking and encourage students to cultivate creative thinking, Learn to carry out learning across disciplines; treat new information sources wisely, know how to process and analyze different information, and take appropriate actions; develop good interpersonal relationships, and cultivate students' communication skills and teamwork spirit. In the context of the information society, mathematics teaching no longer simply focuses on scores and grades but also requires teachers to exercise and cultivate students' core mathematics and abilities to adapt to this new era of challenges and opportunities. Project-based learning focuses on the construction of meaningful inquiry problems in reality. It requires students to explore and learn actively, which is conducive to cultivating students' curiosity and exploration spirit about problems and cultivates students' ability to cooperate, communicate, and unite and help each other through group collaboration.

(3) Promote in-depth teaching of primary school mathematics

Mathematics is an abstract subject. Traditional mathematics teaching is "superficial." Teachers teach it, students learn, supplemented by exercises after class, and even uses sea tactics to learn a certain question type. Furthermore, the teaching model is based on the teacher's perspective. The teacher's teaching method directly affects the student's learning method, and most of the teachers teach from their perspective, just to impart knowledge to teach, so there will be many teachers who have some meaning in the students' classroom Questions expressed disgust and interruption, which have a negative effect on students' psychological emotions and creativity. Educational theory points out that three target dimensions should be achieved in the teaching process: knowledge and skills, process and methods, emotional attitudes and values, while traditional mathematics teaching methods emphasize knowledge and skills learning, ignore process and methods and ignore students' emotional attitudes. Values produce more students with high scores and low energy, which is not conducive to social development. The integration of project-based learning into elementary school mathematics as a new teaching method is based on the transition from the teacher's perspective to the student's perspective, and it also shifts from focusing only on knowledge and skills to focusing on students' psychology and emotions, starting from the individual students, allowing students to freely ask questions worthy of inquiry to meet the curiosity and psychological and emotional needs. Teachers carefully design mathematics project scenarios so that students can find reasonable problem-solving methods in the process and combine abstract mathematics with life situations. Cultivate students' mathematics aesthetics and interest, and promote students' deep learning.

Lesson Plan

In the teacher's lesson plan, the course was designed in the following sections:

1. Opening: At the very beginning of the class introduction of angles, the teacher writes the word angle (in Chinese) on the blackboard for students to read aloud together. After that, the teacher encourages students to find angles around in the classroom.Students are encouraged to say what they find to the rest of the class in an open discussion forum.

2. The teacher introduces angles to the whole class. The definition of an angle is explained.

> These two straight lines and this sharp point have nice names. Does anyone know? (If the student does not know, the teacher will introduce it) We call these two-pointed lines the two sides of the foot. This sharp point is called the vertex of the angle. An angle is composed of a vertex and two edges. (Lesson Plan 01a, 01b)

Because of the definition, students can compare what they have learned from their observation of angles around them. The teacher also provides pictures and other teaching materials for students' recognition of angles.

3. Students draw angles after they have known the basics of angles for further development of the concept. Students draw angles on their pieces of paper or the blackboard.

4. Students are asked to make an angle with two paper strips, pushpins, and arubbereraser head. The teacher may ask students:
"Guess what can we do with those materials? Can we make an angle?" (Lesson Plan 01b)
After the angle ruler is completed, students are asked to manipulate the arms for making a bigger or smaller angle.

5. In the summary, the teacher summarizeswhat they have learned in several tasks. First, the teacher asks the students about what they have learned in general. Students may say anything they have learned.

"Ask the children to close their eyes and think about it together. First, draw a vertex, draw an edge from the vertex, and draw another edge from this point. Is it has done? Please open your eyes." (Lesson Plan 01a)

VI. CONCLUSION

The mediational phenomenon of learning aids production in a project-based learning classroom made a meaningful learning experience for those students in the class. However, we have observed some discrepancies in students' learning aids in different levels of material usage and precision. Our research concluded that preservice teachers implemented project-based teaching into their practical courses.As observed, students are actively engaged; however, teachers presented some problems that can be further refined accordingly with the project-based learning foundations that required for recognizing meaningful actives for students' development of mathematics concepts.

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