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Students' Mathematics Performance and Engagement in an Inquiry-Based Learning Approach

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Abstract

This study explored the use of inquiry-based learning approach in teaching mathematics and its impact on students' performance and engagement of Grade 7 students of Libona National High School. It envisioned to: (1) identify the level of performance of the students in mathematics when exposed to IBL and non-IBL in terms of their pre-test, post-test, and retention test scores;(2) determine the level of engagement of the students in mathematics when exposed to IBL and non-IBL in terms of their, affective and cognitive engagements; (3) differentiate the level of performance of the students in mathematics when exposed to IBL and non-IBL in terms of their post-test; and retention test; (4) find out if there is a significant difference exist in the level of engagement of the students in mathematics when exposed to IBL and non-IBL in terms of their affective and cognitive engagements.

A quasi-experimental research design was conducted to students in two groups: the IBL and the non-IBL. Results revealed that students who were exposed to IBL had significantly higher performance in mathematics as to those exposed to non-IBL in terms of their post-test and retention test. It was also found out that the use of IBL is comparable in terms of the affective engagement of the students but not comparable in terms of cognitive engagement between two groups.

Introduction

Every educational system is dynamic. It requires series of revisions to address the different problems that arise in the field of mathematics teaching. It is undeniable that in every discovery of teaching techniques there will always be another problem that needs a new solution.

For the past years the National Performance of elementary students in the National Achievement Test (NAT) showed a low mean percentage score. The Philippine Star announced last March 12, 2012 that the Grade 6 students obtained an MPS of 68.14% in SY 2010-2011 down to 66.79% in SY 2011-2012. This means that the country's learner's achievement did not reach the standard of 75% National Passing Rate. This rating would mean further that many of the students have deficient performance in mathematics. This situation is an alarming case considering that mathematics is one of the necessary foundations that everyone must acquire.

There are many identified strategies in order to teach and to learn. These strategies, or also known as pedagogies, are helpful in order to achieve a quality teaching-learning

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process.Many researchers found that certain instructional strategies enhance students' learning (Aguanta& Tan, 2018; Guita& Tan, 2018; Segumpan& Tan, 2018; Salingay& Tan, 2018; Saligumba& Tan, 2019; Dagoc& Tan, 2018; Asparin& Tan, 2018). The Philippine mathematics education is hopeful for a classroom that gives equal opportunities for each student to learn. It is essential that the students have access to high-quality, engaging mathematics instruction. The use of inquiry-based learning (IBL) is another technique that would help improve the performance and engagement of students.

Bruner mentioned in the study of Khasawneh (2016) that instruction must relate to the learners' experiences and contexts that they can understand for them to be willing to learn. In the same study, as cited by Dewey (1938), students should involve themselves in the learning process. They should be encouraged to construct their own knowledge based on the prior knowledge and past experiences they already have. As cited by Piaget (1972), each person must construct their own knowledge through their experiences in order for learning to take place. In the study of Liu et al. (2006), inquiry-based learning (IBL) is a student-centered pedagogy which focuses on questioning, critical thinking, and problem-solving.It has been observed that IBL can engage students in learning. According to Vygotsky on the work of Dyjur (2010), a person learns in a socially-related context, with individuals reaching at personal understanding based on their own experiences.

Hence, the study aimed to determine if there are changes in student's performance and engagement in mathematics with the use of Inquiry-based Learning (IBL).

Review of Related Literature and Studies

Students Mathematics Performance

As stated in the National Council of Teachers of Mathematics (NCTM), the vision for mathematics education presented in Principles and Standards for School Mathematics is highly ambitious. Accordingly, it requires solid mathematics curricula, competent and knowledgeable teachers who can integrate instruction with assessment, education policies that enhances and support learning, classrooms with ready access to technology, and a commitment to both equity and excellence. Having identified all these pain points would mean that there will always be a hope to improve poor mathematics performance in the country.

The National Achievement Test (NAT) is a measure of students' competencies in five key subjects which are the Mathematics, Science, English, Filipino and Social Studies. It is administered to determine the quality of education they received. Based from the records, the Libona National High School got 60.69% overall MPS in School Year 2013-2014. This is 15% higher compared to its performance in previous year with MPS 45.19. The mean percentile score in mathematics performance of the students of Libona National High School is 17.28 and 60.62 for S.Y 2012-2013 and 2013-2014, respectively. This means that there is a need to improve the performance in order to achieve at least 75% of passing rate. The result negates the DepEd's vision where they dreamed of Filipinos whose competencies allow them to reach their full potential and contribute significantly to building the nation.

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A lot of studies tried to improve the mathematics performance of the students in the Philippines. One of these is the study of Aguanta and Tan (2018) on the Effects of Dyad Cooperative Learning Strategy (DCLS) on Students' Academic Performance and Attitude towards Mathematics where they found out that students' performance had improved when DCLS was used. The researcher would like to develop another solution to help in improving the mathematics performance of the students using inquiry-based learning approach.

Students' Engagement

Students need to be affectively and cognitively engaged in the class. Fredericks et al. (2004) defined emotional engagement as students' positive and negative feeling towards teachers, classmates, and school. They also claim that emotional engagement links students to an institution and influences students' willingness to do school-related work. Similarly, Park cited in the work of Pannozzo (2005) that conceptualize emotional engagement has also been referred to as affective engagement (Appleton et al. 2006). In the study of Wang and Eccles (2012), they found out that emotional engagement is not directly connected to academic achievement. This contradicts to the study of Archambaul et al. (2009) who mentioned that it is possible that emotional engagement influences academic achievement indirectly through behavioral and cognitive engagement. These two studies having different results are helpful for other researchers to open a new study. Another study states that psychological or emotional engagement includes students' emotional reactions and connections to teachers, peers and the school.

Appleton et al. (2006) contended that the measurement of cognitive engagement from the student perspective would result in a more valid understanding of student experience and meaning. The purpose of the work of Appleton et al. was the development and validation of a psychometrically sound instrument designed to measure students' cognitive and affective engagement from the student perspective. Using the Inquiry-based learning approach, the study tries to prove if there is an increase in cognitive engagement and mathematics performance among the students.

In the literature of engagement theory, cognitive engagement generally refers to the idea of investment in learning. Some researchers also relate cognitive engagement to the extent to which students view education as relevant to their future goals. Cognitive engagement can include the student's use of cognitive, self-regulatory, or metacognitive strategies, and doing extra work beyond the requirements of the school. How each dimension of engagement is operationalized depends on what the researcher is intending to measure.

Inquiry-Based Learning

Inquiry learning is anchored to discovery learning. It is when we begin to ask questions and try to find the answer based from our observations. Inquiry has been presented as a teaching method which combines student-centered, hands-on activities with discovery. We also use inquiry-based learning in our daily lives. According to Millar on the work of Ostergaard (2016), inquiry is often conducted both in everyday life. Skills such as observing, experimenting, classifying, developing a hypothesis, drawing conclusions, designing, planning, and so on are used for inquiry.

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In education, inquiry is a systematic method that allows active participation of the students. Prince & Felder on the work of Khasawneh (2016) stated that Inquiry-based learning (IBL) is an instructional pedagogy that promotes active leaning. It focuses on the process of learning through observation and questioning rather than on getting the right answer to the problem. In addition to that, inquiry signifies deep and critical thinking. The introduction of inquiry-based laboratories has been observed to result in a deeper comprehension of scientific knowledge, increase confidence in understanding and performing science, improve students' attitudes towards science and act to lower attrition rates, Smallhorn (2015). According to Khasawneh (2016) the main principle of IBL aligns well with constructivists' method learning. The main principles in the IBL environment are learner-centered, knowledge-centered, assessment-centered, and community-centered environment. In the IBL environment, learners' prior knowledge and the type of skills they already have so they can help students incorporate it within their existing knowledge (Yilmaz, 2008).

The use of inquiry-based learning as an approach of teaching mathematics will help the students to be more curious and improve their critical thinking. Anchored in Dewey's work, inquiry-based learning is one of the many approaches to learning that includes a process of investigating the material world, and that leads to seeking answers to questions, having discoveries, and rigorously evaluating those discoveries in the search for new meaning" (National Science Foundation, 2005, p. 2). According to Dewey (1938), "Inquiry is the only authentic means at our command for getting at the significance of our everyday experience of the world in which we live". inquiry is also an essential skill for coping with the complexity of this information age and its many challenges such as information overload (National Science Foundation, 2005).

Based from the study of Dyjur (2010), inquiry-based learning is generally recognized as being more authentic for students as it allows them the flexibility to make some of the decisions about their learning; an emphasis on inquiry also tends to promote critical thinking skills. As a result, students may have deeper, more relevant learning experiences when using this approach. He also added that inquiry-based learning promotes student learning "through guided and increasingly independent investigation of complex questions, problems, and issues, often for which there is no single answer". Knowledge is socially constructed and learning and learning occurs in the involvement in communities of practice.

In contrast to traditional pedagogy, IBL focuses on students' active learning. Their role is changed from passive listeners to active explorers, while the role of the teacher is changed from lesson instructor to problem-solving guide. Moreover, thanks to the rapid growth of the Internet, instead of traditional textbooks, knowledge resources from the World Wide Web have become a mainstream element in learning activities. It is beneficial to teachers to conduct IBL, and students can learn knowledge anywhere and at any time. Wu et al. (2015)

IBL pedagogy help students take ownership of their learning and motivate them to work harder, help them develop more independent and sophisticated ways of research capability and confidence, which leads to achievement (Abdi, 2014). In the study of Lambordi, (2016), he stated that students are engaged in solving a scientific problem in a meaningful, inquiry-based manner through hypothesis testing, experimentation, and investigation. This mode of learning

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introduces students to real life, authentic science experiences within the confines of a typical classroom.

According to Llewellyn in the work of Stewart (2008), students' generation of questions is central to the concept of inquiry, and their own curiosity and interest drives their investigation. Generally, learner-centeredness is a core component of most conceptualizations of inquiry. For the purpose of this study, many potential outcomes of inquiry-based teaching and learning were reviewed as possible, regardless of the exact type of inquiry.

The National Science Education Standards (1996) indicated that "when engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations" (Stewart, 2008).

Conceptual Framework

This research used a constructivist paradigm to examine the ways students built on their own cognitive structures through their past experiences. Constructivism is a theory that people are accountable in making their own meaning of the world and utilizing what they know based on former experiences in the process of associating new information to these experiences. Historically, IBL's origin could be outlined to the first work of Robert Karplus during the late 1950s and early 1960s at the University of California-Berkeley (Lawson, 2010). Between 1960s and 1966, the educator Joseph Schwab suggested that instructors should present science in inquiry, and that learners should work in laboratory before being introduced to the formal explanation of scientific concepts and principles (National Research Council, 2000). This was later formalized by Marshal Herron in 1971 with the development of the Herron scale to assess the amount of inquiry within a particular laboratory exercise. According to Dewey in the work of Gomez (2012), inquiry perhaps first introduced the cultivation of critical thinking skills in education in his advocating of schools as environments to develop democratic citizenship.

Inquiry-based learning is supported by the idea of constructivism where students are asked to discover the answer of the occurring problem. It helps them to work independently and develop their engagement. The use of inquiry-based learning is first introduced in science where the problem is solved through a scientific method. 5E instructional Model is a well-established inquiry-based instructional model first devised by the Biological Science Curricuum Study (Bybee, et al., 2006). The 5E instructional model consists of a five phase learning cycle: Engage, Explore, Explain, Elaborate, and Evaluate. In the IBL environment, teachers facilitate self-reflection and evaluation, which are major parts of the inquiry process (Scruggs &Mastropieri, 2007). The teacher asks guided questions to stimulate students' thought process, encourages them to interact, and provides immediate constructive feedback. Students can think aloud, write their thoughts, make observations, analyze, and evaluate themselves and each other (Leonard &Penick, 2009; Simpson & Courtney, 2007).

Methodology

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The study made used of a quasi-experimental research design with two different intact classes. It determined the effect of using Inquiry-based learning approach on the performance and engagement in mathematics among grade 7 students at Libona National High School during the fourth grading period of SY 2018 – 2019.

The subject-respondents of this study were the two sections of Grade 7 secondary school students of Libona National High School. One section with 50 students was the controlled group while the other section with 50 students was the experimental group. A total of 100 students were the subject of this study. These students are of different beliefs, cultures, and social status.

For both groups, the experiment started during the fourth grading in their topics on probability and statistics. The set competencies were evaluated individually and students performed the said competencies.

The researcher prepared a 50-item teacher-made test, with a Cronbach Alpha of 0.770, which covered the topics in the Fourth Grading Period stipulated in the K to 12 Mathematics 7 Curriculum.

To determine the mathematics engagement of the students, the researcher adapted the 5-Point Scale Student Engagement Instrument (SEI) developed by Appleton, J., Christenson, S., Kim D., &Reschly A. (2006). It was pilot-tested to the Grade 8 students of the same school with a Cronbach Alpha of 0.922. The scale is a five-point scale- from strongly agree to strongly disagree.

An analysis of covariance (ANCOVA) was used to see the significant difference on the mathematics performance and engagement of the students exposed to Inquiry-Based Learning approach and the non-Inquiry-Based Learning approach.

Findings

To identify the performance of the students in mathematics in control and experimental group in the pre-test, post-test and retention test, descriptive statistics such as mean, frequency, and percentage were used.

IBL group obtained a mean score of 23.28 while the non-IBL group obtained a mean score of 23.30 in a 50-item teacher-made test during the pre-test. These results revealed that the two groups had a “very low performance” in mathematics.

When the post-test was given, the IBL group got a mean score of 35.16 indicating a “moderate performance”, while the non-IBL group mean score was 32.76 indicating a “low performance” result.

The retention test was given two weeks after the post-test and the result shows that the IBL group obtained a mean score of 36.72 indicating a “moderate performance” result while the non - IBL got a mean score of 31.66 indicating a “low performance”

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To measure the engagement of the students towards Mathematics in both groups before and after the intervention, descriptive statistics such as mean was also used.

Before the intervention, the affective engagement of the students in the IBL group was 4.12 and non-IBL group was 4.09 indicating a "positive engagement" result for both groups. The SEI developed by Appleton et al (2006) was used as an instrument. For the cognitive engagement before the intervention, the IBL group got a mean score of 4.30 indicating a "highly positive engagement" result while the non-IBL group obtained a means score of 4.17 indicating "positive performance" result.

The affective engagements of both groups were measured after the intervention. The IBL and non-IBL group got the mean scores of 4.16 and 3.99 indicating "positive engagement" results. The same procedure was done to measure the cognitive engagement of the two groups. The IBL group got 4.34 means score indicating "highly positive engagement" while the non-IBL group got 4..05 indicating "positive engagement" result.

To compare the performance of the students exposed to IBL and non-IBL in terms of post-test and retention test, the analysis of covariance (ANCOVA) was used.

The F-value between groups in the post-test is 7.17 with a probability of 0.009($p<0.05$) indicating a highly significance difference. Thus, the null hypothesis which stating that the mathematics performance of the Libona National High School students exposed to IBL is comparable to those who are exposed to non-IBL in terms of their post-test scores is rejected. This implies that the IBL group with a mean of 35.16 performed better than the non-IBL group with a mean of 32.76 which would mean further that there is a significant difference found in their performance based form the post-test result.

The result supports the study of Smallhorn, et.al (2015) on inquiry-based learning to improve student engagement in a large first year topic where the shift to inquiry-based learning had improved the learning outcomes of the students. The molding of independent learners requires providing students with the opportunity to formulate and explore questions based on evidence.

Table 1. Comparison of students' performance on the post-test

GROUP	N	MEAN	SD
IBL	50	35.16	4.639
Non-IBL	50	32.76	4.269
TOTAL	100	33.96	4.597

Source	SS	df	MS	F-value	Sig.
Group	143.97	1	143.97	7.17	0.009s
Pre-test	0.233	1	0.233	0.012	0.914
Error	1947.61	97	20.078		
Total	117420	100			

Note: s – significant at 0.05 level

The F-value between groups is 37.732 with a probability of 0.000($p<0.05$) indicating that there is a significance difference. Thus, the null hypothesis, mathematics performance of the Libona

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National High School students exposed to IBL is comparable to those who are exposed to non-IBL in terms of their retention scores is rejected. This implies that the IBL group with a mean of 36.72 has longer retention compared to the non-IBL group with a mean of 31.66 which would mean further that there is a significant difference found in their performance based from the retention result. Notice in Table 1 that the students in non-IBL group perform better compared to the IBL group.

This conforms to the study Khasawneh, et.al (2016) on the effect of inquiry-based learning vs. traditional lecture-based learning, that student perceived IBL pedagogy as a positive experience. Students believed that it improved their confidence in their ability to do math, their knowledge in approaching a problem, their communication skills and their ability to ask inquiry questions.

Table 2. Comparison of students' performance on the retention test.

GROUP	N	MEAN	SD
IBL	50	36.72	3.98
Non-IBL	50	31.66	4.359
TOTAL	100	34.19	4.869

Source	SS	df	MS	F-value	Sig.
Group	641.01	1	641.01	37.732	0.000[s]
Pre-test	59.186	1	59.186	3.483	0.065
Error	1648.114	97	16.991		
Total	2347.39	100			

Note: s – significant at 0.05 level

To determine the significance difference of the students' affective and cognitive engagement towards Mathematics between groups in terms of their post-test, analysis of covariance (ANCOVA) was used.

Affective Engagement

F-value of 2.990 with a significant level of 0.087 ($p>0.05$) indicating that there is no significant difference in the affective engagement of two groups. Thus, the null hypothesis, engagement of the Libona National High School student exposed to IBL is comparable to those who are exposed to non-IBL in terms of their affective engagement, is failed to be rejected. Nevertheless, even the result is comparable between two groups in terms of their post-test score, the affective engagement mean scores of the students increased. However, students in the non-IBL had a highly positive engagement when their family/guardians are there when they need them and when they have some friends in the class. But they are moderately engaged when their classmates do not respect what they have to say.

The result is supported by the study of Osterman cited in the study of Pannozzo (2005) on behavioral and affective engagement that affective engagement have a minimal direct impact on academic achievement. He found that reading and mathematics achievement has no statistical significance when they were regressed on students engagement.

Table 3. Comparison of students' affective engagement between groups.

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GROUP	N	MEAN	SD
IBL	50	4.16	0.38
Non-IBL	50	3.99	0.61
TOTAL	100	4.08	0.51

Source	SS	df	MS	F-value	Sig.
Group	0.762	1	0.762	2.990	0.087[ns]
Pre-test	0.234	1	0.234	0.919	0.340
Error	24.706	97	20.078		
Total	1689.163	99			

Note: ns – not significant at 0.05 level

Cognitive Engagement

As shown in the Table 11, the cognitive engagement of the students when exposed to IBL approach of teaching had a mean score of 4.34 with a standard deviation of 0.38 while students exposed to non-IBL approach of teaching had a mean score of 4.06 with a standard deviation of 0.60. Additionally, The table presented the F-value of 10.166 with a significant level of 0.002 ($p<0.05$) indicating that there is significant difference in the cognitive engagement of two groups. Thus, the null hypothesis stating the engagement of the Libona National High School student exposed to IBL is comparable to those who are exposed to non-IBL in terms of their cognitive engagement is rejected.

The result supports the study of Obery (2018) on measuring cognitive engagement and motivation in formal context where the results of his study revealed that measuring cognitive engagement and motivation significantly predict future aspirations.

Table 4. Comparison of students' cognitive engagement between groups.

GROUP	N	MEAN	SD
IBL	50	4.34	0.38
Non-IBL	50	4.06	0.60
TOTAL	100	4.20	0.52

Source	SS	df	MS	F-value	Sig.
Group	2.510	1	2.510	10.166	0.002[s]
Pre-test	0.718	1	0.718	2.909	0.091
Error	23.951	97	0.247		
Total	1788.699	100			

Note: s – significant at 0.05 level

Conclusion

Based on the findings of the study, conclusions are drawn:

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Mathematics performance of the students in the IBL and non IBL groups is very low in the pre-test. However, the performance of the students in the IBL group improved to moderate level base from their post-test and retention test scores. On the other hand, students' performance in the non-IBL group is low base from their post-test and retention test scores.

Students in the IBL and non-IBL groups have a positive engagement in affective domain before and after the intervention. Students in the IBL group are already highly positive engaged before and after the intervention while in the non-IBL group is positively engaged before and after the intervention in cognitive domain.

Students' mathematics performance exposed to IBL is not comparable to those who are exposed to non-IBL based from their post-test and retention test scores.

Students' affective engagement towards mathematics when exposed to IBL is comparable to those who are exposed to non-IBL. However, the students' cognitive engagement towards mathematics when exposed to IBL is not comparable to those who are exposed to non-IBL.

Recommendation

Based on the summary, findings and conclusion of the study, the following recommendations are listed:

Teachers and curriculum makers are encouraged in using inquiry-based learning because it enables the students to have connections and become more interactive in the class. IBL is a better approach to improve the mathematics performance and retention of the students compared to traditional approach.

To keep the students highly engaged affectively, family/guardian(s) must be willing to help their child and the curriculum must see to it that the classroom should see situations that improve students' relationship within the class. Additionally, to improve the students' affective engagement, the teachers, parents, and administrators must plan something that would help the students to establish a good relationship among their classmates.

Teachers, administrators, and curriculum makers might consider the engagement of the students in the class. Being engaged in any activities will help the students to grow and develop themselves holistically. The use of Inquiry-Based Learning as approach of teaching is very useful for engaging the students into the concepts, theories and abstract ideas in mathematics although it speaks a little engagement on the affective side. Hence, regular counseling of the students may be a good help to improve the affective engagement of the students.

Finally, future researchers may find another way to improve the affective engagement of the students and to strengthen the cognitive engagement using the inquiry based learning. The implementation of this study is highly significant and the use of this method is highly encouraged.

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