The Impact of Android Module-Based Inquiry Flipped Classroom Learning on Mathematics Problem Solving and Creative Thinking Ability

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Abstract—This research uses the Android module based on a strategy called "inquiry-based learning" and "flipped classroom" to help people utilize their cross-disciplinary skills in complex real-world situations. This experiment showed how the Android module-based inquiry flipped classroom learning affects math pre-service teachers' ability to solve mathematical problems and think creatively in geometry. In the third term, 123 students were randomly assigned Android module-based inquiry flipped classroom learning, PowerPoint module-based conventional flipped learning, or conventional learning. The study found that math pre-service teachers were much better at solving mathematics problems and creative thinking when using Android module-based inquiry flipped classroom learning because its use effectively extends learning time, permits the acquisition of more knowledge, and encourages a collective responsibility for learning in order to engage in the process of deeper learning. This type of learning also helps them learn how to deal with real-world problems that they may face in their future jobs. This implication can guide instructional designers on how to help students solve math problems and think creatively.

Keywords—Android module, inquiry flipped classroom learning, mathematics problem solving, mathematics creative thinking

1 Introduction

The development of professional and competent teachers, especially mathematics teachers, needs to undergo tremendous and rapid change to address the development of education. Learning innovations must be carried out continuously and match the demands of learning through integrated and well-structured activities to create a large academic and quality culture. High-order thinking competencies, such as problem-solving and creative thinking skills, are critical in the 21st century and have been highlighted by several scholars [1], [2]. In fact, teacher education programs worldwide have been criticized for being too theoretical, not preparing future teachers for the classroom, and not having a professional focus [3]. There is also a need for teachers to be able to recognize, evaluate, and explain their choices and actions [4]. Therefore, lecturers must create active, flexible, student-centered, and collaborative learning in higher education.

A range of technologies have been used to encourage student involvement. The development of smartphone applications has been made possible in mobile learning to complement educational activities [5]. Combining mobile technology, contextual learning techniques, and relevant learning designs can create a relaxing online learning experience [6]–[8]. An excellent way to create socially engaging and constructivist learning environments, for instance, is to use Android learning material on mobile devices, according to a recent study [9]–[11].

Android is one of the popular operating systems for smartphones and tablets. Android allows everyone to create and develop Android applications for every need[12]. Android learning material on mobile devices may create a socially engaging and constructivist learning environment for students [10], [11]. In addition, the Android module is a convenient, effective, and interactive alternative learning source that can be accessed anytime and from any location via a smartphone [13]. Therefore, an Android module may be utilized in a technology-based classroom to achieve specific learning goals[14]. Moreover, an Android module is more attractive and interactive because it combines digital media formats, such as animations, videos, links, buttons, and others [12].

The "flipped classroom" (FC) is one of the change strategies that can accelerate technology innovation in math education. The flipped classroom strategy provides learners with more flexible study times and multiple assessments to enable students to learn more [15]. Traditional teacher-centered learning is challenged by the flipped classroom strategy, which changes teachers into advocates and facilitators who assist students in teamwork or individual learning [16]. The flipped classroom combines face-to-face learning with ICT-supported learning outside the classroom and has the opposite order of learning to conventional lectures [17]. Students acquire knowledge or skills individually or collectively before class, and then teachers mainly provide questions and guided collaborative learning activities in class [18]. As a result, for various topics such as science and mathematics, this teaching strategy can enhance brainstorming and interaction with peers, develop students' skills in communication and independence in learning, and transform students' learning habits for the better [19]–[21].

As a teaching method, FC is described as a teaching reform that uses mobile technology to modify teaching ideas, instruction objectives, teaching time, and teaching mode so that instructors educate students in class and students complete their assignments at home [22]. Students can access lecture videos, notes, slides, and articles outside the classroom, while teachers can connect and interact with their students through the web of Learning Management Systems (LMS) and encourage deep learning through in-class activities. Flipping the classroom allows for additional time for active learning and problem-solving activities [23].

Moreover, a recent meta-analysis by L. Zheng et al. [24] suggests combining flipped classroom strategies with other educational models, such as inquiry-based learning, to optimize the effectiveness of flipped classroom situations. For example, in STEM education, inquiry-based learning can be optimally utilized in flipped classroom circumstances because the freed-up in-class time can allow students to hypothesize, investigate, discuss, and justify problem-solving strategies [25].

There are several ways to facilitate learning through inquiry by flipping a classroom. In a productive failure-based flipped classroom, students are still expected to complete mathematical exercises despite their failures [26]–[28]. Students are then required to watch a video at home to put together what they have learned instead of using a video to learn how to solve a problem as homework [28]. As in any flipped classroom, the application does this during the course. When implementing an inquiry-based flipped classroom, teachers must carefully consider the arrangement of in-class and out-of-class stages. However, few studies have investigated the efficacy of assisting mathematics lecturers with teaching methods for inquiry-based flipped learning [29], [30]. In addition, inquiry-based learning in flipped classroom settings has received little attention in scientific and mathematics education research. Therefore, combining inquiry-based learning with flipped classroom strategies may result in more time for investigation during class [31].

This research is very important because problem-solving and creative thinking are two skills that need to be mastered and possessed by prospective elementary school teachers [32]. This skill is a basic ability that students should also master. This ability is becoming increasingly urgent due to the demands of an increasingly competitive workforce and complex problems. However, some results indicate a lack of students' ability to solve mathematical problems [33], [34]. Therefore, the systematic study of the process of creating and resolving problems and the ways to organize problem-solving procedures for learning mathematics has become a research priority [2].

Although proficient problem-solving can be enormously useful in both instances, prior research indicates that students frequently struggle with both tasks [35]–[37]. Mathematical creative thinking (MCT) is also an essential competence for pre-service mathematicians and is usually based on an underlying process or a visible product. Creativity, when taught within the context of the 21st century, can assist students in their capacity to adjust to the continuously shifting world that surrounds them[38]. Mathematical problem-solving and the generation of new ideas require creative thinking (CT) [38]. This process involves identifying which objects' regular properties have changed and how they have changed [39]. This strategy encourages students to find meaning in participating and reflecting on events [40]. A critical cognitive skill for students is recognizing when they have not fully thought through the potential drawbacks of a proposed solution [41]. Therefore, this study examines the effect of Android module-based inquiry flipped classroom learning on elementary pre-service mathematics problem-solving and creative thinking skills.

2 Methods

2.1 Research design

This study utilized a quasi-experimental design with a control group design for both the pre-test and post-test. Eight weeks were devoted to the experiment during the third semester of the 2020-2021 academic year. Geometry topics in mathematics classes were taught using Android module-based inquiry flipped classroom learning in experiment group 1. Group 2 of the experiment used a PowerPoint module-based conventional flipped classroom strategy, while the control group engaged in conventional learning. The experiment was conducted in a classroom with the same teacher for each group to avoid unanticipated results.

The iSpring Suite and Website to Apk Bulder application were used to generate an Android geometry module-based inquiry for flipped classroom learning. The Android geometry module-based inquiry for flipped classroom learning was designed to be accessible offline, but its video was only accessible online. The purpose of the videos being posted on Youtube is to reduce application size and make the application easier to install on smartphones. Figure 1 shows the content of the Android geometry module.

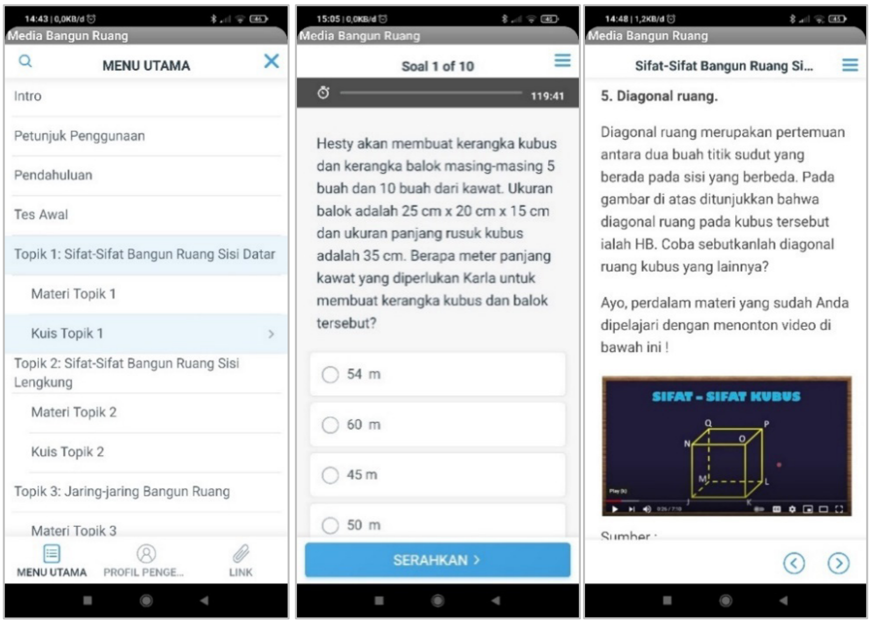

Fig. 1. An Android geometry module-based inquiry flipped classroom learning

2.2 Participants

The activity was implemented during the third semester of elementary pre-service education for the geometry course, which had a total of 123 students. Before the experiment, the three classes were randomly divided into two experimental groups and a control group. They consisted of 41 students in Experimental Group-1 (Android module-based inquiry flipped classroom learning, named the AMIFC group), 41 in Experimental Group-2 (PPT module-based conventional flipped learning, named the PMCFC group), and 41 in the control group (conventional learning, named the CL group). Their report shows that they have a similar background, age, and knowledge of geometry.

2.3 Data collection instrument

This study collected quantitative data through math problem-solving and creative thinking tests. Seventy study participants provided reliability estimates for each instrument. Field [42] stated a Cronbach's coefficient of .70 or higher indicates internal consistency reliability and all study instruments met or exceeded this standard. Before and after the study, all groups were given the mathematics problem-solving and creative thinking skills test to see how well they had done. The processing time for problem-solving skill assessments administered before and after the test is limited to 45 minutes with different questions.

Researchers developed the Mathematics Problem-Solving Skills Test (MPSST) to assess the problem-solving abilities of third-year elementary mathematics pre-service teachers enrolled in a geometry course during the third semester of their study. Three professionals in the field of mathematics teaching had taken the MPSST and approved its content. The MPSST was divided into four sub-scales adapted from Polya [43]. These sub-scales included understanding the problem, generating a solution plan, implementing the solution plan, and concluding. Understanding the problem was the first sub-score, followed by developing a solution strategy, implementing the plan, and solving the problem. The results of Cronbach's alpha also showed that the questionnaire for the usability test was reliable (alpha = 0.912).

In their third semester of pre-service education, students taking a geometry course were given the Mathematics Creative Thinking Skills Test (MCTS), which researchers developed to gauge their mathematics creative thinking capabilities. For the MCTS, three experts in math education confronted each other and verified the test's content. Four indicators of MCT fluency, flexibility, elaboration, and originality are used in the MCTS guidelines [44], [45]. Fluency refers to a person's ability to devise numerous solutions when solving a mathematical problem[46] and flexibility refers to the ability to modify one's problem-solving strategy if one becomes stuck[45]. The term "elaboration" refers to the ability of a specific solution path to allow for extended reasoning. As the last point, originality refers to the individual's ability to find a distinct and unusual path for their degree of knowledge [46]. Furthermore, Cronbach's Alpha results demonstrated that the questionnaire for the usability test was reliable (alpha = 0.744).

2.4 Data analysis

Data from the tests measuring mathematics problem-solving and creative thinking skills were analyzed using the Shapiro-Wilk distribution test, which revealed whether or not the data was normally distributed. Pre- and post-test values were both greater than or equal to 0.05.

As a covariate variable, the pre-test scores of the three groups were used in an ANOVA parametric test to determine any differences with the post-test scores. For further analysis, only variables with a normal distribution were considered. At this point, we used an analysis of variance (ANOVA) to see whether the groups with a normal distribution differed significantly in their pre-and post-test scores.

3 Results

The Shapiro-Wilk test was conducted to determine normality, while the homogeneity test was conducted as a prerequisite for the ANOVA test. The results of the Shapiro-Wilk test indicated that both the pre-test and post-test data had a normal distribution. In addition, variance homogeneity tests revealed that the pre-and post-test data originated from the same group.

3.1 Impact of the Android module-based inquiry flipped classroom learning implementation on mathematics problem solving skills

A paired t-test was performed for each group to determine gain scores and significant differences between the pre- and post-tests. The paired t-test indicated a statistically significant mean difference for each group. Additionally, pre- and post-test scores across groups were statistically significant at the 0.00 level (see Table 1).

Table 1. Paired samples T-test

Treatment	Pre-test	Post-test	Mean Differences	t	df	Sig. (2-tailed)
AMIFC	4.7	9.8	5.1	23.43	40	.000**
PMCFC	4.6	8.6	4.0	36.54	40	.000**
CL	4.6	7.3	2.7	11.93	40	.000**

The information on Table 1 shows the statistical value of IFL, t= 23.433, and p-value = .000< .05; CFL, t = 36.54, and p-value = .000< .05; CL t= 11.93 and p-value = .000< .05 Thus, it is concluded that there was a significant difference in mathematical problem-solving skills for the pre-tests and post-tests of all treatments. In addition, the mean differences for the Android Module-Based Inquiry Flipped Classroom Learning (AMIFC), PPT Module-based Conventional Flipped Learning (PMCFC), and Conventional Learning (CL) were 5.1, 4.0, and 2.7 points, respectively. So, the Android Module-Based Inquiry Flipped Classroom Learning obtained the highest mean difference in improving mathematics problem-solving compared to PMCFC and CL. After a paired T-test, ANOVA (analysis of variance) was used to analyze whether there were significant differences between the three study groups.

Based on Table 2, the value of F is 18.961 with a p-value of 0.000 <0.05, which means there is a significant difference in mathematics' problem-solving skills means between AMIFC, PMCFC, and CL. To find out whether there is a significant difference in the average value of problem-solving skills between the research groups, a post-hoc test was carried out, as shown in Table 3.

Table 2. ANOVA test of mathematics problem solving skills

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	119.63	2	59.81	18.96	.000
Within Groups	378.54	120	3.15		
Total	498.16	122			

Table 3. Post-Hoc analysis of mathematics problem solving skills

	(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	AMIFC	PMCFC	1.29*	.44	.010
		CL	2.39*	.44	.000
	PMCFC	AMIFC	-1.29*	.44	.010
		CL	1.10*	.44	.035
	CL	AMIFC	-2.40*	.44	.000
		PMCFC	-1.10*	.44	.035

Based on the post hoc test results in Table 3, it can be explained that the mathematics problem-solving skills of the AMIFC group paired with the PMCFC group had a significant difference of $p = .010 < 0.05$, while the AMIFC paired with CL also had a significant difference $p = 0.000 < 0.05$. Based on these calculations, this study indicates that Android module-based inquiry flipped classroom learning significantly impacts the mathematics problem-solving skills of elementary mathematics pre-service teachers.

3.2 Impact of the Android module-based inquiry flipped classroom learning implementation on mathematics creative thinking skills

The paired t-test indicated a statistically significant mean difference for each group. Additionally, pre and post-test scores across groups were statistically significant at the 0.00 level (see Table 4).

Table 4. Paired samples T-test mathematics creative thinking skills

Treatment	Pre-test	Post-test	Mean Differences	t	df	Sig. (2-tailed)
AMIFC	4.6	9.6	5	13.400	40	.000**
PMCFC	4.4	8.3	3.9	15.095	40	.000**
CL	4.4	7.2	2.8	9.448	40	.000**

Table 4 shows the statistical value of AMIFC, where $t= 13.400$, and p-value = .000< .05; PMCFC, $t = 15.095$, and p-value = .000< .05; CL $t= 9.448$ and p-value = .000< .05 Thus, it is concluded that there was a significant difference in the mathematical creative thinking skills pre-tests and post-tests for all treatments. In addition, the mean differences for the Android Module-Based Inquiry-Flipped Classroom Learning (AMIFC) = 5, PowerPoint Module-based Conventional Flipped Learning

(PMCFC)= 3.9, and Conventional Learning (CL) = 2.8. Thus, the Android module-based inquiry flipped classroom learning had the highest score in improving mathematics creative thinking skills in elementary school mathematics pre-service than the other two methods. After a paired T-test, ANOVA (analysis of variance) was used to examine the effect of inquiry-based flipped classroom learning on pre-service mathematics creative thinking, as described on Table 5.

Table 5. ANOVA test of mathematics creative thinking skills

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	117.382	2	58.691	15.051	.000
Within Groups	467.951	120	3.900		
Total	585.333	122			

Based on Table 5, the value of F = 15.05 with a p-value of 0.000 <0.05 means there is a difference in mathematics creative thinking skills using AMIFC, PMCFC, and CL. To find out whether there is a significant difference in the average value of creative thinking skills between the research groups, a post-hoc test was carried out, as shown in Table 6.

Table 6. Post-Hoc analysis of mathematics creative thinking skills

	(I) Class	(J) Class	Mean Difference (I-J)	Std. Error	Sig.
Tukey HSD	AMIFC	PMCFC	1.293*	.436	.010
		CL	2.390*	.436	.000
	PMCFC	AMIFC	-1.293*	.436	.010
		CL	1.098*	.436	.035
	CL	AMIFC	-2.390*	.436	.000
		PMCFC	-1.098*	.436	.035

*. The mean difference is significant at the 0.05 level.

Based on the post hoc test results in Table 6, it can be explained that the mathematics creative thinking skills of the AMIFC group paired with PMCFC had a significant difference p = .010 < 0.05. Likewise, the AMIFC paired with CL also had a significant difference p = 0.035< 0.05. Based on these calculations, this study indicates that Android module-based inquiry flipped classroom learning significantly impacts the mathematics creative thinking skills of elementary mathematics pre-service teachers.

4 Discussion

This study applied the Android module-based inquiry flipped classroom learning to help students acquire considerable knowledge and foster mathematics problem-solving and creative thinking in a control class. According to the study's objectives, using the Android module-based inquiry flipped classroom learning in geometry courses improved pre-service teachers' mathematics problem-solving and creative thinking skills in the short and long term after eight weeks of implementation. Several studies indicate that the ability to recognize and express complex relationships in a mathematical problem, as well as to draw different generalizations from these relationships and employ various problem-solving strategies, is an essential component of mathematical creativity [47], [48]. These study results revealed that the Android module-based inquiry flipped classroom learning, used in the experimental group, had more positive effects on mathematics problem-solving and creative thinking skills than in other groups. These results consistently demonstrate the effectiveness of the suggested method. This section describes how Android module-based inquiry flipped classroom learning helps advance teachers' mathematics problem-solving and creative thinking skills in elementary mathematics pre-service.

First, the Android module-based inquiry flipped learning is a transformation of the conventional module that uses ICT to make the existing modules more interesting and interactive. This is because we can add illustrations, animations, audio, and video to it. Students follow the steps in the program from start to finish. Students can improve their learning outcomes (self-assessment) by incorporating exam facilities or interactive evaluation into the Android module-based inquiry flipped learning, allowing for greater student interaction with course materials. Android learning material on mobile devices may create a socially engaging and constructivist learning environment for students [9]–[11]. In addition, the Android module is a convenient, effective, and interactive alternative learning source that can be accessed anytime and from any location via a smartphone [13]. Therefore, it may be utilized in a technology-based classroom to achieve specific learning goals[14].

Second, discussions are facilitated in inquiry-based learning by having students assume collective responsibility for learning and by giving them numerous opportunities to communicate with their classmates. In an inquiry-based flipped learning class, frequent communication practice and collective responsibility for learning appear to be potent methods for enhancing students' modes of learning. After participating in group discussions in class, students began to feel a sense of collective responsibility for their studies. They were required to discuss problems with group members and share their various approaches to find better solutions and enhance their understanding. The discussion consists of articulating and refining one's understanding and ideas and listening to others. Therefore, under the lecturer's guidance, inquiry-based learning provides the opportunity to develop these essential skills through direct experience. This finding supports previous studies that examine the impact of IBL on students' critical thinking skills [49]. In addition, it was discovered that students with an active learning style benefit more from the proposed approach than students with a reflective learning style in terms of learning achievement. Several studies also show that inquiry-based learning with the help of technology can improve students' motivation to learn their learning outcomes, their satisfaction with school, and their self-confidence [50]–[52].

Third, flipped classroom learning gave students more time to learn from easily accessible modules[53], [54]. With this extra time, students can learn everything they need about the geometry course from an Android module. When class time is regularly extended for all students, students' problem-solving skills improve dramatically. As previously stated, students were required to study the Android module (including learning materials, lecture videos, and quizzes) before each class session. As a result, they were able to solve and discuss problems in class. Finally, flipped learning saves students time in the classroom by making the lecturer's explanations of concepts available. Out-of-class time contributed to the reduction of in-class time for each student. This extra time to learn can benefit all students, and the majority will see an improvement in their grades. Several studies have reported similar results: flipped classroom learning can improve students' motivation[55], student performance in mathematics instruction [15]. In addition, a recent study on flipping mathematics classes by Cevikbas and Kaiser [56] indicates that well-designed flipped classroom scenarios can improve students' mathematical thinking and comprehension by employing a variety of teaching methods.

Fourth, several studies state that inquiry-based learning can optimize the effectiveness of flipped classroom situations [24], [57]. Moreover, integrating inquiry-based learning into the flipped classroom increases student engagement, motivation, satisfaction, and decreases anxiety [58].

In sum, Android module-based inquiry flipped classroom learning greatly affects how students develop their mathematics problem-solving and creative thinking skills. It works best when students are aware of and responsible for their actions. Pre-service teachers learned in a way that would stick with them for a long time. This was done by developing their ability to learn independently through inquiry-based flipped learning and by repeating and reinforcing what they had learnt through the Android module, including video, learning materials, and quizzes outside of school. Students will learn independently based on their ability to comprehend the learning materials offered for them. In addition, when the teaching and learning process is conducted online, students can regulate their study time and find comfortable studying environments [59], [60]. Students can also repeat information that they have not fully comprehended. Consequently, learning activities become more student-centered when this paradigm is used. Therefore, they have many resources in the Android module for inquiry-based learning in class.

5 Conclusion

This study aims to examine the effect of Android module-based inquiry flipped classroom learning on elementary pre-service mathematics problem-solving and creative thinking skills. The study found that math pre-service teachers were much better at solving mathematics problems and using creative thinking when using Android module-based inquiry for flipped classroom learning. In this study, Android module-based inquiry flipped classroom learning is beneficial for enhancing problem-solving and creative thinking skills in geometry because its use effectively extends learning time, permits the acquisition of more knowledge, and encourages a collective responsibility for learning in order to engage in the process of deeper learning. However, additional time and effort are required to prepare Android modules, select appropriate problems, and create a conducive environment for discussion under this combined approach. In addition, Android module-based inquiry flipped classroom learning can be implemented in K-12 or higher education institutions in other countries and cultures, with both introverted and extroverted students.

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