Unlocking the Future: Mathematics Teachers' Insight into Combination of M-learning with Problem-Based Learning Teaching Activities

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Abstract: The rapid advancement of information technology has significantly facilitated modern human life. However, despite the swift progress in digital technology, there has been limited headway in leveraging technology to support mathematics education, particularly in the domain of problem-solving. Mobile learning (M-learning) platforms offer promising avenues to address this gap, providing accessible and interactive tools that can enhance problem-solving skills in mathematics through engaging activities, real-time feedback, and personalized learning experiences. Thus, this study aimed to evaluate the implementation of a combination of M-learning and problem-based learning (M-PBL) teaching activities among mathematics teachers. The M-PBL teaching activities were developed based on the M-learning model, Problem-Based Learning model, and Social Constructivism theory, resulting in 17 pertinent activities eligible for execution by mathematics teachers. The evaluation phase was conducted through interviews with three mathematics teachers. Data collection involved interview transcripts and document analysis, with subsequent content analysis based on the TUP Usability Evaluation Model's three facets: technology, usability, and pedagogy. Overall, the participating teachers expressed positive perspectives on the technological, usability, and pedagogical aspects of the M-PBL teaching activities. These activities provide teachers with a valuable resource to creatively teach problem-solving in mathematics using mobile technology, fostering the development of creative and innovative students aligned with the aspirations of the Fourth Industrial Revolution.

Keywords: M-learning, problem-based learning, teaching activities, interview, TUP usability evaluation model

INTRODUCTION

The emergence and evolution of the Fourth Industrial Revolution have inaugurated a transformative epoch, imprinting an indelible mark on the trajectory of technological and scientific advancements globally. This epochal phase signifies a seismic shift in the way societies interact with technology, characterized by the integration of cutting-edge digital innovations, sophisticated automation, and the seamless exchange of data. According to Bonfield et al. (2020), this revolution epitomizes a state of change and progress in terms of human civilization and culture. It is intricately linked to the introduction of modern communication, technological applications, and information control. Alaloul et al. (2020) elucidates that this fourth revolution markedly diverges from its three predecessors. This revolution seamlessly integrates the biological, physical, and digital realms. As a consequence, a myriad of new technologies emerges, exerting an impactful influence across various disciplines.

In response to these transformative developments, teachers are urged to embrace technology as an integral tool for pedagogical enrichment (Payadna et al., 2020). By effectively leveraging technology, teachers not only enhance the quality of their teaching but also cultivate a learning environment that resonates with the dynamic needs of modern students. The dissolution of traditional boundaries ensures that the delivery of knowledge becomes a flexible and immersive experience, fostering an educational landscape that extends beyond the conventional classroom setting (Ehsanpur & Razawi, 2020). Moreover, the profound impact of technological advancements, exemplified by the Internet of Things (IoT) in the context of IR 4.0, has left an indelible mark on both teachers' pedagogical approaches and students' learning patterns. The strategic integration of online content systems, such as mobile learning (M-learning), significantly contributes to sustaining an advanced and efficient education system responsive to the demands of the digital age (Qashou, 2021).

The primary goal of introducing M-learning is to enhance students' motivation to delve deeply into a particular field of study (Chantaranima & Yuenyong, 2021). This is because learning applications on mobile devices have encouraged teachers and students to explore information from various perspectives, generating new ideas. Moreover, freely available, multifunctional, and easily accessible learning applications have attracted the interest of teachers and students in using them optimally (Kamaghe et al., 2020). For instance, during the period of the Movement Control Order (MCO), learning applications such as Google Classroom as an information-sharing platform and Kahoot and Quizizz as assessment platforms were widely used (Alsharida et al., 2021). These learning applications facilitated the implementation of teaching and learning at home during that period. As a result, students were able to maintain a continuity of education despite the challenges posed by the circumstances.

Despite the availability of various learning applications for teachers, it is undeniable that the implementation of technology in mathematics education, especially in problem solving, is still at a low level (Verschaffel et al., 2020). Teachers still predominantly employ one-way communication and are limited to existing learning resources (Le et al., 2022), emphasis on uniform learning methods and top-down teaching approaches (Bakker et al., 2021). Such practices should not persist because contemporary students are exposed to technological advancements in their lives (Luritawaty et al., 2024). The current generation of students, known as Generation Z, is considered techno-savvy and requires interactive, collaborative, and hands-on learning (Hamidi & Jahanshaheefard, 2019). Recognizing and addressing these factors becomes imperative for teachers to bridge the gap between traditional teaching methods and the preferences of a generation deeply immersed in technology.

To enable such changes, a transformation is needed in the field of mathematics education (Engelbrecht et al., 2020). This change must occur to ensure that the current generation of students evolves alongside technological advancements. This study focused on the implementation of a new teaching method involving a combination of M-learning and Problem-Based Learning (M-PBL) that mathematics teachers can use to improve their teaching practices. After the implementation process, there is a need to obtain teachers' perspectives on the effectiveness, efficiency, and satisfaction with the implementation of M-PBL teaching activities. To this end, the researcher chose the interview method to obtain feedback from mathematics teachers on the usability evaluation of M-PBL teaching activities. This evaluation was conducted based on the TUP Usability Evaluation Model, which involves three aspects: technology, usability, and pedagogy (Bednarik et al., 2004).

THE M-PBL TEACHING ACTIVITIES

As a guide, the researchers conducted literature surveys on the theories and models that support the study's constructs. The development of the theoretical framework of this study involves three main components namely the M-learning Model, Problem-Based Learning Model and Social Constructivism Theory. To this end, there are 17 eligible and relevant M-PBL teaching activities that can be conducted by mathematics teachers as shown in Figure 1 until Figure 17. The following is stated in summary as the models and theory used to develop the combination of M-learning with Problem-Based Learning (M-PBL) teaching activities.

- M-learning Model: In this study, the researcher selected the M-learning model by Brown (2005). In this regard, two main components were chosen, flexible learning and learning with electronic devices.
- Problem-Based Learning Model (PBL): In this study, the researcher adopted Wee's (2004) PBL Model to conduct problem-solving lessons. The researcher selected this model as a guide since it evolved from a more fundamental paradigm, namely PBL Model by Barrow (1980). In addition, the model includes various simple activities for teachers to comprehend and implement.

- Social Constructivism Theory: In this study, the researcher selected Lev Vygotsky's 1978 theory of social constructivism. Three components are involved, active student learning, scaffolding, and the Proximal Development Zone (ZPD).

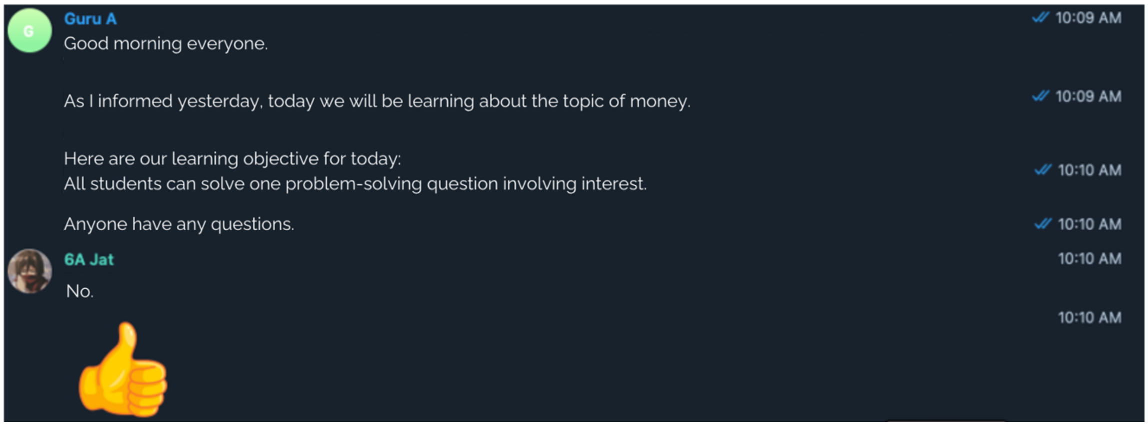

Figure1: Teacher shares the learning objective that the pupils need to achieve using the telegram

Figure 2: Pupils are guided by the teacher to form groups for various levels of ability using the telegram

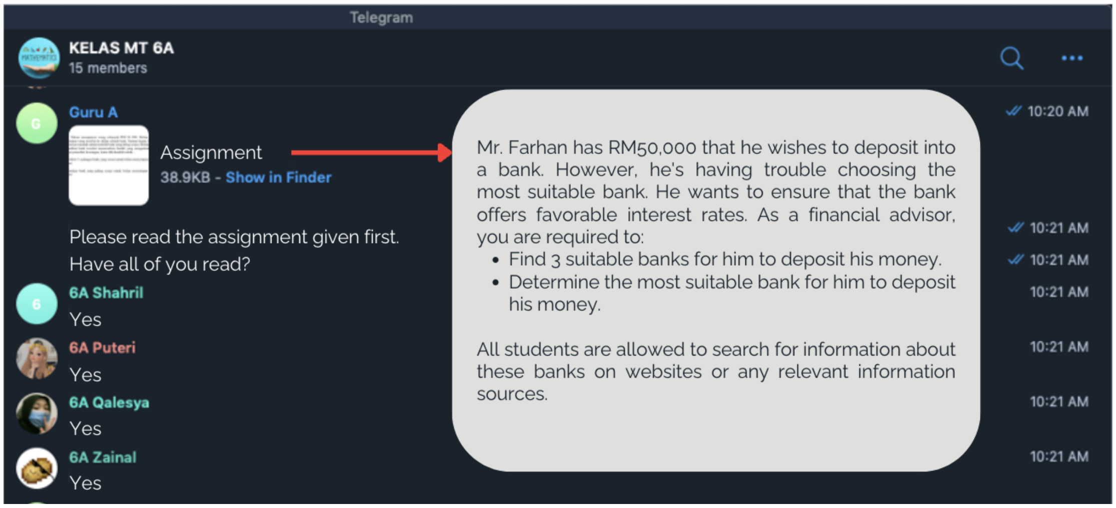

Figure 3: The teacher sets out the tasks (problems) that each group needs to solve using the telegram

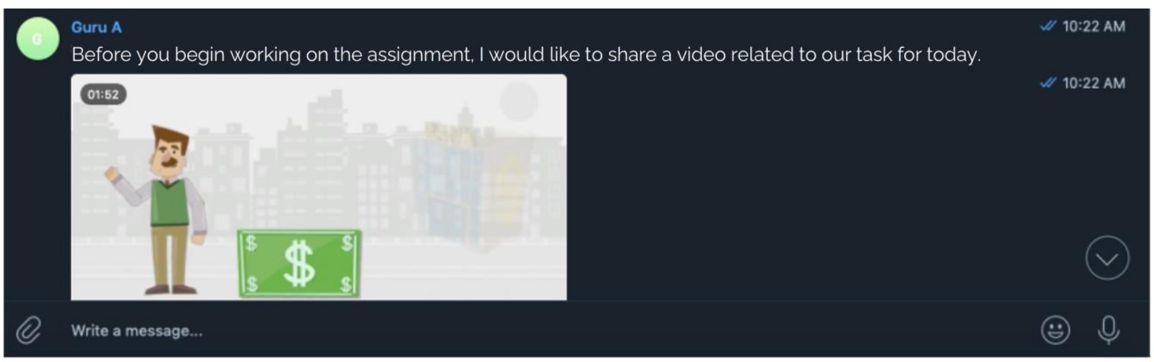

Figure 4: Teacher share several stimulus materials consisting of various forms of media using the telegram

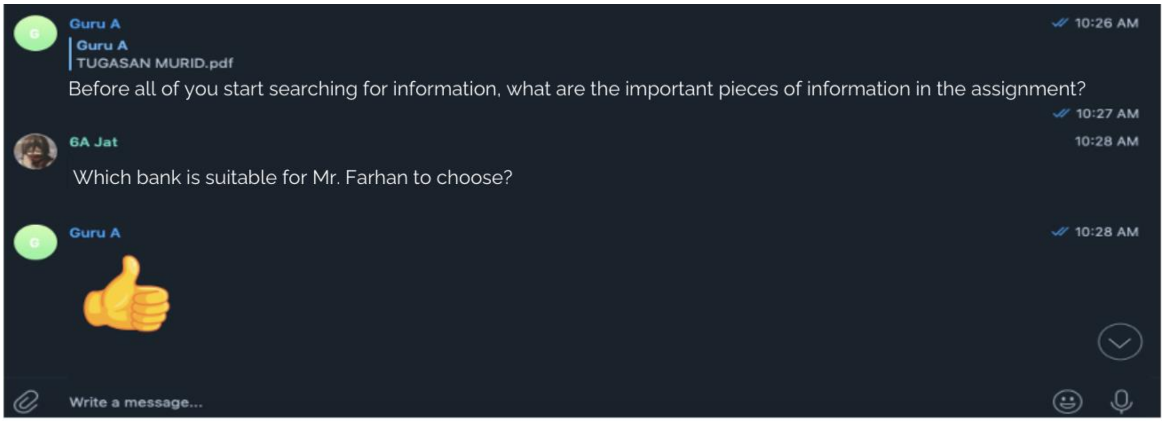

Figure 5: Each group discusses the tasks assigned in the context of their daily living situations using the telegram

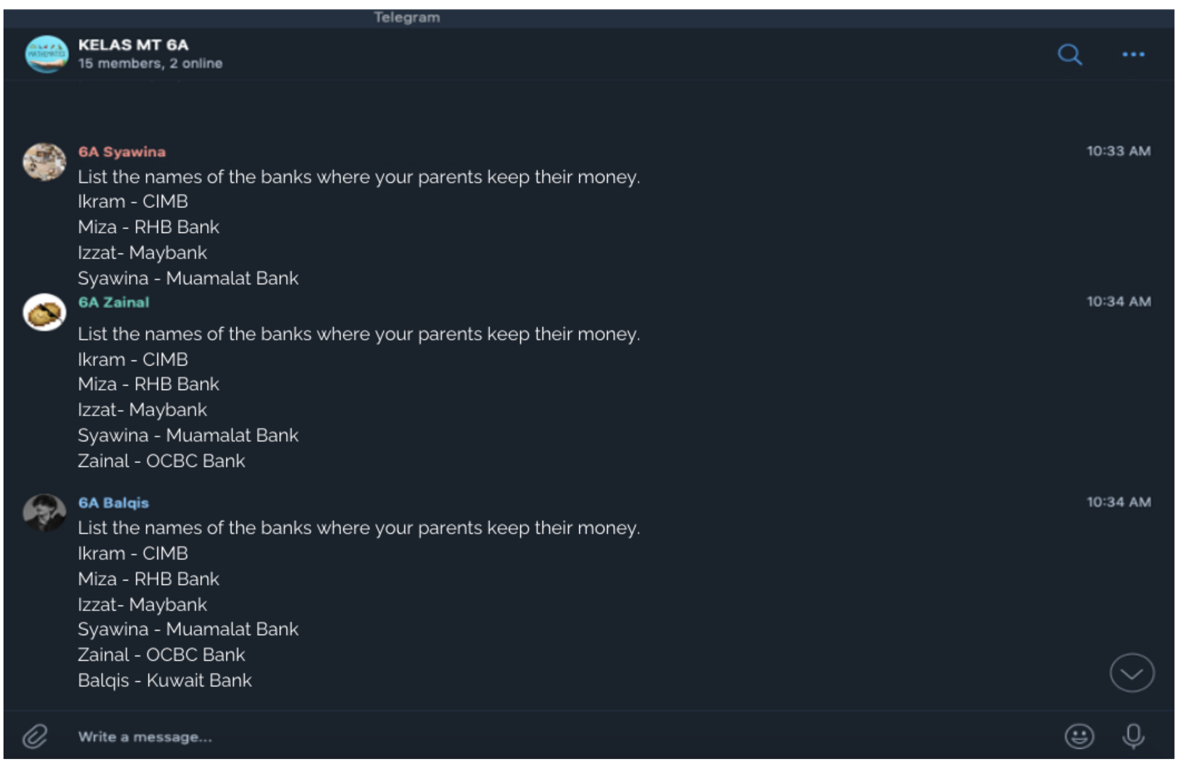

Figure 6: Each group understands and talks about the stimuli material shown using the telegram

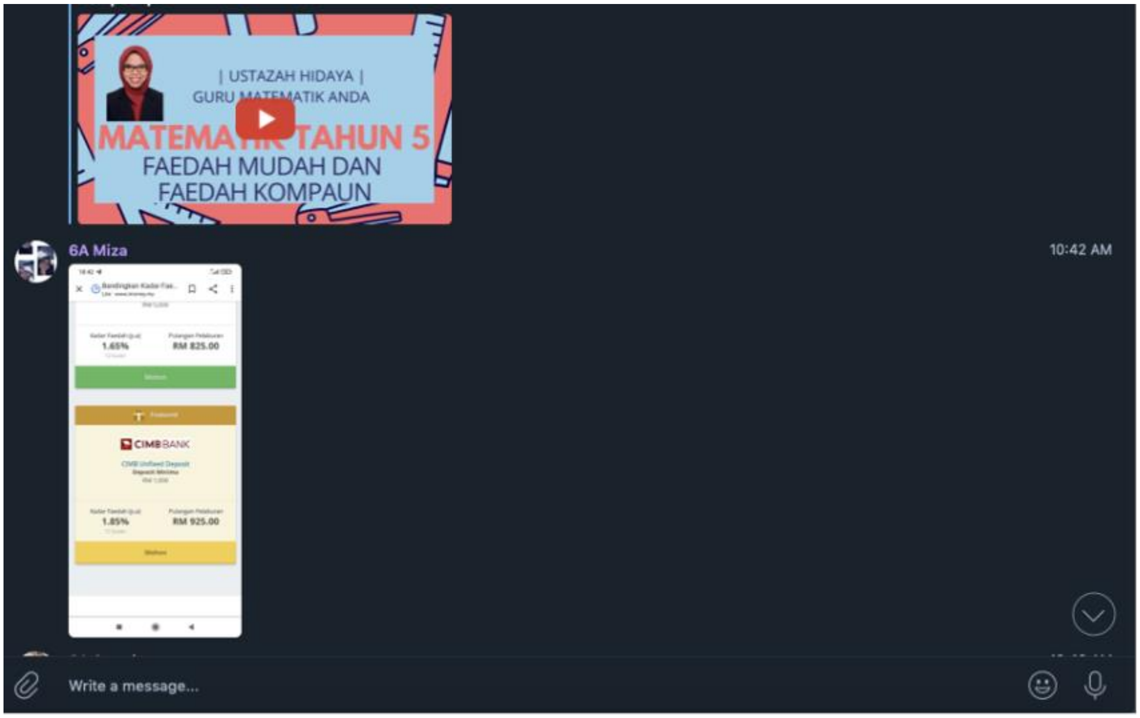

Figure 7: Each group is given time to explore the various applications and other learning media available on the mobile devices to get solution ideas

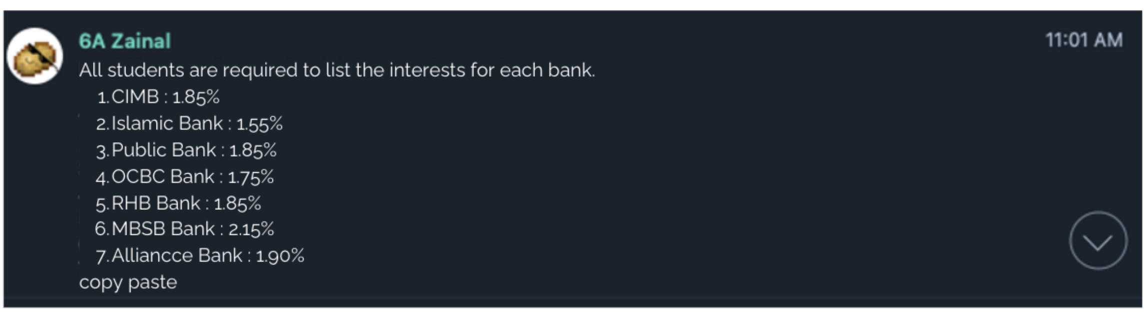

Figure 8: Each group shares information that has been obtained with the teacher and other groups through the telegram

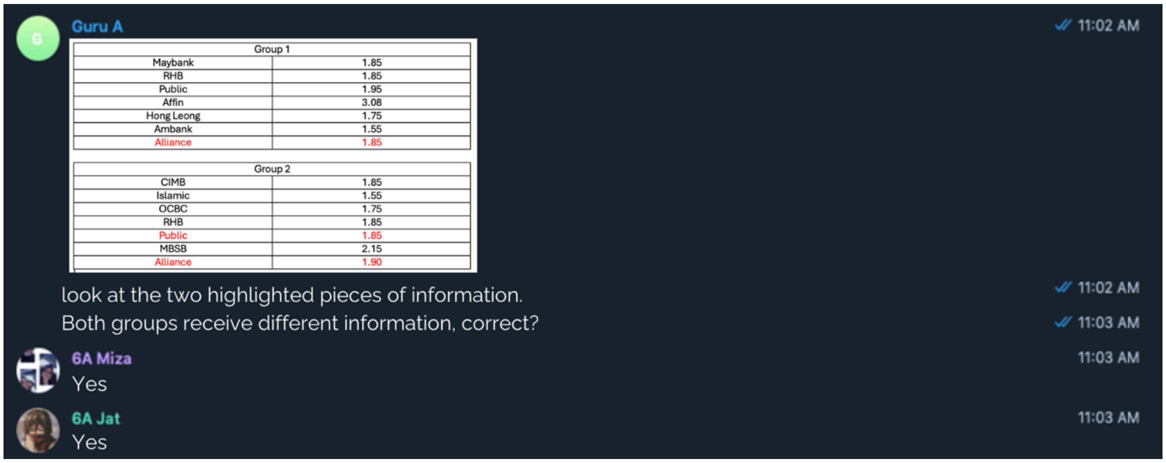

Figure 9: Teacher classify the information obtained from each group according to their preferences through the telegram

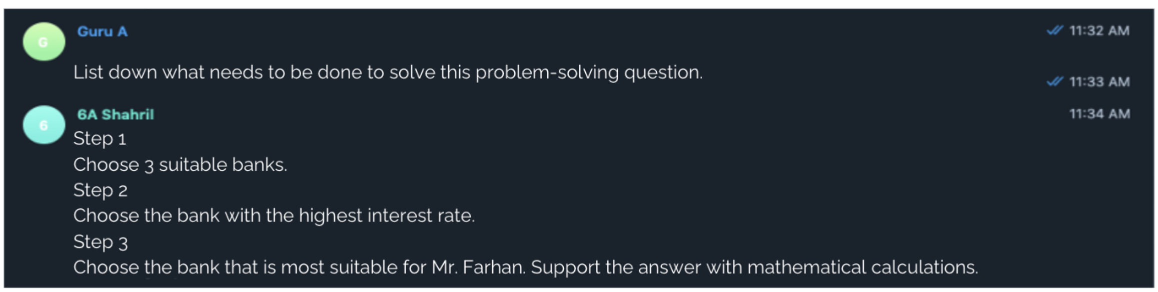

Figure 10: Each group discusses the steps that can be used to complete the tasks through the telegram

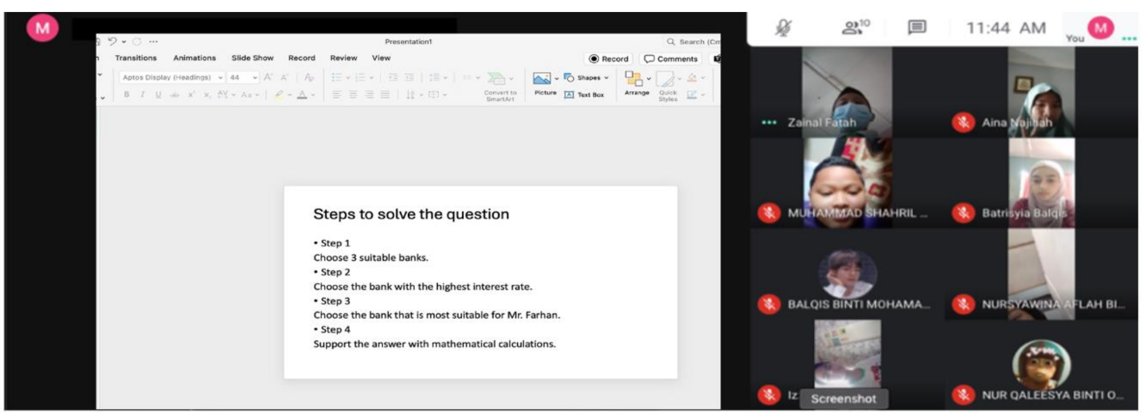

Figure 11: Each group discusses the most appropriate steps to use to complete the tasks given through the Google Meet

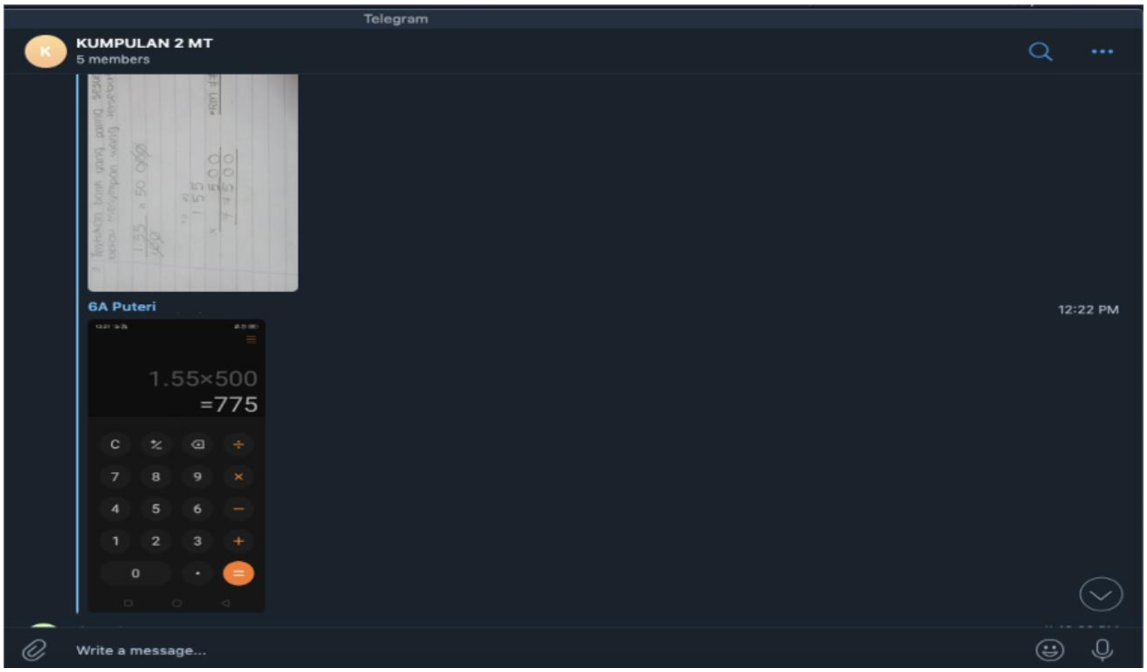

Figure 12: The teacher guide each group to revise the steps that the solutions have selected using the telegram

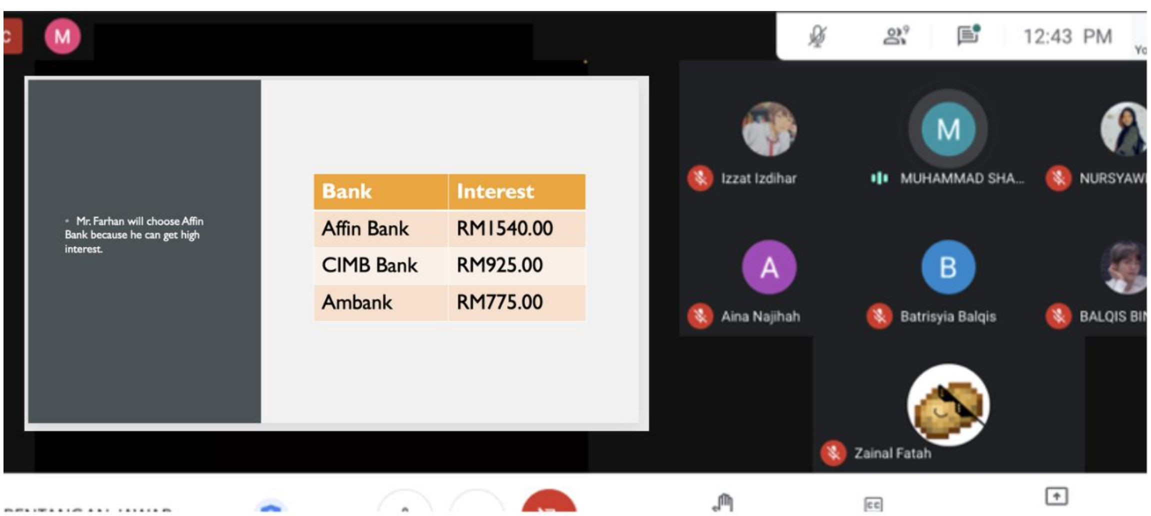

Figure 13: Each group presents the final solution in various forms of graphic media using the Google Meet

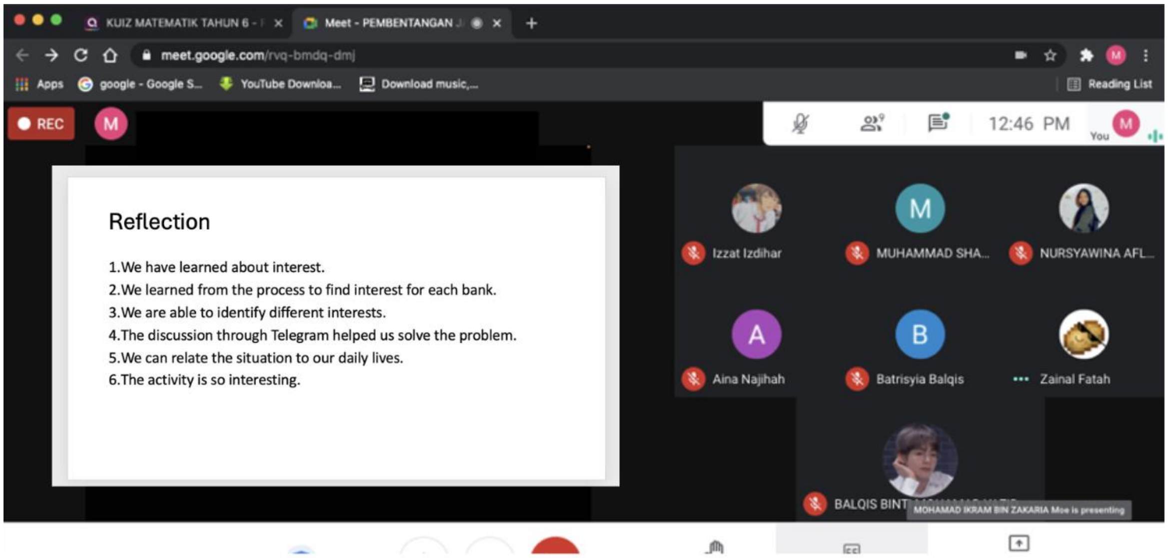

Figure 14: Each group concludes on the learning process and shares it with the teacher and other groups through the Google Meet

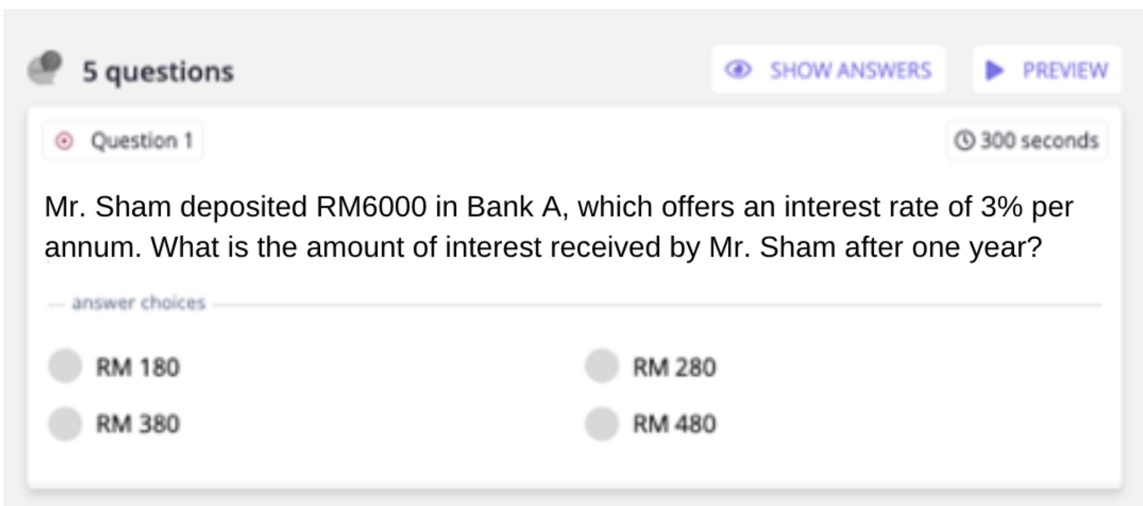

Figure 15: Pupils answer the quiz questions assigned by the teachers through the Quizizz application

Figure 16: The teacher gives feedback based on the marks obtained on Quizizz through the Google Meet session

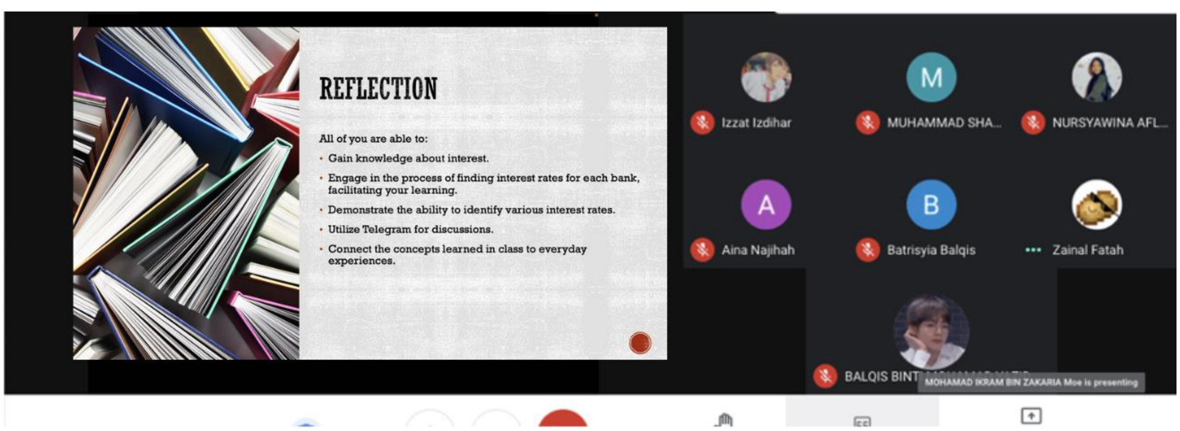

Figure 17: The teacher concludes on the learning using the Google Meet

METHODOLOGY

Research design

The researchers have applied a qualitative approach to assess the usability of the M-PBL teaching activities. This approach is a form of descriptive study involving the direct collection of data in the field (Cilesiz & Greckhamer, 2020). Qualitative data can be described as a form of description involving spoken or written words about human behavior that can be understood (Johnson et al., 2020). Qualitative data can be obtained through observation, interviews, and written materials (Cheung & Tai, 2021). After careful consideration, the researchers chose the technique of data collection through interviews. The interview was conducted according to the TUP Usability Evaluation Model, involving three aspects: technology, usability, and pedagogy (Bednarik et al. 2004). This technique can help the researchers assess the suitability and effectiveness of the M-PBL teaching activities involving minimum access, cost, and time while not compromising individual privacy.

TUP usability evaluation model

The TUP model serves as a guide that researchers can use to assess a model, module, product, or teaching activity that integrates technology into the educational environment (Laurah Markus, 2022). This is because the model was developed with the aim of evaluating technology-based learning environments (Bednarik et al., 2004). Therefore, this model facilitates users who wish to assess the implementation of technology in the development of models, modules, products, or teaching activities. The name of this model is derived from the acronym "TUP," which refers to three aspects: technology (T), usability (U), and pedagogy (P). The model focuses on a checklist that serves as an evaluation tool (Hamid et al., 2023). This checklist has been developed based on Nielsen's Usability Model (1994), involving elements of technology and usability, and the theoretical framework of constructivism theory (Soloway, 1996), involving pedagogical elements in the learning environment (Idris & Md Nor, 2022). Both have been combined to form a theoretical framework in Bednarik's TUP Usability Evaluation Model (Bednarik et al., 2004).

Participants

In this study, the participants are specifically selected through the purposive sampling method. The researcher has identified the characteristics for selecting the participants, such as (1) possessing knowledge and experience in teaching mathematics; (2) having good communication skills; (3) being willing to participate in the study; (4) having the availability to participate in the study; (5) owning at least one mobile device; and (6) having high skills in using mobile devices. Simultaneously, the number of participants is also an important consideration. However, past researchers have stated that there are no specific criteria or numbers for determining the number of participants in qualitative research (Bogdan & Knopp 2003; Delamont & Jones 2012). Therefore, the researchers have chosen three participants (Teacher A, Teacher B, Teacher C). This selection is based on the characteristics established by the researcher. Additionally, these teachers have expressed interest in and willingness to participate in this field study.

Instrument

There are several types of instruments that can be used to collect data in qualitative research. Among them is the interview protocol, which is relevant to qualitative studies. There are three types of interviews that can be conducted: open-ended interviews, informal interviews, and formal interviews (Busetto et al., 2020). Additionally, Engward et al. (2022) explain that there are three types of interviews: unstructured interviews, semi-structured interviews, and structured interviews that can be employed in qualitative research. In the context of this study, the researchers have opted for a semi-structured interview. The items in this semi-structured interview protocol were developed based on the TUP Usability Evaluation Model (Bednarik et al., 2004). This semi-structured interview is administered with the aim of obtaining feedback from teachers regarding the usability assessment of the M-PBM teaching model in real-world contexts.

Validity and reliability of the data

Triangulation is a process that involves using multiple sources of data, researchers, data collection methods, and analyses with the aim of providing the researchers with an opportunity to confirm findings more robustly and reliably (Santos et al., 2020). This technique aims to enhance the validity of research findings by reinforcing them with other methods. In the context of this study, the researchers have collected data using the semi-structured interview technique, and these findings have been corroborated through document analysis, specifically the analysis of lesson plans. Simultaneously, the researchers have sought confirmation from the participants to validate the data and interpretations by asking them to review the data (Craig et al., 2021). Participant review serves to verify and improve the accuracy of the research information obtained. Moreover, this method also serves to enhance the credibility and reliability of the research findings.

Research procedure

The study was conducted from October 1 to October 31, 2023. In each session, the researchers took an active part as observers, while the participants were given autonomy to carry out the teaching activities. Each teaching session was conducted once a week to ensure that teachers could make adequate preparations and that students were better prepared to engage in the subsequent teaching and learning sessions. Following the completion of the M-PBL teaching activities, the researcher conducted semi-structured interviews with all participants. The purpose of this interview was to gather feedback from the participants regarding the teaching activities. The interview session was conducted simultaneously, involving all participants together. This simultaneous approach was employed to further enhance the validity of the interview findings that were obtained (Craig et al., 2021).

Data analysis

In qualitative research, there are various techniques for analyzing data, such as phenomenology, ethnography, and content analysis (Bengtsson 2016). In the context of this study, the researcher employed a content analysis approach to analyze interview data. This aligns with Roller's perspective (2019), which suggests that content analysis can be a suitable approach for analyzing interview data. This approach helps the researcher identify themes, concepts, and meanings. Furthermore, the coding system aids the researcher in addressing the research questions (Elo et al. 2014). Therefore, the researcher undertook the following steps: (1) manually transcribing the interviews; (2) Organizing the data; (3) constructing categories and themes; and (4) coding the data.

RESULTS

This section discussed the usability evaluation of the combination of M-Learning with Problem-Based Learning (M-PBL) teaching activities. This evaluation was conducted through a semi-structured interview based on the TUP Usability Evaluation Model, covering technological, usability, and pedagogical aspects (Bednarik et al., 2004). Overall, participants were satisfied with the technological, usability, and pedagogical aspects of M-PBL teaching activities.

Technological evaluation

This section discussed the theme of technology. There were two categories within this theme. Firstly, the suitability of mobile device usage, and secondly, the use of learning applications. Findings from interviews with participants indicated that the mobile devices and learning applications used in M-PBL teaching activities were appropriate and user-friendly.

> *"Hmmm... I have no issues at all using a tablet or phone. Because we always use them. So... it's really suitable to use these gadgets, both of them." (TB1/R1, p. 1, lines 21-23).*

> *"Google meet, telegram, those are all things I've been using regularly. Our class group used telegram before. So far... I'm okay with using all of them" (TB1/R2, p. 2, lines 32-33).*

Usability evaluation

This section discussed the theme of usability. There were four categories within this theme. First, suggestions for M-PBL teaching activities. Second, the suitability of M-PBL teaching activities. Third, improvement in students' understanding through M-PBL teaching activities. Fourth, the enjoyment of conducting M-PBL teaching activities. Findings from interviews with participants indicated that teachers agreed with the M-PBL teaching activities. At the same time, they felt that all these teaching activities were suitable and capable of enhancing students' understanding. Besides, participants also enjoyed implementing M-PBL teaching activities.

> *"Really like it, sir... because before this... I had to skip teaching problem-solving. The reason is... well, it's difficult to teach that skill during class... now, when there's a method on how to teach, it becomes a bit easier... right?" (TB1/R1, p. 2, lines 44-46).*

> *"Suitable... very much so. Students also learn when they want to solve questions. Moreover... they all have phones anyway." (TB1/R2, p. 2, lines 55-56).*

> *"The kids nowadays... are experts. They can find all the information. It's the information that helps them understand and complete task. Moreover... even if they don't understand, they can ask me or other teachers." (TB1/R3, p. 3, lines 69-71).*

> *"Very enjoyable, sir... I get all sorts of answers... this is the best. Even for getting the students to achieve Band 6, it's possible. Because it produces various responses." (TB1/R1, p. 3, lines 74-75).*

Pedagogical evaluation

This section discussed the theme of pedagogy. There were four categories within this theme. First, exploration activities were part of the M-PBL teaching activities. Second, activities involving the use of learning applications. Third, there were discussion activities in the M-PBL teaching activities. Fourth, assessment activities were part of the M-PBL teaching activities. Interview findings with participants indicated that exploration activities were suitable. At the same time, participants also believed that learning applications such as Google Classroom, Google Meet, and Quizizz were appropriate. Additionally, the teaching activities conducted also encouraged discussions, while assessment activities involving reflection and online quizzes were deemed suitable, engaging, and enjoyable.

> *"This activity is very enjoyable. Students have the opportunity to generate various answers because they search for different information. The best part is when they compare answers. There are groups that tease their friends because their friend used the wrong information." (TB1/R3, p. 5, lines 135-138).*

> *"All those apps are easy to use... access and everything." (TB1/R2, p. 5, line 142).*

> *"Overall... it's okay, sir. The students just discuss. But, you know, their language... it's diverse... even during Google Meet sessions, they respond. When discussing, various ideas can come out." (TB1/R1, p. 5, lines 153-155).*

> *"I see there are two things we assess... first, reflections. Then... answering quiz questions, right? The reflections are okay. It's just... at the beginning, you know. The students don't understand how to do it... when I mentioned something like a parking lot, then they understand. They share what they learned. The quiz is really enjoyable. Plus, the quiz helps*

me assess the students. The reflections help me know what the students learned." (TB1/R1, p. 6, lines 165-170).

DISCUSSION

It was found that teachers involved in this evaluation phase were satisfied with the combination of M-learning with problem-based learning (M-PBL) teaching activities. Specifically, teachers expressed positive views on three evaluated aspects: technology, usability, and pedagogy. This indicates that these teaching activities are suitable and can be further developed in a real educational context. Technological aspect findings show that teachers had no issues using smartphones, iPads, and laptops for implementing M-PBL teaching activities. They felt that mobile devices were suitable for teaching, influenced by factors such as convenience, suitability, and skills. These factors motivated teachers to use mobile devices in their teaching (Al-Rahmi et al., 2021).

Additionally, teachers' skills influenced their ability to conduct M-PBL teaching activities. The study findings indicate that teachers possess high skills in using mobile devices. These skills helped them determine the suitability of mobile devices for various teaching activities (Sophonhiranrak, 2021). It also facilitated their access to learning materials available in various learning applications (Huang et al., 2020). These views align with the study's findings, where teachers' skills, experience, and knowledge eased their use of various learning applications like Google Classroom and Google Meet.

Usability aspects findings also indicate that teachers had no issues implementing suggested M-PBL teaching activities. Teachers found that the proposed teaching activities were suitable for the context of mathematics education. These findings support the views of Sjöberg and Brooks (2022) suggesting that mobile technology's use can guide teachers in problem-solving teaching. At the same time, teachers also found that the suggested teaching in the M-PBL teaching activities could enhance students' understanding of learning (Mapile & Lapinid, 2023). This is because students have knowledge and skills in using mobile devices, impacting their learning. They can use their knowledge and skills to seek various information in learning applications available on their mobile devices (Criollo-C et al., 2021).

Through these activities, students could generate various new ideas (Kacetl & Klímová, 2019) using the gathered information. Furthermore, they could build knowledge and understanding of the desired learning content (Mughal et al., 2018). Additionally, M-PBL teaching activities also increased teachers' enjoyment of problem-solving teaching. Teachers felt that these activities could capture students' interest in learning. One particularly engaging activity was exploration. In this activity, students were given the opportunity to explore learning using various learning applications on mobile devices. Thus, students had the chance to access various information and new ideas through this activity (Kunwar et al., 2023).

Pedagogical aspects findings also show that teachers had positive views on learning activities in the M-PBL teaching activities. Teachers believed that exploration activities were suitable. Nikolopoulou (2018) suggests that exploration activities through mobile devices are efforts made to promote active learning among students. At the same time, exploration activities through this mobile technology can help students build knowledge and enhance their understanding (Holenko Dlab et al., 2020). This activity also helps students build various new and authentic ideas through information obtained from various sources and media (Bernacki et al., 2019).

At the same time, the recommended learning applications were also suitable according to their functions and intended activities. For example, the Google Meet application served as a platform for conducting video conferences. Chinaza's study (2021) shows that this application is highly suitable for immediate use during the COVID-19 pandemic. This application has helped teachers conduct live teaching to deliver learning content, discussions, and reinforcement. Additionally, teachers found that this teaching could encourage discussions and collaboration between teachers and students and among students (Baker et al., 2020). The use of suitable learning applications can create a collaborative approach among students (Ansari & Khan, 2020).

Moreover, teachers also found that the assessment activities conducted were suitable, interesting, and enjoyable. This is because these activities provide information to teachers about the teaching and learning process experienced by both teachers and students. Through this feedback, teachers can assess students' objective achievements (Bachelor & Bachelor, 2016). Thus, teachers can improve the teaching process and subsequently enhance the quality of teaching in the future. At the same time, these activities can also help students increase their self-confidence (Choi et al., 2017), encourage students to think critically, help students identify mistakes in learning, improve students' skills in identifying creative ideas, and monitor learning progress from the initial stage to the final stage (Cunningham, 2018). In conclusion, the usability evaluation of the M-PBL teaching activities shows that teachers have positive views on the technological, usability, and pedagogical aspects.

CONCLUSION

This study holds significant implications for the continual evolution of teaching methodologies, emphasizing the pivotal role of usability and pedagogical considerations in the successful incorporation of technology. In the future, other researchers could delve into the impacts of M-PBL teaching activities on students' mathematics learning outcomes, broadening the scope to encompass diverse educational contexts and subjects. To facilitate the replication of the study, researchers are encouraged to follow all the activities as suggested in the M-PBL Teaching Activities (Table 1). Additionally, researchers should document their procedures meticulously to ensure transparency and reproducibility, thereby contributing to the advancement of knowledge in this area. This includes providing detailed descriptions of each activity, specifying the intended learning outcomes, outlining the technological tools used, and offering guidance on the facilitation of problem-solving discussions. By adhering to these guidelines, researchers can enhance the reliability and validity of their findings and promote the replication of the study in diverse educational contexts. Furthermore, an exploration of potential challenges and a proactive response to the evolving needs of teachers engaged in technology-integrated teaching practices will contribute to the ongoing enrichment of the educational research landscape. This iterative process of refinement and exploration will be pivotal in shaping the future landscape of mathematics education and its profound impact on student learning and teacher practices.

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