Combination of M-learning with Problem Based Learning: Teaching Activities for Mathematics Teachers

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Abstract—This study was conducted to identify elements (teaching activities) that teachers can engage with involving a combination of M-learning methods with Problem-Based Learning methods (M-PBL). This study was conducted using the Nominal Group Technique (NGT) involving 11 experts with various fields of expertise such as mathematics education, educational technology, M-learning, pedagogy and the curriculum as well as primary school mathematics education teachers. The analysis of the findings was carried out using descriptive statistics (percentages) to determine the priority and ranking for each teaching activity. The findings show that overall, there are 30 relevant M-PBL teaching activities that can be carried out by teachers. The findings also show that teachers sharing the learning objectives that the pupils need to achieve using learning applications that are available on mobile devices (98%) ranked first while the teacher classifying the information obtained from each group according to priority through learning applications available on mobile devices (75%) ranked last. In conclusion, this study shows that both methods can be combined to form a new teaching method in the current 4.0 education era.

Keywords—m-learning, problem based learning, nominal group technique

1 Introduction

The development of information technology in the Industrial Revolution 4.0 (I.R 4.0) has facilitated human life in the 21st century. The development of information technology has increased public expectations of educational changes [1]. With the rapid advancement of technology, people have come to expect that education will keep pace with these changes and provide students with the skills and knowledge needed to thrive in a digital world. In particular, the development of information technology has led to an increased focus on using digital tools and resources in education [2]. Students are now expected to have access to computers, tablets, and other digital devices and to use these tools to support their learning across various subjects, including mathematics, science, language arts, and social studies. Various learning concepts have been developed in the 4.0 era to help teachers cultivate the teaching and learning of digital technology materials [3]. These learning concepts are designed to help teachers stay up-to-date with the latest technological developments and equip them with the skills and knowledge needed to incorporate digital technology materials into their teaching effectively.

Mobile learning methods (M-learning) are a proposed learning concept in the revolutionary 4.0 era [4]. M-learning refers to the use of mobile devices, such as smartphones and tablets, to support teaching and learning activities. With the widespread availability of mobile devices and the increasing popularity of mobile applications, M-learning has become an essential component of the digital learning landscape [5]. M-learning has several advantages over traditional classroom-based learning, including increased flexibility and accessibility. With M-learning, students can access learning materials and resources from anywhere and at any time, allowing them to learn on their schedule and at their own pace [6]. In addition, M-learning can support personalized and adaptive learning experiences, which is one of its key advantages over traditional classroom-based learning. Personalized learning refers to the ability of students to tailor their learning experience to their individual needs and preferences [7]. In contrast, adaptive learning refers to the ability of the learning system to adjust to the student's level of knowledge and provide appropriate feedback and support [8].

However, there are also some challenges associated with the implementation of M-learning in mathematical education. Previous studies [9-10] show that teachers have difficulty implementing M-learning in problem-solving lessons. Several issues have been identified, such as the difficulty experienced by mathematics teachers when seeking to combine M-learning with problem-solving teaching methods. Chantaranima and Yuenyong [3] explained that mathematics teachers have difficulty translating the existing teaching methods and models in relation to the new form of teaching practices that should be implemented. As a result, during the implementation process, the mathematics teachers could not convey the concept of mathematics well [11], associate the subject of lessons with everyday life [12], not guide the pupils systematically during the problem-solving process [13], and did not achieve the objectives set [14]. This difficulty occurs because mathematics teachers lack the skills to effectively customize the available models and methods despite their level of knowledge of the technology being at a high level.

Besides, a lack of training and support is also a significant factor contributing to the difficulty of implementing M-learning in problem-solving lessons [15]. By implementing M-learning, teachers must have different skills and competencies than traditional classroom-based teaching. Teachers need to be able to select appropriate mobile applications, create digital content, and manage student engagement in a mobile learning environment [16]. These skills require training and support, which many teachers may not have received. Furthermore, integrating M-learning into problem-solving lessons requires teachers to design learning activities that leverage mobile devices' unique features and affordances [17]. It is because mobile devices have a range of features that can support problem-solving activities that allow students to explore problems and find solutions more creatively and interactively [18]. The features also enable students to collaborate and share their ideas in real-time, fostering collaborative problem-solving skills. This can be challenging, as teachers may not be familiar with the wide range of mobile applications and digital tools available for problem-solving activities [19].

Therefore, providing teachers with professional development opportunities and ongoing support is crucial to help them develop the skills and competencies needed to integrate M-learning effectively into their teaching practices. This can include training on selecting and using appropriate mobile applications, creating digital content, and managing student engagement in a mobile learning environment. It can also include providing technical support and guidance to help teachers overcome any technical challenges they may encounter. By doing so, teachers can use M-learning to enhance their teaching and promote students' learning in problem-solving lessons. To this end, this study focused on producing a number of teaching activities involving a combination of M-learning methods and Problem-Based Learning methods (M-PBL) that mathematics teachers can use to improve their teaching practices based on expert views. The activities were developed based on the principles of M-learning and PBL, which involve presenting students with real-world problems to solve through collaborative inquiry and self-directed learning. As a result, it may help teachers improve their teaching practices and enhance students' learning experiences.

2 Literature review

The following literature review will provide an overview and analysis of research and literature related to the integration of mobile learning (M-learning) and problem-based learning (PBL) in mathematics education. The review will also explore relevant theoretical frameworks that can inform the integration of these two approaches.

2.1 M-learning

Mobile learning (M-learning) has emerged as a popular educational approach recently. In the field of mathematics education, M-learning has the potential to enhance students' problem-solving skills and promote active learning. Several studies [20-21] have shown that M-learning can enhance students' problem-solving skills and promote active learning in mathematics education. M-learning can provide students with immediate feedback and access to a wide range of resources, allowing them to explore mathematical concepts and problems at their own pace [22]. In addition, M-learning can support collaborative learning and communication among students, promoting a deeper understanding of mathematical concepts. Moreover, M-learning can increase students' motivation and engagement in mathematics, allowing them to interact more with mathematical concepts [23].

Despite the potential benefits of M-learning, integrating this approach also poses significant challenges for teachers. One of the main challenges is a lack of training and support for teachers [15], which can make it difficult for them to select appropriate digital tools and design effective learning activities that leverage the affordances of mobile devices. In addition, using mobile devices in the classroom can distract students, leading to decreased attention and engagement. Moreover, integrating M-learning in mathematics requires a significant shift in teaching practices, which can be challenging for teachers accustomed to more traditional forms of instruction [24].

Several studies [25-26] have identified effective strategies for integrating M-learning in mathematics education. One of the effective strategies involves the use of digital tools and applications that support collaborative learning and problem-solving activities. For instance, mobile applications that allow students to work together on problem-solving tasks and provide instant feedback can enhance their engagement and motivation [27]. Collaborative learning using digital tools enables students to work in groups or pairs, share their thinking, and collectively solve complex mathematical problems [28]. This approach can promote critical thinking as students learn from each other and develop a deeper understanding through discussion and reflection.

In conclusion, M-learning has the potential to enhance students' problem-solving skills and promote active learning. However, integrating M-learning in mathematics education poses significant challenges for teachers, including a lack of training and support. Thus, this study aimed to create teaching activities incorporating M-learning and problem-solving lessons to enhance mathematics teachers' teaching practices.

2.2 Problem Based Learning

Problem-Based Learning (PBL) is an instructional strategy that encourages students to learn through problem-solving. It is a student-centered approach that engages learners in real-world problem-solving activities [29]. Several studies [30-31] have shown that PBL positively impacts students' learning outcomes. For example, one study found that students using PBL scored higher on a post-test than those taught using traditional methods [33]. The main reason is that PBL provides students with a more active and engaging learning experience. This method promotes deeper learning and a more comprehensive understanding of the subject by engaging students in problem-solving activities. Another reason is that PBL encourages students to develop problem-solving skills in mathematics.

PBL has been used in various mathematics courses, ranging from basic arithmetic to advanced calculus. For example, one study [34] examined the use of PBL in a high school STEM class. The researchers found that students in the PBL group had a more positive attitude toward mathematics and higher engagement and motivation than the control group. In addition, the PBL group showed a significantly improved understanding of mathematicals concepts and higher mathematical competency levels than the control group. Another study [35] examined the use of PBL in a college-level statistics course. The researchers found that PBL improved students' problem-solving abilities and helped them better understand statistical concepts.

While PBL has many benefits, it can be challenging to implement effectively. One common challenge is developing effective problem scenarios that are relevant and challenging for students [36]. Then, the problem scenarios should be based on real-world problems that students will likely encounter. This can help increase students' motivation and engagement in the learning process. Besides that, a lack of understanding of implementing PBL effectively can hinder its successful implementation in the classroom [37]. Specifically, many studies reported challenges related to the design of problem scenarios, group work facilitation, and assessment of learning outcomes.

To address these challenges, further research is needed to understand better how to implement PBL effectively in different mathematics courses and contexts. This may involve the role of technology in supporting PBL in mathematics education. By providing students with access to online resources, simulations, and other digital tools, teachers can help students engage with mathematical concepts in new ways and promote a deeper understanding of mathematical concepts. However, the use of technology in PBL should be carefully integrated into the learning environment. To this end, the study's main goal was to develop a set of teaching activities that combine mobile learning (M-learning) methods with Problem-Based Learning (PBL) methods, aiming to enhance the teaching practices of mathematics teachers.

2.3 Theory and model

As a guide in the process of implementing this study, the researcher 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 Problem-Based Learning Model, the Theory of Social Constructivism and the M-learning Model. The following is stated in summary as the theory, learning model and teaching system design model used to form the framework in this study.

- M-learning Model: in this study, the researcher selected M-learning model by Brown [38]. There are two main components chosen namely flexible learning and learning with electronic devices.
- Problem Based Learning Model: in this study, the researcher selected the PBL model developed by Wee [39] in order to carry out problem solving lessons. The model has a range of activities that are easy to understand and follow by the teachers [40]. The PBL method involves seven processes; group division, identifying problems, generating ideas, learning issues, self-directed learning, synthesis and application, and reflection and assessment.
- Social Constructivism Theory: in this study, the researcher chose the theory of social constructivism that Lev Vygotsky pioneered in 1978 [41]. There are three elements involved which are active learning among the students, scaffolding and the Proximal Development Zone (ZPD).

3 Methodology

The methodology section will cover the specific approach taken to conduct the study. This will include a description of the study design, the group of experts, and research procedure.

3.1 Research design

The study was carried out between April 2020 to May 2020, which involved a literature review followed by a modified nominal group technique (mNGT) consensus process. This process comprised a consensus meeting that involved experts from different fields [42]. The mNGT has been used to help the researcher obtain a list of teaching activities involving a combination of M-learning methods and the Problem-Based Learning method (M-PBL) that mathematics teachers can use. This technique was chosen because it is a good method to link the ideas generated to an issue or problem [43]. This technique is also suitable for use if a group of experts has various opinions. This is because, ultimately, the differences in opinion can be integrated according to the priority.

3.2 Group expert

As for the modified nominal group technique (mNGT), the expert groups were chosen through purposive sampling [44]. The selection of experts in this method is very important because the findings depend on their opinion [45]. Therefore, the selection of experts is based on the recommendations of Berliner [46] and Mazidah et al. [47], specifically that an expert must have experience in their field for more than 5 years. This ensures that the results achieved at the end of the process are highly serious. The following are the expert criteria set out in this study [43]; (1) have expertise in their field for at least 5 years; (2) have expertise in the field of primary school mathematics pedagogy; (3) have expertise in ICT and are willing to take part; and (4) have expertise in the field of M-learning and have conducted research before.

In addition, the number of experts also needed to be paid serious attention to in this approach. There have been several recommendations given by previous researchers of expert numbers, such as 4 to 8 persons [48], 5 persons [49], and 6 to 12 persons [50]. Based on the recommendations, the researcher in this study selected 11 experts in mathematics education, educational technology, teaching and learning mathematics at a primary school (PBL), and curriculum and pedagogy.

3.3 Research procedure

The researcher has carried out the modified nominal group technique (mNGT) procedure proposed by Ridzuan et al. [43]. Firstly, the expert groups were given a question, problem, or issue. In the study, the researcher slightly changed the process as opposed to the classic NGT. The changes can influence the time taken to gather ideas, whereas classic NGT requires the generation of ideas at a basic level [43]. This will result in the generation of ideas taking a long time. The researcher prepared a preliminary draft of the appropriate activities to be included in the M-PBL teaching activities based on the literature review to overcome this issue. This can help expert groups to focus on the scope of the discussion. Thus, the discussion will be narrowed. This can also lessen the duration of the discussion time from 240 minutes to 90 minutes [44].

Secondly, each expert gave their ideas and opinion. Based on the preliminary draft, the expert groups responded in the form of agreeing or disagreeing with the list of proposed activities. The expert group also gave suggestions and additions concerning the ideas for the appropriate activities for inclusion in the M-PBL teaching activities. Thirdly, the ideas were presented and shared with the other experts, and the ideas were modified during the discussion. Upon completion, a complete list of teaching activities was presented to the expert group to enable them to make decisions relating to the final list of activities that need to be included in the teaching activities.

Lastly, the expert groups voted for each teaching activity by answering on a 1 (really not agreeing) – 5 (really agreeing) scale to determine the position of each teaching activity. The scale used to determine the position of the teaching activities was based on the views of the previous researchers [44,51]. As a result of the voting, the researcher determined the priority value of each activity. Therefore, the researcher obtained a final list of activities based on the experts' priority. The most important activity in order is based on the activities with the highest percentage value and vice versa [52].

4 Results

The data distribution in Table 1 shows a list of the activities to be included in the M-PBL teaching activities for mathematics teachers based on expert views. Overall, 30 suitable and relevant activities should be included in the M-PBL teaching activities based on the expert group's views and results. The findings also show that teachers share the learning objectives that the pupils need to achieve using learning applications available on mobile devices (98%) was ranked first, followed by other activities, while the teacher classifying the information obtained from each group according to priority through learning applications available on mobile devices (75%) was ranked last.

Table 1. The M-PBL teaching activities

No.	Activities	Total Score	Percentage (%)	Ranking
1.	Teachers share the learning objectives that the pupils need to achieve using learning applications available on the mobile devices	54	98	1
2.	Pupils are guided by the teachers to form groups for various levels of ability using the learning applications available on the mobile devices.	47	85	7
3.	Each group divides the responsibilities according to members' abilities and shares that information with the teachers through the learning applications available on the mobile devices.	42	76	12
4.	The teacher sets out the tasks (problems) that each group needs to solve using the learning applications available on the mobile devices.	49	89	5
5.	Teachers share several stimulus materials consisting of various forms of media using the learning applications available on the mobile devices.	44	80	10

No.	Activities	Total Score	Percentage (%)	Ranking
6.	Each group understands and talks about the stimuli material shown using the learning applications available on the mobile device.	45	82	9
7.	Teachers get feedback from each group using the interactive learning apps available on the mobile devices.	47	85	7
8.	Each group discusses the tasks assigned in the context of their daily living situations using the learning apps available on the mobile devices.	49	89	5
9.	Each group questions the teacher about the assigned tasks through the learning apps available on the mobile devices.	44	80	10
10.	Each group sums up the assigned tasks given by the teachers by listing what to do using the learning apps available on the mobile devices.	43	78	11
11.	Each group is given time to explore the various applications and other learning media available on the mobile devices to get solution ideas.	49	89	5
12.	Each group shares information that has been obtained with the teachers and other groups through the learning applications available on the mobile devices.	47	85	7
13.	Teachers classify the information obtained from each group according to their preferences through the learning applications available on the mobile devices.	41	75	13
14.	Each group reviews and reads the findings of the other groups through the learning apps available on the mobile devices.	47	85	7
15.	Each group is given the opportunity to compare the differences in their findings with those of other groups through the learning applications available on the mobile devices.	45	82	9
16.	Each group questions the teachers and other groups based on the information gathered to form new ideas through the learning applications available on the mobile devices.	50	91	4
17.	The teachers can conclude the information that each group obtains through the learning applications contained on the mobile devices.	45	82	9
18.	Each group concludes on the results of the discussions with the teacher and other groups through the learning applications contained on the mobile devices.	46	84	8
19.	Each group discusses the steps that can be used to complete the tasks through the learning applications available on the mobile devices.	48	87	6
20.	Each group discusses the most appropriate steps to use to complete the tasks given through the learning applications available on the mobile devices.	50	91	4
21.	Each group shares the solution steps through a video conference application available on the mobile device.	51	93	3
22.	Each group responds during a presentation session through a video conference conducted using a mobile device.	52	95	2
23.	The teachers guide each group to revise the steps that the solutions have selected using the learning apps available on the mobile devices.	51	93	3
24.	The teachers guide each group to complete the tasks provided using the learning apps available on mobile devices.	44	80	10

No.	Activities	Total Score	Percentage (%)	Ranking
25.	Each group presents the final solution in various forms of graphic media using the learning applications available on the mobile devices.	50	91	4
26.	Each group specifies the justification for each step used to complete the task using the learning apps available on the mobile devices.	50	91	4
27.	Each group is given the opportunity to ask questions and feedback of the presenter group using the learning apps available on the mobile devices.	52	95	2
28.	Each group concludes on the learning process and shares it with the teachers and other groups through the learning applications found on the mobile devices.	51	93	3
29.	Pupils answer the quiz questions assigned by the teachers through the learning apps available on the mobile devices.	49	89	5
30.	The teachers can conclude on the learning using the learning applications on the mobile devices.	52	95	2

5 Discussion

The results indicate that experts have identified 30 teaching activities that combine M-learning methods and Problem-Based Learning (M-PBL) that mathematics teachers could use. These activities are based on the M-learning Model [38], the Problem-Based Learning Model [39], and the Social Constructivism Theory. All the activities listed were deemed acceptable by the experts and prioritized accordingly. The top-ranked activity involved teachers sharing the learning objectives that the pupils need to achieve using learning applications available on mobile devices. The lowest-ranked activity involved the teacher classifying the information obtained from each group according to priority through learning applications available on mobile devices was ranked last.

The findings contrast with Wee's proposed activities in the problem-based learning (PBL) model [39], which suggest that the first activity should involve dividing pupils into groups based on their abilities, assigning responsibilities, and selecting group leaders [53-54]. However, in this study, these activities were ranked 17th (the teachers guide pupils to form groups for various levels of ability using the learning applications available on mobile devices) and 29th (Each group divides the responsibilities according to members' abilities and shares that information with the teachers through the learning applications available on the mobile devices) based on expert views. Nevertheless, expert groups felt that teaching activities involved in sharing learning objectives should be carried out in advance compared to other teaching activities.

The findings support the views of Paolini [55] and Negash [56] that setting learning objectives is a crucial process in teaching and learning. According to the experts, this process should be implemented before other teaching activities because it sets the direction for learning. By sharing learning objectives, pupils can better understand the relationship between what they need to do and what they need to learn. This activity also helps pupils assess their starting points concerning the learning objectives, such as identifying what they need to take note of and where they may require help from a friend or teacher to achieve the predetermined learning objective [57]. Furthermore, this activity can help reduce pupils' anxiety about their ability to succeed and increase their intrinsic motivation to succeed [58].

Previous studies have explored the role of mobile technology in teaching activities that involve setting learning objectives and their impact on student achievement. Mitchell and Manzo's [59] study and Alqurashi's [60] study found that this activity helped pupils set the direction of their learning, monitor their learning process, and assess their self-learning development. The findings of this study also suggest that pupils who can use written instructions and self-regulation strategies, such as setting objectives, self-assessment, and strategy monitoring, were better able to build their knowledge and complete assignments than other pupils. In addition, Rohloff et al.'s [61] study found that teacher feedback and sharing learning objectives throughout the teaching and learning process helped pupils understand what they needed to do to master learning and focus on the critical learning aspects to develop.

The final priority sequence in the list of M-PBL teaching activities involves the teacher classifying information obtained from each group according to priority through learning applications available on mobile devices. Despite being the last priority, this activity is still considered relevant enough to be carried out. This is consistent with the opinion of Douglas et al. [62], who suggest that teachers should play a facilitating role during online learning to enhance student engagement and active capabilities. In this activity, the teacher is a facilitator by classifying information obtained from other groups, ensuring that the collected information is well-organized and easy for pupils to understand. If the information is not presented understandably, it can negatively impact students' learning by hindering their active engagement, as seen in the passive engagement among students. This makes it challenging for pupils to achieve the learning objectives [63]. These findings are supported by Özen and Remzi's [64] study, which shows that effective classroom management by the teacher as a facilitator can create an effective learning environment among students. Thus, effective student learning outcomes are more likely to be achieved if teachers can effectively manage and control the classroom.

Other studies, such as the one conducted by Rayens and Ellis [65], have also emphasized the critical role of teachers as effective facilitators in online teaching. Teachers not only influence the direction and procedures of online learning but also facilitate interaction and relationship-building between teachers and students and among students themselves. Effective teacher facilitation can increase student motivation to actively engage in learning, organize and manage student learning, and ultimately help students master learning content. These findings highlight the ongoing importance of teachers in the learning process, even when teaching is delivered online. Failure to facilitate learning effectively can lead to difficulties and challenges for students in achieving their learning goals [66].

6 Conclusion and future research

This study proposes 30 M-PBL teaching activities that can be used by mathematics teachers when teaching problem-solving by integrating M-learning. These activities were based on the M-learning model, problem-based learning model, and social constructivism theory. It was also found that setting learning objectives is an important process that should be implemented in advance while implementing the M-learning method. Besides, the study emphasized the importance of teachers playing the role of facilitator during online learning implementation to enhance active capabilities and engagement among pupils. Overall, the study concluded that teachers could use all the M-PBL teaching activities listed as guidance to help them overcome any challenges they may encounter while integrating M-learning into the problem-solving lesson. In the future, other researchers may use the M-PBL teaching activities as a guide to design and develop a new teaching model that can help mathematics teachers teach problem-solving by combining M-learning and problem-based learning methods.

7 References

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