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Effect of Model-Eliciting Activities using Cloud Technology on the Mathematical Problem-Solving Ability of Undergraduate Students

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Problem-solving is considered as an important skill for learning Mathematics. Integration of cloud technology into Model-Eliciting Activities (MEAs) has been considered as an instructional approach to study students' mathematical problem-solving abilities. The purposes of this study were to evaluate the suitability of the MEAs using cloud technology, and assess the mathematical problem-solving ability of undergraduate students learning the proposed model compared with the criteria of 50%. The participants were 50 undergraduate students who were enrolled on Numerical Analysis courses, selected by using a purposive sampling technique. We conducted quasi-experiments using a one-group design to determine the impact of the model on students and assessed whether the students had exceeded the criterion for mathematical problem-solving ability. The research instruments were instructional plans of the MEAs using cloud technology, a suitability assessment form, and a mathematical problem-solving test. The data were analysed quantitatively using descriptive statistics such as mean and standard deviation, and a t-test. The findings revealed that 5 experts evaluated the model as being "most suitable", and that the mathematical problem-solving ability of the undergraduate students exceeded the criterion of 50% at a .05 level of statistical significance. The students displayed satisfactory competence in implementing key mathematical concepts to solve problems.

Keywords: model-eliciting activities, cloud technology, mathematics, problem-solving, undergraduate students

INTRODUCTION

The national and population quality development trends are driven by innovative technology and education (Pikultong & Lertamornpong, 2019). It is necessary to develop the education system in accordance with industrial development in the era of Thailand 4.0 - a policy vision for economic, research and education reform driven by

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innovation and technology. Utilizing technology in education has progressed from human learning to solving problems. Therefore, learning approaches should include guidelines that encourage students to apply knowledge as part of their thought processes (Noor et al., 2020).

Mathematics is one of the core educational subjects and an essential skill in the 21st Century (Dede, Hidiroglu, & Guzel, 2017). One of the weaknesses with regard to mathematics education in Thailand is that students lack thinking and problem-solving skills (Office of the Education Council, 2017). The main aim in organizing mathematics activities is to encourage students to use mathematical abilities to solve problems and develop a problem-solving thinking process (Kannan, Sivapragasam, & Senthilkumar, 2016; Sungkawadee, 2020). This enables students to make connections between the real-world and mathematical solutions problems (Jannoom & Thamsuan, 2017). Teaching preparation that involves ascertaining what students know will help teachers provide more appropriate mathematical facts or information and also make more interesting learning process (Sari, Yaniawati, & Kartasasmita, 2019; Angraini & Wahyuni, 2021).

Eliciting information is a learning and teaching strategy that prioritizes learners and provides a more stimulating academic environment, while making learning memorable by connecting previous and new knowledge (Gravemeijer et al., 2017). Moreover, it is an important step in the development of students' mathematical thinking whereby the teacher challenges students to explain and analyze their own methods when it comes to finding the answers (Pertamawati & Retnowati, 2019). By using questions and educational technology tools to encourage students to express their thoughts by speaking or explaining, the focus in this stage is on eliciting multiple answers from students to a particular problem. Mathematical facts, knowledge, and ideas will not be extracted without facing the problems or instructional environment which provide the tools for obtaining such information. Students also need stimulation, associations, and reminders to activate their memories.

The Model Eliciting Activities (MEAs) approach is a learning process in which students learn to find answers through problem-solving (Pikultong & Lertamornpong, 2019). The requisite for MEAs is the application of mathematical knowledge. With regard to MEAs, learning activities are organized by teachers to better understand students' ideas. The MEAs model is employed as an instructional tool to develop students' mathematical thinking in various mathematical contexts (Batisa, 2017). The advantage of MEAs in a classroom context which is different from other traditional models is it requires students to engage in self-adaption, self-documenting, self-monitoring for validity of the model including revising their solutions (Dede, Hidiroglu, & Guzel, 2017). The development of problem-solving through the application of mathematical models is an important part of the mathematical learning process (Zulkarnain et al., 2021).

According to a strategic plan by the Ministry of Education (MOE) in Thailand, a requirement in higher education is to use Information Communication Technology (ICT) for lifelong learning, including the promotion of higher information literacy scores (Ministry of Education, 2017). In response to changing social and technological contexts, instructional pedagogy should be adjusted accordingly (Kultawanich, Koraneekij, & Na-Songkhla, 2015).

Cloud technology is popular for use in education, and many researchers are using cloud-based tools for educational purposes, such as a cloud service to support learning and teaching mathematics (Denton, 2012). The idea of using cloud technology in support of teaching and learning in higher education is recognized as essential for improving quality education and for preparing for social change in education (Lakshmi & Dhanalakshmi, 2016). To establish a learning environment that promotes thinking, cloud technology is needed to support learning activities involving students, instructors, and information resources (Iji, Abah, & Anyor, 2017). However, few studies have utilized cloud-based tools to support students learning mathematics.

To effectively develop problem-solving amongst students, teachers should employ and apply the most appropriate technology as a tool for promoting and expanding mathematical thinking to improve problem-solving (Kasiolas, 2017; Indrawati, 2021). In recent years, learning technology has taken on a significant role for university students (Hussain, Cakir, & Candeğer, 2018). For this reason, cloud technology has been the educational research focus of several scholars (Rassovytska & Striuk, 2017). When utilizing ICT for teaching and management in education, the key consideration is how to apply or design learning activities as much as possible to make the most of cloud technology, and to benefit from the management of learning. The question that arises is: What approaches do cloud technology use to elicit the ideas, related knowledge, feelings, and meanings ascribed by students? (Ali, Nasr, & Gheith, 2018).

As mentioned previously, this study attempted to propose a learning model based on the principles of MEAs incorporated with cloud technology, to analyse the effect of the proposed model on problem-solving among undergraduate students. It also examines how the use of cloud technology through MEAs influences mathematical problem-solving ability. The study also introduces the use of cloud-based tools as an eliciting technique based on the principles of MEAs.

The next sections provide a brief review of the related literature, an outline and explanation of the methodology used, followed by the findings, discussion and a conclusion in the final section.

Review of Related Literature

Model Eliciting Activities

Overview of Model Eliciting Activities

Mathematics is directly concerned with thought processes, which are therefore an important tool in learning mathematics (Noor et al., 2020). Eliciting is the process of obtaining answers or solutions according to students' thought processes (Deniz & Akgun, 2016; Pikultong & Lertamornpong, 2019). Mathematical problem-solving is a component of mathematical thinking (Gravemeijer et al., 2017). Eliciting in term of instructional pedagogy is defined as a range of techniques or procedures that enable the teacher to encourage learners to provide information in writing or through speech. Typically, it involves asking students to use and express their thoughts through language, vocabulary, and rules related to the lesson content (Dede, Hidiroglu, & Guzel, 2017).

Model Eliciting Activities (MEAs) were developed by the mathematical community as an approach to teaching mathematics that uses open-ended and real-life mathematics problems to model mathematical solutions (Batista, 2017). MEAs are designed to support students in the examination of mathematical models and to provide approaches for teachers to better understand students' thinking (Pikultong & Lertamornpong, 2019). Several researchers have studied and implemented MEAs in mathematical contexts (Batista, 2017).

For teachers, eliciting is a powerful diagnostic tool that serves as a starting point for lesson planning by providing important information regarding what students know (Supap & Naruedomkul, 2016). It also encourages teachers to be flexible rather than relying on familiar information. However, eliciting requires not only a solution or method in the form of mathematical language and knowledge but also activities teachers can employ to stimulate students to express their emotions, feelings, memories, and experiences (Pertamawati & Retnowati, 2019).

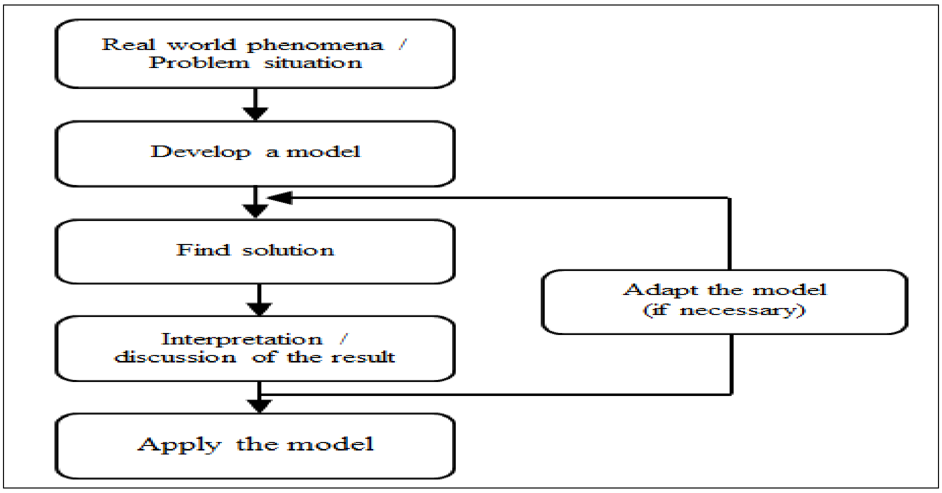

Figure 1
The acquisition of a mathematical model (Hernández et al., 2017)

Principles of Model Eliciting Activities and Related Work

The six principles of the MEAs instructional framework that we are adopting consist of Model Construction Principle, The Reality Principle, The Self-Assessment Principle, The Construct Documentation Principle, The Construct Shareability and Reusability Principle, and The Effective Prototype Principle (Dede, Hidiroglu, & Guzel, 2017). The benefits of MEAs for teaching and learning are an increased level of conceptual understanding, problem-solving abilities, and teamwork skills (Batista, 2017).

There are different aspects of study related to MEAs. With regard to the aspect of implementations, researchers such as Dede, Hidiroglu, & Guzel (2017) examined the appropriateness of mathematics student teachers' developments of MEAs based on the principles of MEAs. The literature with regard to the implementation of MEAs to achieve specific learning goals, e.g., the MEAs using the topic of trigonometry are presented for engaging students in making sense of mathematics (Pertamawati & Retnowati, 2019). Studies with regard to aspects of the solutions process of MEAs, such as that of Batista (2017), investigated student processes associated with finding mathematical solutions classified by performance in terms of their mathematical thinking levels. The results indicated that the ability of low-performing students to propose and develop adequate solutions was comparable to that of average- and high-performing peers.

Cloud Technology for Education

Cloud technology provides educational tools - commonly referred to as cloud-based tools or cloud-based applications - in the form of online or web-based applications that can be provided without needing to install programs on electronic devices as they are generally accessible via a web browser (Imran, 2018; Semenikhina, Drushlyak, & Bondarenko, 2019).

Breeding (2012) and Denton (2012) suggested that cloud-based tools for deployment in education, including support for the virtual/online learning environment, can be divided into the following five categories: collaboration tools, data gathering tools, content creation tools, presentation tools, and communication tools.

Cloud-based tools can be used to support students' learning by providing the following smart advantages - online mathematical software without the need to install a program on electronic devices, tools that allow users to characterize displays, and support for a variety of devices. Many cloud-based tools are free or provide basic versions for free, and some are specifically designed for learning mathematics. There is ease of access at anytime and anywhere. All this reduces the cost of the infrastructure needed, helps students manage their information more easily, and can be accessed by both desktop computers and other portable devices (Kasiolas, 2017; Indrawati, 2021).

Several researchers have studied the implementation of cloud technology as tools for learning and classroom instruction. For instance, Denton (2012) found that students' conceptual understanding is higher after studying via cloud technology. The research finding by Lakshmi and Dhanalakshmi (2016) who conducted research into the use of Moodle in the cloud using mobile learning, show that it positively influences students' learning processes and also improves their engagement. Additionally, the results of a survey on teachers' use of technology in the classroom revealed that most intend to utilize cloud technology as a tool to support learning activities (Kasiolas, 2017). Similarly, a study by Clooney and Cunningham (2017) examined pre-service students' opinions on the key attributes of high quality mathematics instruction provided on cloud technology, while the impact on students' learning included improved mathematical communication, making connection tools, and representations. Moreover, Ali, Nasr, and Gheith (2018) presented the use of software as a service (SaaS), one of three main kinds of cloud services applications, and proposed a conceptual model as an elicitation tool for Cloud Enterprise Resource Planning. The research conducted by Daher and Anabousy (2020) indicated that students use expectations, and mathematical relationships examined using cloud technology including mathematical software, as the reason for their solution modifications.

Mathematical Problem-solving

Problem-solving is an important skill in mathematics education (Rahman & Ahmar, 2016; Purbaningrum, 2017). It is relevant to the use of mathematical thinking, which is essential in solving both real-world and mathematical problems (Demitra & Sarjoko, 2018; Gunawan et al., 2020). In addition, Zulkarnain et al. (2021) suggest increasing mathematical problem-solving of students as a foundation for developing their thinking processes (Umugiraneza et al., 2017). The mathematical problem-solving process gives students the opportunity to develop their ability to adjust and modify their approach to new problem situations. A learning approach that develops students' mathematical thinking by providing problems that need to be analysed, either individually or in groups, in order to generate solutions, will enable students to improve their mathematical performance (Widowati et al., 2017; Rudibyni, Perdana, & Elisanti, 2020). Solving mathematics problems effectively requires higher order thinking skills and an understanding of the mathematical context (Noor et al., 2020).

Based on the principles of MEAs and the benefits of cloud-based tools as mentioned above, we employed MEAs as an approach to learning that develops students' thinking and is suitable for promoting their problem-solving abilities. This study thus integrated the adoption of cloud technology to support the principles of the theoretical teaching approach known as MEAs.

METHOD

The steps for conducting the research are as follows:

The relevant study exploration

(1) studying the concepts underpinning the development of mathematical eliciting, (2) studying the framework surrounding the principles and approaches of MEAs in mathematics, and (3) analysis of relevant documents and research.

The development of MEAs using cloud technology

We have identified cloud technology that can be used as a tool to promote mathematical thinking and eliciting activities based on the principles of MEAs, and have determined the learning activities and the use of cloud technology to support each activity in a manner consistent with the components of MEAs' principles. The types of cloud-based tools were selected based on suggestions by Breeding (2012) and Denton (2012). The principles of MEAs were applied and synthesized as a framework for a learning model using cloud technology as tools, as presented in Table 1.

Table 1
The framework of a learning model using cloud-based tools based on the principles of MEAs

Cloud-Based Tools	Principles of MEAs	Learning Activities
Content creation tools (Google Docs)	1. Model Construction Principle	Students read/listen to the given problem; They then determine whether the solutions can be obtained using a mathematical model
Content creation Tools (Google Docs)	2. The Reality Principle	Students explain their ideas and discuss everyday life and experiences
Data gathering tools (Google Drive)	3. The Self-Assessment Principle	Students evaluate the validity of alternative solutions to the problem
Content creation Tools (Google Docs, Google Slides, Google Meet)	4. The Construct Documentation Principle	Students solve the problem using mathematical modeling
Collaboration tools, Data gathering tools, Reflection tools (Google Classroom, Google Drive)	5. The Construct Shareability and Reusability Principle	- Students discuss the shareability and usability of the model - Students discuss and determine whether such solutions can be used in similar situations
Presentation tools, Communication Tools (Slideshare, Google Meet)	6. The Effective Prototype Principle	Students propose and explain their own problem-solving ideas and solutions

The MEAs' framework (Dede, Hidiroglu, & Guzel, 2017) was adopted to determine an organizing learning approach. The learning activities and the supporting cloud technology consisted of the following steps. Step 1: Attracting attention (Content creation tools, Presentation tools), Step 2: Realization, contemplation, and connection to problems in real life (Content creation tools, Communication tools), Step 3: Prepare to solve problems (Data gathering tools), Step 4: Solve mathematical problems (Content creation tools), Step 5: Test model performance (Data gathering tools, Collaboration tools), and Step 6: Summarize and apply the model (Presentation tools, Communication tools). The proposed model was examined in terms of suitability by five experts who have experience in educational cloud technology and mathematics pedagogy before being used to conduct on class.

Implementation

Instructional plan of the MEAs using cloud technology

This study applied the principles of the MEAs model by using cloud technology to support mathematical learning activities. The learning objectives of the Numerical Analysis course are to enable students to understand numerical algorithms and implement them as a mathematical model through the collection of data. For this reason, the study was employed in the context of this course.

From related research in MEAs and cloud technology, we analysed cloud services as tools for mathematics education activities. The implementation of the MEAs using cloud technology in a Numerical Analysis course is presented in Table 2.

Table 2
The syntax of MEAs using cloud technology in the instruction on a numerical analysis course

Mathematics lessons	Feature of MEAs' implementation tasks	Learning activities	Supported Cloud Technology
Unit 1 Error Analysis	- Reflection - Discussion between students - Take home assignments	Step 1 Attracting attention-students read/listen to the given problem Step 2 Realization- students analyse the material to assess their understanding and discuss them in class Step 3 Prepare to solve problems – students study the example problem to develop a model for error analysis Step 4 Solve mathematical problems – students practice for solution of error analysis using the appropriate formula Step 5 Test model performance – students comment on their peers assignments Step 6 Summarize and apply the model - students post and interpret their works to the class on Google Apps when the assignment is due	- Content creation tools - Presentation tools - Cloud reflection tools(Online notebook, Google Apps) - Cloud Storage (Google Drive) - Cloud Collaboration tools - Communication tools
Unit 2 Fixed-point Iteration	- Leading questions - Sharing of knowledge between instructor and students - Class assignments	Step 1 Attracting attention- leading questions by instructor Step 2 Realization- student answer the question for connection to fixed-point to problems in real life Step 3 Prepare to solve problems- students synthesise the relevant definitions of fixed-point and fixed-point iteration to develop a model Step 4 Solving mathematical problems-students compose their solution using software Step 5 Test model performance- students comment on their peers' assignments Step 6 Summarize and apply the model - students propose the solution to the class	- Content creation tools - Presentation tools - Spreadsheet software - Online Mathematical Application/Software - Cloud Collaboration tools
Unit 3 Finding a root of continuous function	- Discussion between students - Apply basic mathematical concepts in the class - In-class and take home assignments	Step 1 Attracting attention - using social interaction techniques Step 2 Contemplation - check readiness for study Step 3 Prepare to solve problems - students discuss basic mathematical concepts for developing a model for	- Data gathering tools - MathWorks Cloud, Online mathematical application/software - Social interaction techniques - Presentation tools,

	finding a solution Step 4 Solve mathematical problems - students construct their work by finding a root of continuous function using MathWorks Cloud/available software Step 5 Test model performance - students verify, explain the result and revise if it not correct Step 6 Summarize and apply the model - students propose the solution to the class and on Google Apps/presentation tools when the assignment is due

Procedure of implementation

The quantitative study was adopted to examine the effectiveness of MEAs using cloud technology in terms of conducting instruction as part of a Numerical Analysis course. The implementations were carried out for 8 weeks. The sample consisted of 50 undergraduate students who participated in this course. The process of implementation of the MEAs using cloud technology in the Numerical Analysis course was conducted using quasi-experiment for one-group posttest only design. This consisted of five stages as shown in Figure 2.

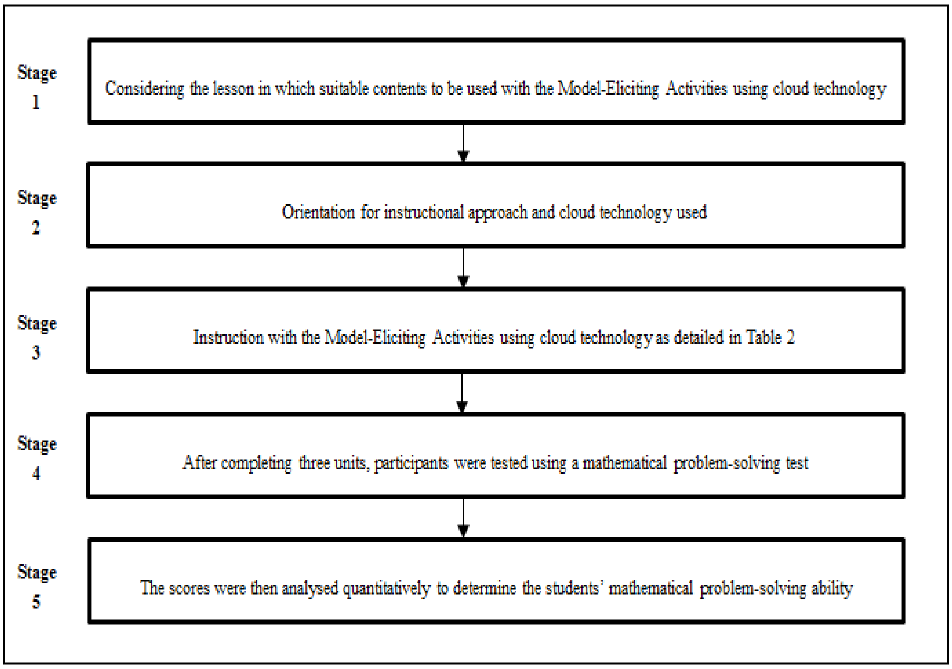

Figure 2
The process of implementation of MEAs using cloud technology

Research Instruments

The research instruments for collecting data were as follows:

The suitability assessment form

The authors modified an assessment tool comprising points from a study by Shyshkina, Kohut and Popel (2017). It consisted of two key assessment points: the suitability of supported technology and the suitability of the mathematics instruction. Responses were given on a 5-point Likert scale. All items of the suitability questionnaire were reviewed and approved in terms of validity by five experts. The reliability of the assessment form calculated by the Cronbach's alpha coefficient was 0.70.

Mathematical problem-solving test

This test consists of 6 questions related to the contents in the Numerical Analysis course. The difficulty index was in the range 0.26 - 0.78, the discriminant index was in the range 0.44 - 1.07, and the reliability value was 0.79.

Data Analysis

The data were analysed using descriptive statistical analysis and inferential statistics.

Mean ($\bar{x}$) and standard deviation (S.D.) for the experts' answers based on the Likert scale responses were calculated. The results were then interpreted in terms of the following criteria (Kultawanich, Koraneekij, & Na-Songkhla, 2015).

Mean 4.50–5.00 - most suitable

Mean 3.50-4.49 - very suitable

Mean 2.50-3.49 - suitable

Mean 1.50-2.49 - less suitable

Mean 1.00-1.49 - not suitable

The posttest scores with regard to mathematical problem-solving, approximately normally distributed, were analysed by mean and standard deviation. The Cronbach's alpha coefficient was used to consider the reliability of the research instruments. T-test was performed to determine the comparison with a 50% criterion at a significance level of .05.

FINDINGS

Assessment of the suitability of the model

Table 3
Expert assessment of the suitability of the proposed learning model

Item	Assessment scores		Interpretation
	$\bar{x}$	S.D.	
Elements of the model	4.40	0.89	Very suitable
Using supporting tools	5.00	0.00	Most suitable
Learning activities	4.80	0.44	Most suitable
Flexibility in application	5.00	0.00	Most suitable
Overall	4.80	0.33	Most suitable

As shown in Table 3, the overall scores based on the expert assessment were at the 'most suitable' level. The items with the highest scores were those involving the use of supporting tools and flexibility in application, which implies that the experts agree on the practical application of the proposed learning model.

Analysis of mathematical problem-solving ability

The mathematical problem-solving ability of the undergraduate students using the proposed learning model was analysed by comparing the criteria of 50% with regard to the test using a one sample t-test, the details of which are presented in Table 4.

Table 4
Mean mathematical problem-solving ability scores of students compared with the required criteria

	n	$\bar{x}$	S.D.	St. Error Mean	t	Sig.
Problem-solving ability	50	58.57	23.58	3.33	2.569	.006*

Note: The test value is 50, *p < .05

As indicated, the mean mathematical problem-solving ability score was 58.57. The score with regard to mathematical problem-solving is relative to the required criterion of 50%. This indicates that the mean score was significantly higher than the required criteria at a significance level of .05.

DISCUSSION

The implementation of the MEAs with cloud technology utilized in this study involved a learning model incorporating cloud technology based on the principles of MEAs. To be able to solve mathematical problems, students must first be able to interpret and understand the problem. As the findings indicated that the undergraduate students' mathematical problem-solving ability after using the proposed model was higher than 50%, this may be due to cloud technology providing tools to encourage students to recognize the concepts, formulae, or theorems they used (Batista, 2017) to interpret and develop the mathematical model based on the relevant data. In this study, in the process of organizing mathematics activities students encounter a mathematical problem and then come up with a method of solving it. This is consistent with the findings of Purbaningrum (2017) and Pertamawati and Retnowati (2019) who found that facing and exploring solutions themselves promote students' thinking processes and sense-making. Using teaching methods based on the self-assessment principle and the construct documentation principle, mean that students solve problems and check their validity using software available on the cloud. There is a function on the cloud that shows the process of conceptual knowledge that must be used to explain solutions by displaying various means of mathematical representations, e.g., graphs or equations (Cen & Cai, 2017). This is consistent with Denton's (2012) concept of learning mathematics which indicates that students should be encouraged to participate in the creation of new knowledge from previous knowledge. Cloud tools, including online mathematical software are provided for rationally testing mathematical models that meet the constructs of the shareability and reusability principle of the MEAs approach. For these reasons, the students in this research have demonstrated mathematical problem-solving ability better than the minimum criterion. The findings of this study conform to those of Denton (2012) that using cloud technology provides students with a better understanding in the context of a lesson, thus developing their problem-solving ability (Denton, 2012; Daher & Anabousy, 2020).

Using technology including cloud-based tools and applications is evocative of a new flexibility and practical possibilities for enhancing teaching and learning, as well as providing new challenges in making the most of the cloud's potential. The importance of a blend of MEAs with other cloud mathematics activities or learning technologies should be recognized and considered.

CONCLUSION

This study presents Model-Eliciting Activities using cloud technology. The model was evaluated by experts as being 'most suitable', before being used to study the mathematical problem-solving abilities of undergraduate students after learning with this model. The conduct of this instructional model is investigated in terms of its effectiveness with regard to implementation on a Numerical Analysis course. An analysis was performed of quantitative data collected from students' posttest scores. The results imply that the MEAs using cloud technology significantly contributed to the students' problem-solving abilities making them higher than the threshold criterion. Thus, in addition to the adoption of cloud technology, the skills and expertise of instructors are other factors affecting students' problem-solving ability. This may suggest the need to use this approach and consider such factors as variables in another study.

The findings of this study contribute to the work of other educators who are interested in teaching and learning approaches that emphasize eliciting information in writing or through speech and which use cloud-based tools to support learning processes and problem-solving. For future work, the framework of Model-Eliciting Activities using cloud technology as proposed here can be applied with other aspects of learning theory in mathematics education.

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