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PAPER

An Inductive Reasoning Strategy with Cloud-Based Symbolic Mathematics Software to Improve Undergraduates' Mathematical Knowledge

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ABSTRACT

Mathematics involves thinking and reasoning, both of which should be emphasized to improve students' knowledge and abilities. The main aim of this study was to examine undergraduate students' conceptual and procedural mathematical knowledge after exposure to software-embedded inductive reasoning strategy in cloud-based environments. Purposive sampling techniques were used to select participants—60 undergraduate students enrolled in the Ordinary Differential Equations (ODEs) course. A quasi-experimental approach using a post-test control group was adopted for the study. Research instruments included a test of mathematical knowledge and an inductive reasoning strategy with cloud-based symbolic mathematics software. The data were analyzed using a quantitative approach involving mean, standard deviation, and a t-test. The results revealed that the mathematical knowledge of the experimental group statistically exceeded the 60% criteria at the 0.05 significance level. The mathematical knowledge of students in the experimental group was significantly better than that of the control group at a statistically significant level of 0.05. The results of this study imply that incorporating cloud tools as part of the inductive reasoning strategy had a positive impact on students' mathematical knowledge.

KEYWORDS

cloud technology, inductive reasoning strategy, mathematical knowledge, symbolic mathematics, undergraduate students

1 INTRODUCTION

Mathematics in higher education is seen as a key subject with an important role to play in enhancing cognitive skills and its use as a tool in science and technology [1], [2]. Mathematical reasoning is considered an important skill for the 21st century [3]. Reasoning skills, including inductive and deductive reasoning, play an essential role in the development of students' mathematical thinking [4], [5].

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Combined with mathematical knowledge, they enhance deep cognitive performance with regard to mathematical phenomena. This process is considered essential for learning mathematical content, which is one of the important achievements of mathematics education [6], [7]. As far as mathematical knowledge is concerned, conceptual and procedural knowledge have been emphasized to improve mathematical skills and encourage students to succeed in learning mathematics [8].

An inductive reasoning strategy is a teaching method that involves suggesting previously learned concepts to students in order to obtain a better visualization of mathematical concepts while stimulating their mathematical thinking [9]. The effects of such a strategy have been examined with regard to mathematical content, and it has been found to have positive effects on students' mathematical performance [2], [6], [10].

Cloud technology has become a tool for improving and modernizing education in many countries [11], [12]. When it comes to supporting mathematics learning, various aspects of cloud technology have been recognized as imperative for improving the quality of teaching and preparing individuals for a changing society [13]–[15]. It also plays an important role in the teaching of mathematics in higher education [16]. Previous studies have shown the potential of cloud technology as a teaching medium and cognitive tool to support the display of computational results and to stimulate students to engage and become interested in learning mathematics [15], [17], [18]. According to [2], conceptual learning involving inductive reasoning strategies using mathematical software can develop higher-order thinking in students. For this to be possible, the functionality of cloud technology applied in a teaching context for the benefit of students needs to be considered [19]–[21].

Several advantages are associated with the use of cloud technology in the learning process: stimulation, motivation, ease of use, availability, connectivity, communication tools [13], [22]. Teaching practices supported by digital software are now recognized as tools to inspire and encourage students to become more involved in learning activities by developing their mathematical thinking [4], [23]. Therefore, mathematics teachers should adapt their pedagogical approach by incorporating cloud technologies, including symbolic mathematical software, in order to help students by involving them more and encouraging a better understanding of mathematical concepts [1], [24], [25].

As cloud-based mathematics software has been developed to enable the calculation of algorithms, it should be easier for students to explore the various stages of the calculation process on their own. Importantly, [26] has suggested that the development of mathematical concepts and procedural knowledge through the application of mathematical software is an essential part of the mathematical learning process. In addition, students will be able to study the derivation of displayed solutions in a sensible way. Prior knowledge can be used to understand the stimulus, which encourages them to explain the corresponding reasoning and can help develop their specific knowledge of mathematics [2], [10], [27]. However, few studies have examined mathematical software tools in conjunction with the inductive reasoning strategy in the context of the mathematics classroom in higher education. This study applies cloud-based software to support a specific approach to teaching mathematics based on an inductive reasoning strategy.

As mentioned earlier, the study problem is whether an inductive reasoning strategy with cloud-based math software is a factor to consider when it comes to students' mathematical knowledge. Ultimately, the study will attempt to answer the following main research questions: Is the average mathematical knowledge score of students after learning through an inductive reasoning strategy with cloud symbolic mathematics software greater than 60% of the total score? Are there differences between the mathematical knowledge scores of students using an inductive reasoning strategy with cloud symbolic mathematics software and those of students with conventional instruction? The aims of this study were to:

- Study the mathematical knowledge of undergraduate students using the inductive reasoning strategy with the cloud symbolic mathematics software against a criterion of 60 percent of the total score.
- Compare the mathematical knowledge of undergraduate students between groups using an inductive reasoning strategy with cloud-based symbolic mathematics software and a conventional approach.

The remainder of this paper is presented as follows: In Section 2, the literature and related works are reviewed and discussed. Section 3 describes the materials and methods that support the methodology used to conduct the study. In addition, our framework for approaching learning is also proposed. The main results of the study are presented and discussed in Sections 4 and 5, respectively. A conclusion, future research, and recommendations make up Section 6.

2 RELATED WORK

2.1 Inductive reasoning strategy

This subsection of the paper reviews the theoretical framework of the inductive reasoning strategy, its related work, and examines its possible contribution to the promotion of mathematical knowledge.

To master learning objectives, clearly thought-out learning activities are essential for students [28]. Inductive reasoning strategy in terms of instruction has been identified as a teaching method that generally requires students to observe the various examples presented by instructors in order to develop understanding and then let the students arrive at conclusions, including procedures for finding solutions based on their understanding [7], [29]–[31]. Based on this new-found understanding, they will then be able to regulate fundamental concepts and apply them to new situations [32]. The framework for the inductive reasoning model suggested by [31] consisted of observation of specific examples, methods, and patterns in order to make assumptions and determine conclusions. Additionally, [33] also elaborates on the framework of the mathematics inductive reasoning approach, including the main structure associated with the cognitive ability of students to find similarities and differences between the attributes and relationships of mathematical concepts.

It has been suggested that the inductive reasoning strategy is appropriate for conceptual learning and for enhancing mathematical knowledge in terms of implementation based on their understanding [34], due to it including techniques for encouraging students to use mathematical thinking in various ways until they have accumulated the desired knowledge [30]. In this context, the acquisition of knowledge or skills through educational experience derives from asking relevant questions that challenge students to think, find solutions, and explore, all of which will lead to the development of deeper cognition on the part of students [35]. This statement is supported by the study of [9], who found that instructors can advance students' mathematical thinking by posing them problems, asking them to find and examine solutions, and acquiring new points of view. From this understanding and these experiences, instructors will be able to supervise the use of mathematical concepts and algorithms and practice their use in extended problems [2], [32]. These explain why students who are exposed to following inductive reasoning strategies will find that their mathematical knowledge is indirectly promoted. The advantage of inductive reasoning in a mathematics context, unlike that found in the traditional approach, is that it focuses on concepts involving finding and interpreting data in order to obtain an overview [6].

On account of the clear benefits when it comes to mathematical performance development, the impact of using inductive reasoning strategies has been examined with regard to content-based mathematics courses. For example, [6] found that the students' mathematics motivation increased as a result of learning through an inductive reasoning strategy assisted by GeoGebra, compared to those taught using conventional learning. As stated in [2], the inductive reasoning strategy using GeoGebra leads to improved higher-order thinking skills compared with the conventional method. In another study [10], infographics were applied using the inductive method, and it was found that the students' post-test measure of conceptual thinking ability was significantly higher than the pre-test ability.

With regard to the application of this strategy with the support of another approach, [36] found that dealing with mathematics inductive reasoning problems improved the solving abilities of students after using inductive reasoning to encourage problem solving integrated with the development of mathematical concepts. The studies involved the implementation of an inductive reasoning strategy with other tools to accomplish particular educational goals, e.g., [6] revealed that the motivation of students in mathematics increased after learning via an inductive reasoning learning strategy assisted by the GeoGebra software. Based on their findings, the inductive reasoning strategy was employed as an instructional approach to develop students' cognition. With this strategy, students were able to use their cognitive processes to enhance their learning outcome in various aspects of mathematical knowledge [2]. As a result, it was determined that this strategy positively affects mathematical performance in terms of knowledge development, including thinking skills and reasoning. Therefore, the inclusion of cloud technology for instruction is an important aspect of encouraging students to study mathematics more meaningfully [35], [37].

Based on a synthesis of the literature, an instructional approach using an inductive reasoning strategy in terms of mathematical context was employed in this study. This approach consisted of four stages: introduction, learning activities, implementation, and determination.

2.2 Cloud technology for online education: Symbolic mathematics software

Here we give a brief explanation of cloud-based educational technology, including symbolic mathematical software, and discuss its usefulness for teaching and learning mathematics.

The educational cloud technology is generally associated with the cloud service model, the cloud deployment model, and cloud computing tools [38]. Based on service functionality, cloud technologies used in education are categorized into six groups as follows [39]: 1) SaaS (Software as a Service), 2) PaaS (Platform as a Service), 3) HaaS (Hardware as a Service), 4) IaaS (Infrastructure as a Service), 5) CaaS (Communication as a Service), and 6) DaaS (Desktop as a Service).

During the COVID-19 pandemic, an adaptation of cloud-based solutions to support online education became a critical part of higher education institutions [13], [40], [41]. In the past few years, cloud technology has played an important role as a mathematics learning tool, adapting pedagogical methods to online learning conditions for university students [15], [26], [42]. This has become important with regard to encouraging students' learning development [43]–[45]. Following [46], it is suggested that the virtual manipulation of mathematics points that can be accommodated by computer software is similar to physical manipulation. Similarity [1] found that students who received the teaching approach using computer game applications obtained better scores than those using the traditional approach. Consequently, cloud software could be used to practically support the mathematics learning process.

Mathematics learning goals that go beyond principles and theories involve using appropriate technology, media, and other resources [47]. The advantages of using technology in teaching mathematics include engaging students in learning in such a way as to develop their interest in mathematics, enhance performance, promote lifelong learning, encourage positive interaction, and allow them to engage in constructivist learning [25], [48]. It has been suggested that teaching mathematics without the aid of technology may not adequately reflect the process of mathematical cognition development [2]. The perspective of using cloud services in terms of learning strategies has been recommended as having benefits for both students and instructors [39], [40], [49]. Mathematical concepts as well as procedures, especially abstract ones, can be better visualized using interactive learning with the assistance of cloud technology compared with traditional methods [12], [46].

There are studies on the implementation of cloud technology in support of mathematics learning. According to [50], employing Microsoft mathematics in the classroom is essential for supporting students' learning because it is more practical than conventional teaching. They also found that students' interaction with computers and their understanding of mathematical concepts were improved by such tools, something that conventional teaching might not achieve. Similarly, [51] found that there were significant differences between using and not using cloud software as instructional tools by instructors in their mathematics' classrooms. The authors of [52] found that students have better learning outcomes and improved critical thinking skills after using cloud technology in a blended learning situation.

The services of the educational cloud can be accessed anytime, anywhere, and on any device [53]. Likewise, its use can induce significant differences in teaching methods, approaches, and learning activities within the classroom, as well as enhance the learning environment [48], [54]. This includes collaboration, enthusiasm, interaction, and creativity [55]. The support of cloud technology-based educational resources in the form of symbolic mathematical software also plays a key role in promoting effective learning in the 21st century [26]. With the outstanding features of cloud technology that it is flexible as well as allowing access without the need to install software on devices, it has been popularly used in learning activities [54], [56]. In this regard, [57] implied that students can use cloud technology as well as mathematical software to investigate mathematical relationships as a reason for adopting their methods.

Wolfram Alpha, a cloud educational platform, offers symbolic mathematical software based on mathematical knowledge and calculation. It has been developed to accurately represent advanced mathematical solutions such as differential equations, systems of equations, and calculus [58]. Wolfram Cloud, a SaaS cloud service model for education, includes the function of solving complex differential equations with numerical methods and displaying the results directly in symbolic form. As a virtualization tool, learning resource management was included. This becomes increasingly useful in improving the visualization of mathematical concepts as well as procedures in an interesting manner [59]. It can be accessed through the Internet in the form of system software without installing a program [39]. In particular, it has been deployed as an explanatory tool to describe the relevant characteristics of the solution as represented by graphs, analytical solutions, and other functions. Furthermore, it also enables users to examine algorithms, consider more interesting mathematical concepts, and make them understandable through visual representations with the use of colorful text and graphics. It has been recommended that mathematics cloud software could be a new mode for educational content management for students [17], [60]. Wolfram Alpha uses other cloud tools such as discussions and presentations to facilitate students' learning outcomes and provide for the adaptation of teaching strategies. Students perceive the mathematical solution process by actively exploring reasoning through practice in an online environment and obtaining independent learning through problem solving. The representation of solutions in both approximate and exact forms is possible with such an online platform [61]. In addition, Wolfram Alpha provides more than just geometric or algebraic information in comparison with GeoGebra. It has visualization capabilities and is also outstanding for symbolic computations and manipulations, an aspect that is consistent with the contents of the course used in this study and the inductive reasoning approach framework. Moreover, it emphasizes the need to suggest prior knowledge to students and encourages students to use their mathematical thinking in such a way as to allow them to achieve better visualization with regard to mathematical concepts. Consequently, the utilization of emerging technology with regard to learning strategies in the academic environment of universities is therefore a crucial feature when it comes to adapting to the post-COVID-19 situation in such a way as to ensure educational sustainability in the future [62]. From our point of view, this implies that it may be a fruitful approach to deploy when it comes to providing mathematical content and procedures, developing practical skills, and enhancing the mathematical knowledge propensity of students.

Several previous works have focused separately on inductive reasoning strategies and the use of mathematics software. However, only a few studies have emphasized the utilization of cloud technology-based platforms as media and learning resources in selected mathematics education environments for students with regard to inductive reasoning strategy. Consequently, this study considers a mathematics course for undergraduate students involving a learning approach using an inductive reasoning strategy supported by Wolfram Alpha.

2.3 Mathematical knowledge

This subsection deals with mathematical knowledge and its associated framework.

Generally, instructors are certainly engaged in determining students' learning involving mathematical knowledge [9], [27]. Based on the study of Teacher Education and Development Study in Mathematics (TEDS-M), three important requirements in terms of professional mathematics teachers have been specified. These are knowledge of mathematics content, knowledge of pedagogy, and general teaching knowledge [63]. Mathematical knowledge is accordingly part of the assessment of educational needs [64] and also represents the mathematical abilities of students [65]. There are two main categories of mathematical knowledge: conceptual knowledge and procedural knowledge [66]. Conceptual knowledge reflects mathematical conceptual understanding and the ability of students in reasoning involving the use of definitions of concepts, relationships, or representations [65]. Procedural knowledge relates to procedural fluency–the ability to know how and when to use an algorithm [65], [66]. It also relates to the performance skills needed to carry out procedures flexibly, precisely, effectively, and suitably [8]. In the domain of ordinary differential equations (ODEs), conceptual knowledge and algorithm skills based on knowledge of other disciplines are essential for learning effectively. Another study has shown that students' discovery and construction of knowledge are supported by instructor-student and student-student interactions, [67]. Students acquire knowledge regarding concepts and procedures via learning activities in which they apply their own reasoning [68], [69]. In our experience, it is also a reflection of the students' ability to understand the rationale of mathematical processes. As instructors our view of mathematics learning and our analysis of mathematics education are that mathematics abilities related to conceptual knowledge, understanding, and procedural skills are particularly important in mathematics classrooms and furthermore, are needed for students to learn successfully.

In this study, we examine students' abilities with regard to the mathematical knowledge of concepts and procedures. Conceptual knowledge includes the following aspects: relationships between concepts in mathematics, representations, and reasons for mathematical methods. Procedural knowledge can be demonstrated by applying proper procedures based on relevant rules and conditions that allow students to obtain solutions accurately.

Based on previous research and the theoretical framework mentioned above, few studies have combined the inductive reasoning strategy with other teaching methods or with cloud-based technology in the form of mathematical software. We have therefore filled this gap by adding cloud services to support the pedagogical approach used in this study.

3 MATERIALS AND METHODS

An inductive reasoning strategy that integrates cloud-based software into a mathematics course is presented in this section.

3.1 Research design

A quasi-experimental design involving the use of a posttest control group [70] was adopted for this study. We initiated the intervention process by selecting two classes with no difference in initial mathematics ability and then apportioning class one as the experimental group (using learning involving an inductive reasoning strategy where Symbolic Mathematics Cloud Software is used to support learning activities) and class two as the control group (using a conventional approach). Regarding the learning stages with regard to an inductive reasoning strategy for the experimental group, the process of organizing mathematics activities for each lesson included a set of four learning stages, namely 1) Introduction, 2) Learning Activities, 3) Implementation, and 4) Determination, as presented in Table 1.

Table 1. Framework of the inductive reasoning strategy with Cloud Symbolic Mathematics Software

Stages	Strategy and Activities	Learning Activities Assisted by Symbolic Mathematics Cloud Software
1. Introduction	Students were asked questions to review relevant prior knowledge.	Students read and listened to the given examples provided in cloud files.
2. Learning Activities	Example situations were presented on New Notebook, Students reviewed such examples, explored examples of relationship situations in order to be used as information for consideration in determining hypotheses about the principle of finding solutions.	Students analyzed ODEs classification, explored data and function visualization.
3. Implementation	The process of putting a decision or plan into effect; execution derived from the study of the examples based on their concepts and understandings. – Students brainstormed ideas with their peers' using graphs displayed on the software to compare, analyze, and distinguish between the features of ODEs. – Students were encouraged to show their reasoning.	Typed or uploaded the mathematics problem the student wanted to solve into the software. The solution was represented in the approximate form of a function and graph.
4. Determination	Summarized the principles derived from the example studied. – Students were exposed to deciding on the features of ODEs and making conclusions using methods for finding solutions with regard to each form of ODEs.	Students engaged in tasks or activities that with solutions could then be created online and shared with peers.

3.2 Participants

The participants selected for this study were 60 undergraduate students enrolled in the ODEs course at a Thai university. They were divided into two groups: an experimental group and a control group. Each group comprised of 30 students.

3.3 Procedure and implementation

The study was conducted for a period of one semester. The symbolic mathematics cloud software utilized to support mathematics instruction based on an inductive reasoning strategy in this study was Wolfram Alpha. The university's cloud networks were accessible for students, and most of them had mobile devices, which allowed them to access the software. Before conducting the experiment, the functionality and access to the Symbolic Mathematics Cloud Software by connecting to the Internet through the websites www.wolframalpha.com and www.wolframcloud.com were introduced. Inductive reasoning strategy with Symbolic Mathematics Cloud Software was then implemented in the case of the experimental group, while conventional learning was applied to the control group. The post-test was then carried out. In this study, we examined conceptual knowledge in three main aspects: 1) Relationships of mathematical concepts, 2) Principles of mathematics, and 3) The reasons for mathematical procedures. Procedural knowledge in three main aspects was investigated: 1) Problem-solving, 2) Problem identification, and 3) Computation, according to the conditions of the principles.

3.4 Research instruments

The materials for the experiment constructed by the author were an instructional plan of inductive reasoning strategy with Symbolic Mathematics Cloud Software.

The instrument for data collection was the mathematical knowledge test created by the authors. It consisted of a set of questions in the context of the ODEs course based on an inductive reasoning strategy that evaluated the students' conceptual and procedural knowledge after completing the course. Before the test was distributed to the participants, its validity was investigated with the help of three experts who reviewed it and gave recommendations. This test included two sections: Section I and Section II. Section I contained five items with regard to the concept of ODEs. Section II contained five items, focusing on carrying out procedures that were appropriately related, such as asking students to explain the process of finding solutions for ODEs. The difficulty index was in the range of 0.20 to 0.80, the discrimination index was in the range of 0.20 to 0.97, and the reliability of the test was determined by McDonald's omega coefficient to be 0.80.

3.5 Data analysis

Data in the study were collected from class participants' post-test scores obtained with regard to a mathematical knowledge test. The statistics used for data analysis were quantitative in nature using descriptive statistical analysis measures such as mean ($\bar{x}$) and standard deviation (S.D.). The McDonald's omega reliability coefficient was used to determine the reliability of the study instruments.

To verify whether the findings were significant, it is important to perform normality and homogeneity tests of the scores with regard to mathematical knowledge obtained previously. The Kolmogorov-Smirnov test was performed in terms of the normality test, and a Shapiro-Wilk test was used to verify the quality of variances in the sample. The normality and homogeneity tests are as shown in Tables 2 and 3, respectively.

Table 2. Normality test for mathematical knowledge

	Class	Shapiro-Wilk		
		Statistic	df	Sig.
Mathematical knowledge	Experiment	0.962	30	0.339
	Control	0.967	30	0.471

The results of the normality test obtained with regard to the value of significance based on the Shapiro-Wilk test for the experimental group was 0.339 > 0.05, while for control group it was 0.471 > 0.05. This implies that the data were normally distributed.

Table 3. Homogeneity test for mathematical knowledge

	Levene Statistic	df1	df2	Sig.
Mathematical knowledge	0.281	1	58	0.598

Using a Levene's test, the equality of variance in the scores with regard to the sample's mathematical knowledge was verified. It was determined that the significant value was 0.598, which > 0.05. Therefore, we met the assumption that the data have homogeneity of variance.

With regard to the post-test scores, the mathematical knowledge of both subject groups was normally distributed. The data were analyzed in terms of mean and standard deviation, and therefore parametric tests were used in order to answer the research questions [71], [72]. As the competitive examination of personnel to serve as teacher, civil service, and educational personnel has the threshold for passing of 60 percent of the total score [73], we used this 60% criterion in this study. A one-sample t-test was performed to make a comparison with the 60% benchmark, while an independent sample t-test was used to investigate the difference between the two groups in terms of testing the hypotheses at the 0.05 level of significance. The effect size was determined using Cohen's d value [74].

4 MAIN RESULTS

4.1 Results for the average mathematics knowledge score of undergraduates

The mathematical knowledge of the undergraduate students who were exposed to inductive reasoning strategies with symbolic mathematics cloud software was analyzed by comparing the results based on the criteria of 60% of the full score. These are presented in Table 4.

Table 4. Average student results on the mathematical knowledge post-test in relation to the required criteria

Mathematical Knowledge	Mean	S.D.	t	df	Sig.
Conceptual knowledge	34.92	5.36	5.022	29	0.000*
Procedural knowledge	35.65	3.12	9.905	29	0.000*
Overall	70.33	6.74	8.426	29	0.000**

Notes: *$p < 0.05$ The test value is 30, **$p < 0.05$ The test value is 60.

Table 4 shows the mean post-test mathematical knowledge score of the undergraduate students who learned using the inductive reasoning strategy with symbolic mathematics cloud software for conceptual knowledge. This was 34.94, while for procedural knowledge it was 35.65. The overall mean mathematical knowledge score was 70.33. Using a one-sample t-test, it was determined that the mean of the post-test score with regard to conceptual and procedural knowledge and the overall score with regard to mathematical knowledge were significantly higher than the reference value of 60 percent of the full score at the level of 0.05. This implies that undergraduate mathematics students' knowledge scored reasonably highly in terms of the criteria.

4.2 Results concerning differences in mathematical knowledge between groups

In order to answer the research question as to whether there are differences between the scores for mathematical knowledge between students using Symbolic Mathematical Cloud Software as an instructional technology tool in conjunction with inductive reasoning strategy and those engaged in conventional learning, the descriptive analysis regarding mean scores is presented in Figure 1. The independent sample t-test was employed to investigate whether or not the undergraduate students' mathematical knowledge was affected by an approach to learning involving an inductive reasoning strategy with symbolic mathematics cloud software and also determine its effect size (refer to Table 5).

Figure 1 shows the students' mean mathematical knowledge scores at the post-test. The results show that students in the experimental group achieved higher mean scores for conceptual knowledge, procedural knowledge and overall mathematical knowledge, than those in the control group.

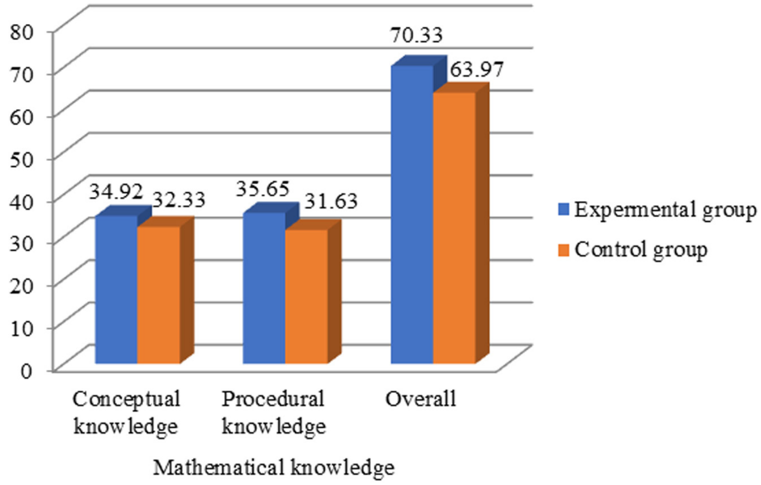

Fig. 1. Average post-test mathematical knowledge scores for the experimental and control groups

In Table 5, the t-test for independence was used to compare the difference of the post-test mean score between the groups, as determined by the level of statistical significance ($\alpha < 0.05$). The significant value of 0.000 < 0.05 was observed for the mean difference in terms of mathematical knowledge. Thus, it was implied that the differences between the experimental and the control group with regard to the aspects of mathematical knowledge were statistically significant. The experimental group students were significantly better in terms of mathematical knowledge than were the control group students.

Table 5. Comparison of the difference between the mean mathematical knowledge scores for the post-test of the experimental and control groups

Group	N	Mean	S.D.	t	Df	Sig.	Effect Size
Experiment	30	70.33	6.74	3.773	58	0.000*	0.97
Control	30	63.97	6.31				

Note: *$p < 0.05$.

In terms of practical significance, it is necessary to determine whether, if applied, the use of symbolic mathematical cloud software as an educational technology tool in conjunction with an inductive reasoning strategy would help students improve their overall mathematical knowledge. The effect size in terms of Cohen's d was 0.97. The difference found was significant [75]. This means that the effect on students' mathematical knowledge was clearly significant. As the experimental group scored significantly better than the control group, this suggests that this learning approach would improve undergraduates' mathematical learning outcomes in terms of conceptual and procedural knowledge.

5 DISCUSSION

One aspect of mathematics teaching aimed at improving students' mathematical performance is the use of optimal strategies in the classroom. The study presented in this paper deploys a learning approach using cloud-based symbolic mathematics software based on an inductive reasoning strategy in the context of a mathematics course. The aim is to determine whether this approach, applied in the context of an ODEs course, can help improve the mathematical knowledge of undergraduate students. Students' mathematical knowledge was studied, compared to a 60% criterion, and differences in mathematical knowledge between a control group and an experimental group were compared. The results show that students' mean score exceeded the 60% criterion for mathematical knowledge at a statistically significant level of 0.05. This can be explained by the fact that the attributes of cloud-based mathematics software indicate that it offers significant advantages that help to make it a suitable tool for learning calculus. The characteristics of mathematics involve reasoning, which is undoubtedly a necessary skill for learning mathematics at all levels of education, particularly in the context of higher education, where mathematics is more abstract than at other levels. In terms of the effect of the inductive reasoning strategy alone on mathematical knowledge from a teaching point of view, this approach follows the constructivist approach. In addition, the presence of software that can display mathematical models as well as graphs probably constitutes a more engaging learning environment than that found in a conventional teaching approach and can be considered an enjoyable learning experience [54]. Students learn best in an intelligent and stimulating learning environment, resulting in intellectual improvement in terms of mathematical performance while working at their own pace [56], [69]. Students are stimulated by engaging in comparative analytical thinking while carrying out appropriate activities. This helps them to create hypotheses, linking existing knowledge to new knowledge with the aid of visualizations that enable them to plausibly deduce the necessary principle [25]. With regard to these statements, the students in the present study demonstrated mathematical knowledge above the required criterion.

As the results showed that the experimental students performed better on the post-test in terms of mathematical knowledge than the control group, this may be due to the inductive reasoning approach in terms of teaching strategy. This is a technique that offers students opportunities for interpretation and encourages them to give reasonable explanations of mathematical concepts. To be able to find mathematical solutions, students must first be able to explain and interpret the classification of a problem according to the type of equation framework. Inductive reasoning strategies are also quite practical in terms of improving assessment skills since, in this context, students have to think about generalizations based on their observations [7]. Students were curious when it came to participating in the learning process, as they had access to visuals and easy-to-use software. Consequently, learning concepts and problem-solving procedures can be acquired through interactive, visual activities and the functionality of the software provided. Teaching methods at the implementation stage mean that examples based on concepts and understanding are explored. In addition, students practiced using mathematical representations on the cloud-based software to explain the process of procedural calculation [41]. These processes therefore better contribute to students' acquisition of mathematical knowledge since they require them to think about how to identify problems and reason in terms of the relevant concepts. Furthermore, as previous similar studies have shown, the results imply that learning approaches involving inductive reasoning strategies effectively improve students' cognitive learning outcomes [2], [6], [10], [35], [36].

Within the context of the teaching environment, students are allowed to engage in mathematical activities. The instructor, using available teaching materials, can develop lessons and exercises and explore these problems and their solutions using the cloud-based symbolic mathematics software without having to modify the teaching program. In addition, students can participate in learning through hands-on interactions using the software's features, where students will perceive the classification of ODEs and engage in a step-by-step solution, or discuss the problem with their peers using task activity questions. Instructors can better understand their students' current state of learning, and students can recognize their own processes of conceptual and procedural understanding. Thanks to its features, mathematical graphs, concepts, and solutions are displayed on the computer screen as they have been conceptualized by the students. As the software gives students the opportunity to explore the problem and observe the geometric features of the solution function, their cognitive learning processes are enhanced. Similar results have been obtained in previous studies [1], [2], [43], [52], [54]. The implication is that cloud technology in mathematics education makes it possible to combine the active learning approach in any given environment. Consequently, a mix of mathematics teaching approaches could be achieved with other cloud-based learning technologies. It was also noted that it would be useful to provide information on the views of academics or educators interested in applying the approach in the context of mathematics education.

6 CONCLUSIONS

The inductive reasoning strategy involving Symbolic Mathematical Cloud Software was investigated in terms of its impact on mathematical knowledge in the context of an ODEs course in higher education. The study was guided by the following two research questions: 1) Is the mean score of students' mathematical knowledge after learning with the inductive reasoning strategy using the symbolic mathematical cloud software above the 60% threshold? 2) Are there differences between the mean score of students' mathematical knowledge using the inductive reasoning strategy using the Symbolic Mathematical Cloud Software as a technological teaching tool and the mean scores resulting from conventional learning? We conducted a quasi-experiment using a post-test control group design to determine whether students' mathematical knowledge scores had exceeded the 60% criterion and examined the impact of the pedagogical approach on undergraduates by comparing the mathematical knowledge of students in the two subject groups.

In this paper, the research questions were answered. The results reveal that the post-test means for each aspect and the overall mathematical knowledge of students in the experimental group were significantly higher than the 60% criterion. The experimental intervention had an effect on undergraduates' mathematical performance in terms of knowledge. There was a statistically significant difference between students' mean post-test mathematical knowledge scores in the experimental and control groups, with the experimental group outperforming the control group by obtaining the highest score.

The results of this study support the adoption of cloud-based educational software in university-level mathematics courses due to the important factors of meaningful participation, learning success, and the acquisition of conceptual and procedural knowledge. The results are important for mathematics teachers when it comes to employing effective teaching strategies to improve students' knowledge of mathematical concepts and procedures. They also reflect a practical perspective for mathematics teachers seeking to improve the quality of their teaching to help students improve their mathematical reasoning and knowledge. In terms of implications, instructors and other educational stakeholders should include online activities to develop mathematical reasoning skills in the curriculum of undergraduate mathematics students that can be applied in similar situations. In conclusion, concepts of mathematical efficiency and procedural accuracy can be improved through practice. The use of cloud technology can change the means of acquiring these learning objectives by incorporating them into mathematics classroom activities or by adopting other techniques for teaching reasoning skills.

For future work, these results may suggest adopting the approach while considering other factors as variables for improving students' learning experience with mathematics. We recommend that mathematics teaching strategies be designed in conjunction with digital teaching materials to provide better opportunities for students of all skill levels.

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