education sciences

MDPI

Article

Enhancing Algebra Learning: Online Tutoring as a Technological Alternative for Grade Seven Students

Hooi Lian Lim [1,*], Thiam Yew Wun [1], Cheng Meng Chew [2] and Rozniza Zaharudin [1]

[1] School of Educational Studies, Universiti Sains Malaysia, Minden 11800, Pulau Pinang, Malaysia; tywun@usm.my (T.Y.W.); roz@usm.my (R.Z.)
[2] School of Education, Humanities and Social Sciences, Wawasan Open University, Penang 10050, Pulau Pinang, Malaysia; cmchew@wou.edu.my
* Correspondence: hllim@usm.my

Abstract

This study aimed to develop and evaluate the effectiveness of an online tutoring program (OTP) based on the Structure of the Observed Learning Outcome (SOLO) model and the Community of Inquiry (CoI) model for learning basic algebraic concepts step by step. The application of the OTP involved 13 mathematics teachers and 289 Grade 7 students during classroom lessons. A mixed-method approach was applied, with a quasi-experimental method used to collect quantitative data. The students' feedback was collected through an interview survey. All the mathematics teachers were also interviewed after the implementation. The quantitative findings of the paired samples *t*-test showed *p*-values of 0.00, indicating that there was a statistically significant difference between the mean scores of algebraic expressions and linear equations after using the OTP. The results of the qualitative study showed that both student feedback and teacher provided expressive insights that extend and refine the OTP in the context of algebra teaching and learning. This study confirmed that an OTP in school settings could positively affect the teaching and learning of algebra.

Keywords: online tutoring program; algebraic expression; linear equation; feedback; technology tool; mixed-method; SOLO model; CoI model

1. Introduction

Algebra forms the core topic of the secondary school mathematics curriculum. It consists of generalized arithmetic shifts from the domain of numbers to the domain of unknowns, which uses letters as representation (Ting et al., 2018). It is considered a foundation topic for all mathematics and science subjects that allows further access to technical professions.

Despite the fact that algebra comprises a substantial part of the mathematics curriculum in secondary school, many students encounter considerable problems in learning algebra (Arnawa et al., 2021; Kolovou & Van Den Heuvel-Panhuizen, 2010; Kurniawan et al., 2021; Stoelinga & Lynn, 2013). Students who begin the study of algebra face learning challenges concerning the general foundational set of understandings necessary to negotiate this topic (Rakes et al., 2010).

Drijvers et al. (2014) assert that online educational resources are designed to facilitate the efficient and effective acquisition of conceptual knowledge. Technology-integrated curricula, including computer-based instructional programs for traditional classroom settings, online learning platforms, and digital tutoring systems, have been shown to exert

Check for updates

Academic Editor: Cheryl Brown

Received: 7 September 2026
Revised: 8 October 2026
Accepted: 8 October 2026
Published: 15 October 2026

Copyright: © 2026 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license.

a significant positive influence on students' comprehension of foundational concepts. Hence, algebra software programs are widely available, and many of them are even free (Bouhineau et al., 2002; Desmos Studio, 2025; Hohenwarter, 2002; Kwelle & Charles-Ogan, 2024; Schneider, 2000; Mathspace, 2025; Soft Warehouse, 1995; Solfitri et al., 2024; Photomath Inc., 2023; Waterloo Maple, 2000). However, some of these programs are tailored for specific algebra topics, especially advanced concepts at the university level. They typically emphasize procedural skills and symbol manipulation rather than helping students to master fundamental concepts. Struggling students may need the step-by-step guidance to effectively grasp these abstract ideas. In other words, a more personalized, human-style diagnostic approach may help them strengthen their understanding of algebraic concepts.

Therefore, this study developed a more user-friendly online technology tool to facilitate students' connection between algebraic conceptual mastery based on the hierarchical manner tasks. It was also effective to diagnose the students' strengths and weaknesses, along with their responses to solving the hierarchical levels of tasks. In addition, immediate and informative feedback was provided for students' correct or incorrect responses.

Aims of the Study

This study aimed to develop an online tutoring program (OTP) that enables Form One students to learn basic algebraic concepts through a step-by-step approach and to investigate the effects of the OTP on students' performance in algebra. In addition, this study examined students' and teachers' views of the implementation and effectiveness of the OTP. Specifically, this study was conducted to achieve the following objectives:

I. To develop an online tutoring program (OTP) that enables Form One students to learn basic algebraic concepts through a step-by-step approach.
II. To study the effect of the OTP on enhancing the Form One students' learning of basic algebraic concepts.
III. To study the students' learning engagement experiences with the online tutoring program (OTP).
IV. To study the teachers' experiences with the application of the online tutoring program (OTP).

2. Literature Review

2.1. Challenges in Learning Algebra

The most challenging aspect of developing the algebraic abilities of students at the earlier stages of middle school is to master some important concepts of algebraic notation, variables, functions, and properties of numbers (Farah et al., 2021). These four basic concepts have been classified as major algebraic ideas and need to be understood and developed to build a solid foundation of algebraic problem-solving ability in the classroom (H. L. Li & Zulnaidi, 2024). This concern is evident from Stoelinga and Lynn's study (Stoelinga & Lynn, 2013), which indicated that many eighth- and ninth-grade students required to take the basic algebra course are underprepared because of weak foundations in these basic concepts. This failure might cause students to fall further behind when taking the advanced mathematics course (Agoestanto et al., 2019).

Malaysian middle school students are also faced with a similar problem. The Trends in International Mathematics and Science Study (TIMSS), conducted by the International Association for the Evaluation of Educational Achievement (IEA), highlights a significant difference in the performance between Malaysian and Singaporean students, especially in the topic of algebra (Adnan et al., 2021). Singh et al. (2021) noted that algebra as a topic is considered complex and abstract among students at Malaysian secondary schools. The students have to deal with abstract concepts and formulas, memorization, and symbol

manipulation, which make this topic challenging to learn. The primary reason is that the majority of students, especially Form One students who start to learn algebra topic, lack a solid understanding of fundamental algebraic concepts, leading to various misconceptions in the basic concepts of algebra such as the concept of an unknown, variable, equation, fraction, and negativity. In the Malaysian primary school mathematics curriculum, the syllabus includes a small section at the end of the arithmetic operations chapters that encourages pupils to explore the "unknown" world. These activities are inherently algebraic, as they prompt students to think about number properties and arithmetic operations. However, there is no clear evidence of how much emphasis is placed on discussing this section in classrooms. It remains uncertain whether teachers fully recognize its importance and necessity (Subramaniam et al., 2023). Farah et al. (2021) revealed that many Malaysian students remain uninterested in and worried about learning algebra concepts, which are perceived as overly abstract and too difficult to study.

2.2. The Role of Technological Tools

According to Drijvers et al. (2014), online resources are expected to contribute to concept mastery efficiently and effectively. Technology-based curricula included computer-based curricula for use in onsite classes, online courses, and tutoring curricula had significant effects on students' understanding of basic concepts (Mat Dangi & Mohamed Saat, 2021; Rakes et al., 2010). Barkatsas et al. (2016) and Kalonde (2017) revealed that there were significant effects of technology integration in mathematics teaching and learning in both rural and urban areas. With the use of technological tools, the students can easily imagine, understand, and master basic mathematics concepts to connect them with more abstract mathematics concepts.

2.3. Effectiveness of Technological Tools in Teaching and Learning of Algebra

Online mathematics learning has evolved from computer-assisted practice and formative assessment to adaptive tutoring, intelligent tutoring systems, dynamic mathematical environments, and AI-supported learning. Platforms such as Cognitive Tutor, ASSISTments, MathSpring, ALEKS, Khan Academy/Khanmigo, and IXL provide different forms of individualized practice, feedback, adaptive learning, mathematical visualization, and tutoring. Cognitive Tutor pioneered the integration of cognitive modeling and intelligent tutoring in school mathematics (Koedinger et al., 1997; Roschelle et al., 2021; Khan Academy, 2025).

Literature reviews have also shown that various types of technological tools or web-based interactive graphing calculators and activity platforms such as Computer Algebra Systems (CAS) (Schneider, 2000), GeoGebra (Hohenwarter, 2002), Aplusix-Editor (Bouhineau et al., 2002), Maple (Waterloo Maple, 2000), DERIVE (Soft Warehouse, 1995), MATLAB R2024a (Kwelle & Charles-Ogan, 2024), Wizer.me (Solfitri et al., 2024), Photomath Inc. (2023), Desmos Studio version 7.37.0 (2025), Mathspace (2025), Graspable Math (Goldstone et al., 2017), and ALEKS (Roschelle et al., 2021) have been developed to enhance students' algebra learning. All these computer system programs or interactive platforms are built as a powerful tool to solve mathematics numerical and word problems, especially algebra. They are widely available, and some of them are even free software programs. Although these platforms provide valuable opportunities for algebra practice, tutoring, visualization, and adaptive learning, they differ considerably in their underlying pedagogical approaches and in the extent to which they explicitly structure learning according to a hierarchical progression of cognitive complexity. Furthermore, some of these programs are specifically designed for specific algebra content or advanced algebra topics, particularly at the university level, and generally focus more on the students' procedural and symbol manipulation skills instead of mastery of basic concept features. Weak students might require step-by-step

guidance to master the abstract concept effectively. They need a more human-style method for diagnostics purposes to strengthen their mastery of the algebraic concept. Considering this situation, researchers found an option for a more sophisticated and useful computer program that allows students to have better guidance with a step-by-step method.

In order to embrace technology in mathematics teaching and learning effectively, according to Nisbet (2020), teachers are required to implement engaging tools and dynamic technology. This would help students with diverse learning needs to concretize mathematical concepts. One possible method for helping the students is through online tutoring. Typically, tutoring is carried out in face-to-face settings in which the tutor and tutee meet at a specified time and location. However, recent rapid improvements in information and communication technologies, and the increase in access to the internet have made it possible for tutoring to be conducted via the internet (Kersaint et al., 2011). Lessons in the context of after-school programs that involve tutoring, additional practice, or technology integration can significantly benefit students in learning algebra (Cunico et al., 2022). Meanwhile, in a study by Roschelle et al. (2016), an online mathematics homework intervention positively impacted seventh-grade students' mathematics achievement at the end of a school year. Students with low, rather than high, prior achievement benefited more. In addition, the intervention provided students with personalized feedback and tips that immediately proved that educational technology increases mathematics learning.

3. Theoretical Framework

The basis of this theoretical framework is developed based on two intertwined educational models, namely the Structure of the Observed Learning Outcome (SOLO) model (Biggs & Collis, 1982) and the Community of Inquiry (CoI) model (Garrison et al., 2000). The SOLO model is a hierarchical taxonomy for assessing students' cognitive development. It classifies the learning outcomes into four progressive levels, namely unistructural, multistructural, relational, and extended abstract. This model guides the design of instructional tasks that correspond with diverse depths of understanding in the algebraic concept learning process. On the other hand, the CoI model centers on the vital elements for generating a meaningful and engaging online learning experience. It consists of three interrelated elements, namely cognitive presence (the process of constructing meaning through sustained reflection and discourse), teaching presence (the design, facilitation, and direction of learning), and social presence (the ability of participants to identify with the group, communicate openly, and build relationships). Simultaneously, these models formed a vigorous theoretical basis that supports the development of a cognitively engaging and socially interactive online teaching and learning environment for algebra as a topic.

The framework is enacted through the four key components that correspond with the principles of both the SOLO and CoI models. First, content delivery of algebraic expressions and linear equations is structured to acquire basic knowledge, allowing the students to build cognitive complexity progressively. This content is presented through clear instructional guidance, corresponding to the teaching presence element of CoI. Second, a series of four-level SOLO-based tasks is developed, focusing on each SOLO level. These tasks vary from identifying simple mathematical elements (unistructural) to constructing and applying generalized concepts (extended abstract), supporting cognitive presence through increasingly complex problem-solving. Third, immediate feedback is embedded within the system to inform the students whether their responses are right or wrong, along with explanations and worked solutions. This corresponds with teaching presence, enhancing learning through timely guidance and encouraging reflection (cognitive presence). Ultimately, the reporting of the results enables students to monitor their performance based on SOLO levels, fostering self-awareness and metacognitive regulation. When integrated with

opportunities for interaction and reflection, this component can also enhance social presence by encouraging discussion and collaborative learning. In general, all the components work symbiotically to encourage deep learning in an online environment that is cognitively structured, instructionally supported, and socially engaging.

The OTP was designed to address a different instructional need. Most existing systems emphasize procedural fluency, problem completion, adaptive practice, or symbolic manipulation. In contrast, the OTP focuses specifically on conceptual development through a hierarchical progression based on the SOLO taxonomy.

The distinctive contribution of the OTP is the integration of the SOLO model and Community of Inquiry (CoI) framework within a single learning environment. Unlike platforms that primarily adapt difficulty levels, the OTP systematically structures tasks across unistructural, multistructural, relational, and extended abstract levels, enabling students to move gradually from recognition of patterns to generalized algebraic reasoning. In addition, the feedback provided not only indicates correctness but also provides guidance linked to students' errors. The performance reporting feature further allows teachers to diagnose students' strengths and weaknesses according to specific SOLO levels.

The conceptual framework (Figure 1) is the integration of the SOLO and CoI model. The SOLO model offers a cognitive taxonomy that guides the development of learning tasks at ascending levels of complexity. Meanwhile, the CoI model ensures that the online teaching and learning environment is pedagogically sound and socially engaging. In this framework, both models are integrated into the design of the online tutoring program, which emphasizes the teaching and learning of algebraic expressions and linear equations. The program incorporates structured content delivery, four-level SOLO-based tasks, immediate feedback mechanisms, and performance reporting. The combination of the cognitive depth offered by SOLO with the interactive, reflective environment of CoI model, the outcome of this program, aimed to generate a rich online learning experience that supports meaningful and sustained learning.

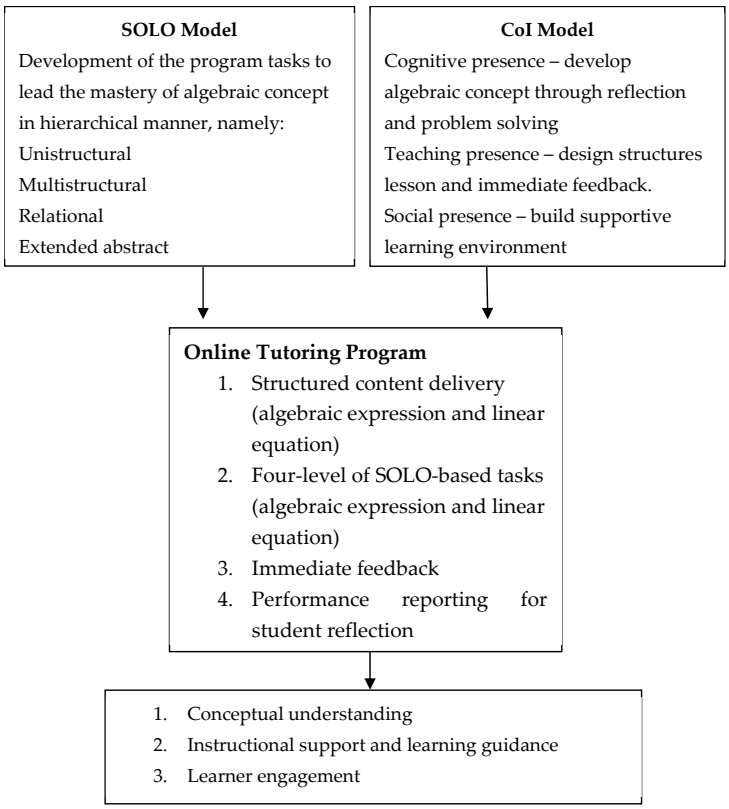


Figure 1. Conceptual framework.

4. Methodology

This study used an explanatory sequential mixed-methods design. A quasi-experimental pretest and posttest design was used in the quantitative phase of this study. In the qualitative phase, an interview survey was conducted to examine the students' views about the implementation of the OTP. Additionally, this study employed a semi-structured interview to explore the teachers' views about the application of the OTP.

In this study, a quasi-experiment with a one-group pretest–posttest design was conducted. It involved a single group that completed the pretest and posttest design for the dependent variables. The reasons for utilizing this experimental design were: (i) When exploring new interventions, a single-group design can serve as an initial step to gauge potential effectiveness. The primary purpose was to evaluate the feasibility, usability, and preliminary educational value of a newly developed online tutoring program (OTP) before undertaking a larger-scale controlled trial. Such designs are commonly used in educational technology research during the early stages of intervention development to determine whether an innovation is implementable in authentic classroom settings and warrants further investigation (Best & Kahn, 2016). (ii) This approach could provide preliminary data that may inform more rigorous future studies and reduce the influence of external factors such as cross-group interaction effects (Best & Kahn, 2016). (iii) This study was conducted in eight schools located in rural districts where access to educational resources and qualified mathematics support was limited. School administrators and teachers preferred that all participating students receive access to the intervention because many students were already experiencing significant learning difficulties in mathematics. Under these circumstances, withholding access to a potentially beneficial learning support tool by assigning students to a non-intervention group was considered educationally undesirable.

4.1. Participant

Eight secondary schools located in three districts in Kedah, Malaysia, were selected for the implementation of the OTP. The selection of schools was based on the availability of computers, sufficient internet connection, and the permission to carrying out data correction by the school principals. Cluster sampling was used to select desired classes to be involved in this study. Based on the discussion with the mathematics teachers, fourteen Form One (Grade 7) classes with an average of 20–25 students in each class were chosen. All the Form One students were aged 12–13 years old and studied in public secondary schools. Thirteen mathematics teachers for the classes applied the OTP to 289 students during their teaching and learning of the algebraic expression and linear equation topic.

4.2. Development of Online Tutoring Program and Pre- and Posttest

The content of the online tutoring program (OTP) was constructed based on the Malaysia Form One Mathematics Secondary School Standard Curriculum (*Kurikulum Standard Sekolah Menengah-KSSM*). Two main topics in algebra were selected, namely algebraic expressions and linear equations. Four related learning standards were covered in the tutoring program, namely:

i. Using letters to represent quantities with unknown values.
ii. Deriving algebraic expressions based on arithmetic expressions that represent a situation.
iii. Forming linear equations in two variables based on a statement or a situation, and vice versa.
iv. Solving problems involving simultaneous linear equations in two variables.

The OTP consisted of 11 scenario-based tasks to assist the development of the students' algebraic ability in algebraic expressions and linear equations. All items in the tasks were in an open-ended format.

The development of the OTP tasks was based on the SOLO (Structure of the Observed Learning Outcome) model. The four levels (unistructural, multistructural, relational, and extended abstract) of the SOLO model embody both main features: an increase in the application of the information (in the form of data, diagram, figure, text, etc.) given in the task and an increase in the complexity of the answer structure expected. According to this model, when students answer a task, the response structures could basically be categorized into five main levels (pre-structural, unistructural, multistructural, relational, and extended abstract). In addition, the pre-structural level indicates no response given by the students; the features of the other four levels could be applied to construct questions in a hierarchical manner.

Each component of algebraic expression was assessed in the form of an, $an + b$, and $n + b$. It was assessed through three cognitive complexities:

i. Investigating patterns;
ii. Solving near and far cases;
iii. Forming algebraic expressions.

In this context, the term 'near cases' indicated the items that could be solved by step-by-step or counting. It was the next term of the pattern shown. On the other hand, 'far case' represented the item that forced the students to generalize the pattern because it went beyond reasonable practical limits of a step-by-step solution. Each component of linear equation is assessed in the form of y = an, y = an + b, y = n + b, and y = an + bm. It is assessed through the three cognitive complexities:

i. Investigating pattern;
ii. Solving the near cases;
iii. Solving the far cases, forming the algebraic expression and linear equation, and applying linear equation to solve the problem.

Three secondary school teachers and three mathematics education lecturers reviewed the newly developed scenario tasks to determine the content evidence validity. The revision was done based on the comments given to ensure the items were relevant and they represented the content domain as stated in the syllabus. In addition, the first version of the scenario tasks was piloted, and the psychometric properties were determined using Rasch analysis (Lian & Idris, 2006).

The OTP was hosted online at http://www.bmg-project.com/ (accessed on 1 June 2019). Before using the OTP, the students were required to register their demographic details on the landing page. After that, they were required to log in by using their identity card number and password.

There were two components for each topic. For example, for the topic of algebraic expression, the students had to finish the first component (number pattern) before proceeding to the second component (pictorial pattern). The questions appeared from the simplest to the hardest to lead the students from the arithmetic concept to the algebraic concept, which is more abstract. The students were required to read the information shown carefully before typing and submitting their answers (see Appendix A).

Feedback is given after the answer is typed and submitted. Positive and immediate feedback is shown if the answers are correct. The immediate feedback comprises two main pieces of information: correctness and reinforcement. First, the students will be informed that their answers are correct. Second, the feedback reinforces what they do correctly (see Appendix B).

If the students answer wrongly, detailed and immediate feedback will be shown. The feedback comprises three main pieces of information. First, the feedback will inform them that their answers are incorrect. Then, information will be given about what they should improve and develop. Finally, the proper solution will be shown to the student (see Appendix C).

In addition, the students could view their performance by clicking the result feature. Thus, they are able to view their overall performance as well as their performance in each component for both topics.

The mathematics teachers are also able to easily detect their students' strengths and weaknesses through the results shown in the results feature. The teachers can identify the students' algebraic ability based on the item levels that they could answer, whether the item is a, b, c, d, and e (refer to Table 1).

Table 1. Indicators of students' algebraic ability in algebraic expression.

Item Level	Indicators of Students' Algebraic Ability
a	understand the pattern given
b	extend the next term
c & d	identify the recursive relationship between the variables
e	identify the linear relationship between the variables by forming an algebraic expression

Meanwhile, the content of the questions in the pretest and posttest was identical for both topics, namely algebraic expressions and linear equations. The tests were developed by researchers who are experts in Mathematics Education. There were 12 questions (6 tasks) for the algebraic expression topic and 10 questions (5 tasks) for the linear equation topic. The students were required to identify like terms and form algebraic expressions and linear equations based on the scenario shown. Each task contained two related questions. Based on recommendations from experienced secondary school mathematics teachers and the standard school marking scheme, the first question in each task was allocated 2 marks and the second question was allocated 3 marks. Consequently, each task carried a total of 5 marks.

The maximum score for the algebraic expression test was therefore 30 marks (6 tasks $\times$ 5 marks), while the maximum score for the linear equation test was 25 marks (5 tasks $\times$ 5 marks). Students' raw scores were subsequently converted into percentages to facilitate comparison and interpretation of performance across the pretest and posttest administrations.

The content coverage of the questions was aligned with the Form One mathematics curriculum. The test's content validity was determined by the six school mathematic teachers. The validation procedure was determined by calculating the CVI (Content Validity Index). Based on the calculation, the I-CVI value is 1 and the S-CVI/Ave is 0.94. The result of the analysis shows that the instrument of this study has an excellent content validity because the I-CVI value meet Lynn (1986) criteria, in which the minimum value for I-CVI is 0.78 for 6 to 10 experts. Besides that, the S-CVI/Ave value also meets the satisfactory level, in which, according to Polit and Beck (2006), the acceptable value for S-CVI/Ave must be more than 0.90. From the results, it can be concluded that all questions for each topic of this study were built with a good degree of content-based evidence of validity.

4.3. Data Collection

The study procedures involved three stages. First, before the implementation of the OTP, a pretest was administered to the students involved. The test consisted of 11 scenario tasks, namely 6 algebraic expression tasks and 5 linear equation tasks. Next, the students were exposed to the OTP for the first topic, namely algebraic expression. Before the implementation, all the teachers involved were required to:

i. View the scope and content of the tutoring program.
ii. Ensure alignment between the learning outcome and the teaching and learning activity.
iii. Plan the lesson carefully and creatively so that the teaching and learning process is fun and beneficial for students. Teachers had prepared lesson plans for both topics involved with the implementation of the tutoring program.

During implementation, lessons generally followed a common structure. Teachers first introduced the algebraic concept and learning objectives through a classroom explanation. Students then accessed the OTP in the computer laboratory and completed the assigned activities independently while receiving immediate automated feedback from the system. Teachers acted primarily as facilitators by monitoring student progress and clarifying questions when necessary. Across schools, approximately 20–30% of lesson time was devoted to teacher-led instruction and 70–80% to student interaction with the OTP.

Although some variation in teaching style and classroom management practices was unavoidable due to the natural school setting, the core intervention remained consistent because all students engaged with the same online platform, tasks, instructional sequence, and feedback system.

All the mathematics teachers involved had conducted their lessons in the school computer lab as the students needed to access the online tutoring program App along with the lesson. After they have finished the teaching and learning of the algebraic expression topic for 4 weeks, Posttest 1 was conducted. The test consisted of six tasks. Besides that, the researchers also conducted individual interviews with all the teachers and collected written feedback from the students. Before the individual interviews were conducted, the researcher requested permission from the school principals and teachers for the interview session. The permission letter was distributed to the teachers to request permission in taking part in this interview session.

Next, this study proceeded to the second topic (linear equation) using the OTP, and after 4 weeks, Posttest 2 was conducted, which consisted of five tasks. Thus, the duration of the implementation of the OTP for both topics took around two months.

All the mathematics teachers involved were individually interviewed after the application of the OTP for the first topic. They were requested to give feedback for the following three aspects:

i. The effectiveness of the OTP in teaching;
ii. The effectiveness of the OTP in learning;
iii. Suggestions for improvements to the OTP.

The students' written feedback was also considered in the process of monitoring the implementation of the OTP. They were required to write their feedback independently on the paper provided regarding the four main aspects of the OTP, based on the three dimensions of the Community of Inquiry (CoI) model:

i. The conceptual relationship between arithmetic and algebraic expression (cognitive dimension);
ii. The four level tasks shown (teaching dimension);

iii. The information and explanation provided if the students answered incorrectly (social dimension);
iv. The display of pictures, tables, and animations (teaching dimension).

4.4. Ethic Consideration

Before data collection, ethical approval was obtained from the Policy Research and Evaluation Sector Committee, the Educational Planning and Research Division, Ministry of Education Malaysia in 2019, reference No.: KPM.600-3/2/3-eras (3260); the Kedah State Education Department, reference No.: JPK.SPS.UPP 600-1 1/2 Jld. 8 (52); and the Director of the District Education Office. Participation was voluntary, and informed consent was obtained from all participants (namely 13 participating mathematics teachers and 289 students) and the parents or legal guardians of student participants. Approval was also obtained from the principals of the participating schools before the study commenced. Participants were assured that their responses would be kept confidential and anonymous and that they could withdraw from the study at any time without penalty. All data were used solely for research purposes and stored securely to protect participants' privacy.

4.5. Data Analysis

The quantitative data from both the pretest and posttest were systematically analyzed using the Statistical Package for the Social Sciences (SPSS) Statistics version 29 To determine whether there were significant differences in students' performance before and after the intervention, a paired-samples *t*-test was conducted. Meanwhile, students' learning engagement experiences were examined using interview survey data. The data were analyzed and categorized according to the three dimensions of the Community of Inquiry (CoI) framework: cognitive presence, social presence, and teaching presence.

For the teachers' interview data, the data were transcribed, and then, a thematic analysis was conducted to analyze the interview transcripts. In the thematic analysis, the researcher analyzed the data closely to identify common themes based on the Community of Inquiry (CoI) model and a set of priori codes obtained from the literature, which applied the CoI model to investigate social presence, cognitive presence, and teaching presence through the interview method (Waddington & Porter, 2021). There were four main steps in conducting the thematic analysis. First, transcribe and carefully read the transcripts to identify the predefined themes. Second, create the initial codes based on the CoI model. Third, group all codes into the sub-themes and themes according to the CoI model. Finally, re-examine the coded-data and themes to ensure accuracy and reflection of the model.

Indicatively, some teachers have stated that the OTP offered tasks in a logical sequential order, from simple to complex, thus enabling them to convey the algebraic concepts better and minimizing their teaching load in the process. The answers were originally coded as being a clear explanation of content and structured tasks that facilitate teaching. These codes were further subdivided as sub-themes: clear explanation of content, which was further subdivided into the broad theme teaching presence.

The validation of the qualitative data was rated by two researchers. The interrater reliability was computed using the data collected in order to examine the raters' agreement, namely the percentage of agreement, which can be calculated as the number of agreement scores divided by the total number of scores. Cohen's kappa (κ) was used to determine the level of agreement between the two raters. The analysis yielded a kappa value of $\kappa = 1.00$, indicating perfect agreement (100%) between the raters. This result demonstrates that the two researchers consistently assigned the same ratings to all qualitative data.

5. Findings

A Kolmogorov–Smirnov test was conducted to assess the normality of the pretest and posttest data. The results indicated that the data for the pretest were normally distributed, D (289) = 0.061, p = 0.071. Similarly, the data for the posttest did not significantly deviate from normality, D (289) = 0.063, p = 0.059. Given that all p-values were greater than 0.05, the data met the assumption of normal distribution required for conducting parametric tests. These results support the appropriateness of using paired t-tests.

Based on the result of the paired samples t-test shown in Table 2, the mean value for the pretest of algebraic expressions was 7.92. The mean value for the posttest of algebraic expressions was 29.25 (increased 21.33). The mean score for algebraic expressions increased from 7.92% to 29.25%, representing an improvement of 21.33 percentage points.

Table 2. Paired samples t-test for algebraic expression scores (pretest vs. posttest).

Measure	N	M	SD	t	df	p
Pretest Algebraic Expression	289	7.92	9.29			
Posttest Algebraic Expression	289	29.25	21.01	−18.35	288	0.00

The standard deviation for the pretest of algebraic expressions was 9.29 and for posttest of algebraic expressions was 21.01. The p-value was 0.00. Because of this, it can be concluded that there was a statistically significant difference between the mean scores of algebraic expressions. Participants demonstrated significantly higher posttest scores for the algebraic expressions topic following participation in the OTP.

Meanwhile, based on Table 3, the mean value for the pretest of linear equations was 2.16. The mean value for the posttest of linear equations was 21.38 (increased 19.22). Linear equation scores increased from 2.16% to 21.38%, representing an improvement of 19.22 percentage points.

Table 3. Paired samples t-test for linear equation scores (pretest vs. posttest).

Measure	N	M	SD	t	df	p
Pretest Linear Equation	289	2.16	4.04			
Posttest Linear Equation	289	21.38	21.41	−15.32	288	0.00

The standard deviation for the pretest of linear equations was 4.04, and for the posttest of linear equations was 21.41. The number of participants in each condition (N) was 289. The p-value was 0.00. Because of this, it can be concluded that there was a statistically significant difference between the mean scores of linear equations. Participants demonstrated significantly higher posttest scores for the linear equation topic following participation in the OTP.

The extremely low pretest means suggest a possible floor effect, indicating that many students possessed limited prior knowledge of the algebra concepts before participating in the online tutoring program. The comparatively large posttest standard deviations reflect differing levels of improvement among students following the intervention.

Although statistically significant improvements were observed, the absolute posttest scores remained relatively low. This finding should be interpreted in the context of the student population involved in this study. The participating schools were located in three rural districts where mathematics achievement levels were generally low. Based on centralized assessment results, approximately 65–70% of the participating students scored grade D (weak) and grade E (failed) in mathematics before entering secondary school.

Consequently, many students began this study with extremely limited algebraic knowledge, as reflected in the very low pretest means (7.92% for algebraic expressions and 2.16% for linear equations). These results indicated that students were operating near the floor of the assessment scale before the intervention. The increase in the posttest scores showed that students acquired foundational algebraic knowledge that had previously been absent.

5.1. Written Feedback from Students

The students' written feedback was also considered in the process of monitoring the implementation of the OTP. They had been asked to give feedback independently about the four main aspects of the OTP aligned to the three dimensions of the CoI model after they learnt the first topic (algebraic expression). All the feedback was analyzed and grouped into three categories based on each aspect (refer to Table 4).

Table 4. Written feedback analyzed based on three categories.

No	Aspect	Dimension	Three Categories
1	The conceptual relationship between arithmetic and algebraic expressions	Cognitive	Well understood/understood, lack of understanding, not understood
2	The four-level tasks are shown	Teaching	Very clear, lack of clarity, unclear
3	The information and explanation provided if answered incorrectly	Social	Very sufficient/sufficient, lack of sufficiency, insufficient
4	The display of pictures, tables, and animations	Teaching	Very clear/clear, lack of clarity, unclear

The results of the category of students' written feedback are shown in Table 5. Based on Table 5 for aspect 1, 237 out of 289 students responded that they have a good understanding of the conceptual relationship between arithmetic and algebraic expression. In total, 275 out of 289 students responded that they were clear about aspect 2, namely the content of the four-level tasks shown. For aspect 3, 263 out of 289 students responded that the information and explanation provided were sufficient if they answered incorrectly for the task. For aspect 4, 273 out of 289 students found that the display of picture, tables, and animations was clear.

Table 5. Students' feedback for the four aspects.

Aspect 1 The conceptual relationship between arithmetic and algebraic expressions				
Categories	Well understood/ understood	Lack of understanding	Not understood	Total
Number of students	237	38	14	289
Aspect 2 The four-level tasks shown				
Categories	Very clear/clear	Lack of clarity	Unclear	
Number of students	275	10	4	289
Aspect 3 The information and explanation provided if answered incorrectly				
Categories	Very sufficient/sufficient	Lack of sufficiency	Insufficient	
Number of students	263	20	6	289

Table 5. *Cont.*

Aspect 4 The display of pictures, tables, and animations				
Categories	Very clear/clear	Lack of clarity	Unclear	
Number of students	273	11	5	289

5.2. Aspect 1: The Conceptual Relationship Between Arithmetic and Algebraic Expression (Cognitive Dimension)

The majority of the students (82%) in the three districts found that they better understood the conceptual relationship between arithmetic and algebraic expression through the online tutoring program. Examples of their feedback were:

a. I have a clearer understanding through the online tutoring program.
b. I have a better understanding because the relationship was shown interestingly.
c. I can understand easily through the online tutoring program.

A few students commented they lacked understanding or did not understand the conceptual relationship between arithmetic and algebraic expressions because they did not understand the meaning of the terminologies asked, namely 'arithmetic' and 'algebra'. Examples of their feedback were:

a. I only understand what I had learnt.
b. I lack the information about these (arithmetic and algebra).

5.3. Aspect 2: The Four-Level Tasks Shown (Teaching Dimension)

The majority of the students (95%) in the three districts found that the tasks shown in the online tutoring program were clear, and they could easily respond as they appeared in a hierarchical manner. Examples of their feedback were:

a. The task can be read and responded easily.
b. The sequence of tasks leads me to answer easily.
c. The sentences in the tasks are easier to be understood.
d. The task is easier to be understood as it is shown in bilingual.

A minority of the students commented that some of the tasks were very difficult to respond to.

5.4. Aspect 3: The Information and Explanation Provided if Answered Incorrectly (Social Dimension)

The majority of the students (91%) in the three districts commented that the explanation provided in the online tutoring program was clear and sufficient if they answered incorrectly. Examples of their feedback were:

a. The explanation is very clear and easy to understand especially for the wrong answers.
b. The explanation is clear and sufficient.
c. I understand the errors I made.
d. I get a better idea for the solution.
e. The solutions shown are easy to be understood.

A minority of students commented that the sounds that appeared when they answered correctly or incorrectly were slightly noisy.

5.5. Aspect 4: The Display of Pictures, Tables, and Animations (Teaching Dimension)

The majority of the students (94%) in the three districts commented that the display of pictures, tables, and animations were clear and attractive. Examples of their feedback were:

a. *It can lead me to get the correct solution.*
b. *The display is easier to be read and understood.*
c. *Very attractive and motivate me to answer the next questions.*
d. *Very attractive and creative.*
e. *Very clear.*

5.6. Feedback from Teachers

All the teachers involved had been individually interviewed after the application of the OTP for the first topic. They were requested to give feedback about the implementation of the OTP. All the feedback from the teachers is presented in Tables 6–8.

Table 6. Teachers' feedback about the effectiveness of the OTP in teaching.

Themes	Sub-Themes	Description	Teacher
Teaching	Clear explanation of content	The tasks appeared to flow from basic to advanced; thus: (a) Easier for teachers to guide the students in understanding the concept. (b) Saved the teachers' time and reduced their workloads as all the related tasks and solutions were provided completely. The diagrams and tables provided were useful to help the teacher explain the concept.	Kam, Jamal, Zaina, Norol, Nora
Social	Attract the students' attention	The animation, graphic, and sounds were very attractive and interesting, attracting the students' attention during the lesson. It motivated the students to learn and even compete with friends for the correct response. The content had been represented interestingly, step by step, from basic to difficult. The students could easily understand the systematic manner of explanation.	Shu, Hil, Fari, Norol, Suria, Sya
Cognitive	Development of 21-century learning environment	It helped to develop students' self-motivation. The students could learn independently. It developed student-centered learning.	Mar

Table 7. Teachers' feedback about the effectiveness of the OTP in learning.

Themes	Sub-Themes	Description	Teacher
Social	Excited and enjoy learning	Hands-on through a computer was more interactive and interesting. The animation and diagram were interesting. The students were enjoying learning with their peers in the classroom. Immediate feedback was very useful to guide the students to respond correctly for the next tasks.	Kam, Fari, Zaina, Nordi, Norol, Mar
Cognitive	Easily understand the hierarchical manner of tasks	The systematic step-by-step solution enables the students to understand the concept easily. The good quality of tasks led the students to learn the topic level by level.	Shu, Hil Suria

Table 7. *Cont.*

Themes	Sub-Themes	Description	Teacher
Teaching	Learn independently	Students could learn the topic at home. They could repeat until they mastered it as the program allowed them to try an unlimited number of times. The immediate feedback and sound provided (once the response sent) were very useful to motivate them to get the correct answer. Students could learn through their hand-held phones anywhere and anytime.	Nora, Suria, Sya
Social	Development of competitive spirit in learning	It motivated the students to learn and even compete with friends for the correct response.	Sya

Table 8. Teachers' feedback regarding suggestions about improvements to the OTP.

Themes	Sub-Themes	Description	Teacher
Teaching	Increase the number of animation and audio features	Comics and animations could be added to increase the effectiveness. An audio explanation of the solution could be added. The appearance was supported by some music.	Kam, Mar, Sya
Teaching	More topics can be added	All other important topics could be added to the program to develop students' learning. The students learnt the concept easily through the program.	Shu, Hil, Norol
Teaching	The content of the topic as an introduction	Details about the content of the topic could be added as an introduction to the program to enable recall in the students.	Jamal
Teaching	Can be accessed online or offline	Students always faced internet connection problems. It would be more user-friendly if the OTP could be used either offline or online.	Fari, Nordi

Table 6 shows the response of teachers concerning the effectiveness of the OTP in teaching. The feedback is combined into teaching, social, and cognitive themes. According to the teachers, the tasks were introduced in a clear and systematic way, starting with the simplest ones and proceeding to the more complex ones, which made it easier to explain the concepts of algebra and lessened the workload. The explanation of ideas was also supported by visual materials, including diagrams and tables. Moreover, the graphics, sounds, and animations captured the interest of the students and made them more interested in the lessons. It was also observed by teachers that the program was useful in promoting student-centered learning and independent learning among the students.

Table 7 shows the perception of teachers on the effectiveness of the OTP in aiding the learning process of the students. The teachers noted that students were enthusiastic and liked learning using the program since they found the activities interesting and highly visual. The feedback that was given immediately assisted the students in detecting their errors and correcting them. Teachers also mentioned that the hierarchical structure of tasks helped students to grasp the algebraic concepts with relative ease since the lessons were offered in stages. Moreover, the program promoted self-directed learning where students could redo the tasks any time and refer to the learning material.

The recommendations of teachers on how to improve the OTP are indicated in Table 8. It was suggested by teachers to incorporate more animations and comics, as well as audio explanations, to ensure the program is interesting and efficient. Others even proposed that background music should be incorporated to make the delivery better. Moreover, the teachers suggested developing the program by including more mathematics subjects to enable the students to receive a focused learning approach. The other recommendation was to offer a concise introduction to the topic content so that the students would recall the previously acquired knowledge. Another issue that was brought up by teachers was the need to have online and offline access to overcome internet connection challenges.

The feedback from both teachers and students indicates that the implementation of the online tutoring program (OTP) provided several pedagogical benefits while also revealing areas that require improvement. Overall, the responses from both groups consistently highlight the effectiveness of the program in supporting conceptual understanding, engagement, and independent learning. On the side of the students, most of them indicated positive learning experiences on the four aspects considered. The majority of students reported that the OTP made them realize the conceptual connection between arithmetic and algebraic expressions better. The hierarchical structure of the four-level tasks also allowed them to answer questions with less difficulty since the four levels of tasks were presented in a progressive manner starting with simple tasks and going to the complex questions. Moreover, the students liked the fact that there were instant explanations in case they gave wrong answers, and it could make them see the mistakes they made and know how to overcome them. Their interest and desire to learn were also enhanced by the use of pictures, tables, and animation. On the same note, the feedback of teachers facilitated these findings. The teachers also cited that the systematic organization of the tasks enabled them to more easily lead the students in learning the concepts of algebra and made their jobs less demanding since the tasks and solutions were already systematized in the program. Another finding made by them was that the multimedia contents, graphics, and animation captured the attention of the students and helped to make the learning experience more engaging and student-focused.

6. Discussion

The increase in access to the internet made it possible for tutoring to be conducted online. An OTP is considered a possible method for helping students learn mathematics (Offenholley, 2014). Using an OTP as a source of teaching and learning can support the new era of standards in teaching mathematics and provide learning support to students.

This study confirmed that an OTP in the Malaysian school setting could positively affect the teaching and learning of algebra. The development of an OTP based on the integration of the SOLO and CoI models proved that it could become a powerful assessment framework that teachers can adapt when developing tasks for almost any mathematics topic. In addition, it also helped the students focus their attention on a specific concept at each stage of cognitive development. As a result, the teachers are not only able to promote a valuable tool to diagnose learners' weaknesses in mathematics learning but also provide the students with a more powerful tool to develop their mastery of mathematic concepts more systematically (Lim & Wun, 2020; Simpson et al., 2010; Vrachnos & Jimoyiannis, 2017).

Moreover, the results of this study yielded four findings, namely teachers' feedback about the effectiveness of the OTP in teaching, teachers' feedback about the efficacy of the OTP in learning, teachers' feedback and suggestions about the improvement of the OTP, and students' input in four aspects (conceptual relationship between arithmetic and algebraic expression; the task shown; the explanation provided if answers are incorrect; and the display of pictures, tables, and animations). All the findings from both parties were

analyzed based on the three main dimensions of CoI, namely cognitive presence, social presence, and teaching presence.

For the cognitive presence dimension, using the OTP in teaching algebra provided a clear explanation of the content, attracted the attention of the students, and played a major role in the development of the 21st-century learning environment. This impact was clear in the teachers' feedback after using the platform. It was noticed that the OTP made it easier for the teachers to guide the students in understanding the concept, saved the teachers' time, and reduced their workloads as all related tasks and solutions were provided (Karakose et al., 2023).

Algebra has long been identified as an area of difficulty in the teaching and learning of mathematics. However, the finding revealed that 82% of the students had better understood the conceptual relationship between the arithmetic and algebraic expressions after using the OTP, as the samples stated that "*I have a better understanding because the relationship was shown interestingly*", "*I can understand easily through the online tutoring program*." It seems that using the OTP was able to improve the majority of the students' attention during the lesson by providing interesting content. Thus, the students could easily understand and develop their self-motivation and student-centered learning. This finding is similar to the findings obtained by Hassan and Sulaiman (2018), and Fakhar and Hussain (2020), who found that GeoGebra helped students visualize abstract concepts such as variables and equations. It developed a stronger conceptual understanding and made fewer calculation errors. One the other hand, Reynolds and Joseph (2021) revealed that the Urban High School students in U.S. who applied Mathspace in learning algebra showed a significant improvement in their algebra learning but showed performance decline during the non-use phase. In addition, the OTP motivated the students to learn and even compete with their friends for the correct responses. This practice would overcome the negative attitude towards algebra (Julius et al., 2018; Prendergast & Treacy, 2018).

According to Nyet et al. (2016), the concepts of algebra are the most difficult aspect in developing algebraic abilities. The OTP focused on algebra concepts by building a solid foundation of problem-solving in the classroom. This could be seen by the diagrams and tables provided, which were useful in helping the teacher to explain the concept of algebra in the classroom. This could simplify students' connection to conceptual understanding. Besides that, the visual tools for algebra allowed the students to adopt a visual language and helped them to work with complex algebraic concepts easily (Alsaeed & Arabia, 2017).

Meanwhile for the teaching presence dimension, 95% and 94.5% of the students commented that the tasks shown in the OTP were easy to understand and led them to getting the correct responses effectively, as commented in the following samples: "*The sequence of tasks leads me to answer easily*" and "*The task is easier to be understood as it is shown in bilingual.*" It was found to be very attractive and creative. In other words, the explanation provided in the OTP in the learning of algebra showed that the use of the OTP was exciting and enjoyable due to the interesting design of the teaching and learning platform. In addition, it has been proven to be interactive and enjoyable (Han et al., 2021). It helped students to understand easily by providing step by step solutions which allowed them to learn the topic level by level, as the following samples stated: "*Very attractive and motivated me to answer the next questions*" and "*Very attractive and creative.*" The use of the OTP overcomes the limitation of time and location as students could use it at any time and with any device. This made the learning of algebra independent. The OTP had shown its capability to motivate the students to learn and even competed with friends for the correct response. The implementation of the OTP in the teaching and learning of algebra was conducted in modern-day classrooms. The usage of technology in teaching and learning algebra helped change how students learn new concepts and how mathematics teachers

assess students' performance in a 21st-century classroom (Kalonde, 2017; Koji et al., 2016; Q. Li et al., 2013).

Additionally, teachers discovered that the OTP is an extremely user-friendly teaching tool which enable students to learn on their own. Students can receive guidance as many times as needed until they thoroughly understand the topic. Consequently, the OTP can be conveniently used on a smartphone or computer, at any place or time. This tool clearly saves teachers' time and reduces their workload by offering comprehensive tasks and solutions.

For the social presence dimension, one of the main advantages of the OTP is providing immediate feedback, which is very useful in guiding students to respond correctly to the next tasks. It will also motivate them to get the correct answer. Giving immediate feedback helped the students become aware of the correct answers and use them to improve their weaknesses. In contrast, they were still mindful of the topic (Gürkan, 2018). In this study, 91% of the students showed a positive attitude towards the feedback provided in the OTP. Fyfe and Rittle-Johnson (2016) revealed that the feedback may reduce students' cognitive overload by giving them control over 'when' and 'how' they process the feedback and use it.

In the meantime, the teachers noted that the animations, graphics, and sounds included in the OTP were highly appealing and engaging which capturing the students' attention during the lesson. This also encouraged the students to learn and even compete with their peers to give the correct answers.

7. Conclusions

Based on the responses from the teachers and students, the OTP received a positive reaction. This was consistent with the CoI model by emphasizing the three main dimensions—social presence, cognitive presence and teaching presence—for describing the teaching and learning in online asynchronous discussion.

The teacher was always required to provide a focused, concentrated, and reflective teaching presence to create and sustain the discovery-based relationship of inquiry between the teacher and student. Teaching presence was defined as "the design, facilitation and direction of cognitive and social processes for the purpose of realizing personally meaningful and educationally worthwhile learning outcomes" (Stenbom et al., 2012). In the OTP, a task-based environment was demonstrated on a cheerful, engaging platform and the student received immediate feedback. The requirement of teaching presence, as shown in this study, leads the interaction, engages the student when appropriate, and provides clear and direct instruction. Cognitive presence allowed the intellectual and knowledge commitment of both teacher and student to be expressed. This process occurred in an environment shaped by social and teaching presence with interaction, reflection, analysis, and resolution. In this study, the cognitive presence was demonstrated by the teacher and assisted by the student. The last element of a CoI framework is social presence, which allows the students to interact in order to project their individuality and relate it to a meaningful discussion. In short, the research results provided strong evidence that social presence should be inculcated in an online learning environment (Han et al., 2021; Stenbom et al., 2012).

Nevertheless, feedback from students and teachers also indicates that the online tutoring program (OTP) could be further enhanced to better support learning. Students emphasized the need for clearer explanations of key mathematical terminology, more manageable task difficulty, and less distracting audio cues. Teachers suggested incorporating richer multimedia elements, including animations, comics, and audio support, as well as providing concise introductory content to help students connect new concepts with prior knowledge. In addition, expanding the program to other mathematics topics and enabling

offline access were identified as important improvements. Future development of the OTP should consider these recommendations to increase student engagement, accessibility, and overall learning effectiveness.

In short, based on the quantitative and qualitative results, the OTP has been proven to be beneficial for mathematics classrooms as it elicits a significantly positive response across the three dimensions. It is particularly suitable for students who require a more human-centered diagnostic approach to strengthen their mastery of algebraic concepts. These important features, however, are often lacking in existing algebra learning tools which primarily focus on developing students' procedural and symbolic manipulation skills rather than reinforcing fundamental conceptual understanding.

The integration of the SOLO and Community of Inquiry (CoI) models within the online tutoring program (OTP) effectively supported holistic algebra learning by combining structured cognitive development with meaningful online engagement. Feedback from both students and teachers highlighted the program's clarity, interactivity, and ability to promote independent learning. Through strong teaching presence, active cognitive engagement, and supportive social interaction, the OTP fostered deeper understanding, learner autonomy, and sustained motivation. These findings indicate that the SOLO–CoI framework is a robust approach for designing digital mathematics instruction that enhances academic achievement while developing 21st-century learning competencies.

Additionally, the SOLO–CoI framework offers a valuable model for understanding learning in online asynchronous discussions through the dimensions of cognitive, social, and teaching presence. The findings suggest that its principles can be applied across various subjects and learning contexts. To maximize its effectiveness, curriculum developers, educators, and instructional designers should enhance the OTP through greater use of technology and interactive teaching strategies that strengthen social connectedness in virtual environments. Teacher training, attention to feedback from both students and educators, and policy-level support such as curriculum alignment and broader adoption can further strengthen OTP implementation and expand its educational impact.

8. Limitations and Future Research

In conclusion, the findings indicated that all three presences are strongly evident in the use of the OTP for learning algebra. However, there are some limitations that need to be addressed. These results cannot be generalized to all mathematics topics. The increase in scores was observed after students participated in the OTP; however, due to the absence of a control group, causal conclusions cannot be drawn. Therefore, it is recommended to conduct an experiment that involves a comparison of two groups on similar studies on other topics. Moreover, this study was restricted by the reliance on self-reported feedback from students and teachers, which might introduce the issue of response bias or reflect social desirability. In addition, the absence of long-term follow-up data might limit the ability to evaluate the sustained impact of the OTP on the students' learning outcomes. Thus, further research should address these gaps to strengthen the evidence base. Given the current implementation of the OTP, this research could provide valuable insights into the field of education. Researchers with similar interests can use this study as a reference to understand the dimensions of Community of Inquiry (CoI) presence in online classes and as a basis for more in-depth studies of their own.

Author Contributions: Guidance and mentorship, H.L.L.; Conceptual Refinement, H.L.L.; Critical Review and feedback, H.L.L.; Methodology and Validation, T.Y.W., C.M.C., R.Z. All authors have read and agreed to the published version of the manuscript.

Funding: The authors disclosed receipt of the following financial support for the study and publication of this article: This study was supported by the Hasanah Foundation, Malaysia [grant number: 1090/19].

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by Policy Research and Evaluation Sector Committee, the Educational Planning and Research Division, Ministry of Education (protocol code KPM.600-3/2/3-eras (3260) and date of approval: 27 February 2019).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the corresponding author due to ethical restrictions.

Acknowledgments: The authors gratefully acknowledge the financial support provided by Hasanah Foundation, Malaysia [grant number: 1090/19].

Conflicts of Interest: The authors declare no conflict of interest. All data, analyses, and conclusions presented in this paper represent the authors' objective and unbiased perspectives.

Appendix A

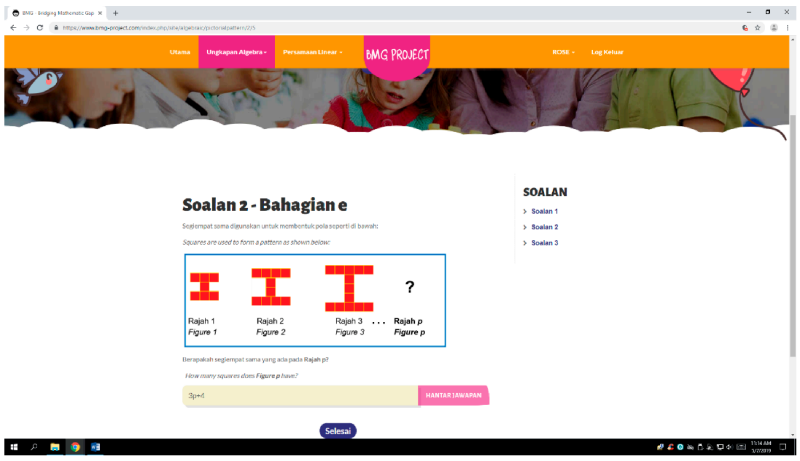


Figure A1. Example of a task in an algebraic expression.

Appendix B

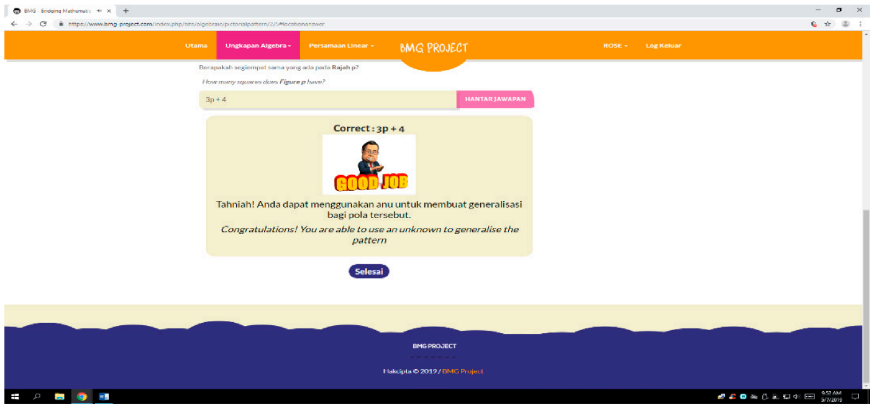


Figure A2. Feedback presented if answered correctly.

Appendix C

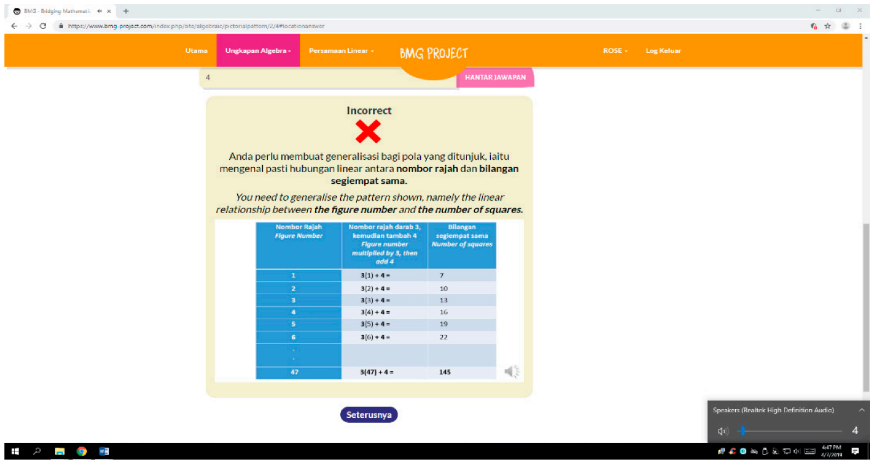


Figure A3. Feedback presented if the question posed is answered incorrectly.

References

Adnan, M., Abidin, Z. Z., Mustam, A. A., Maat, S. M., Sutama, S., Prihaswati, M., & Zulnaidi, H. (2021). The ability and analysis of students' errors in the topic of algebraic expression. *Journal of Physics: Conference Series*, *1988*(1), 012049. [CrossRef]

Agoestanto, A., Sukestiyarno, Y. L., Isnarto, R., & Lestari, M. D. (2019). The position and causes of students errors in algebraic thinking based on cognitive style. *International Journal of Instruction*, *12*(1), 1431–1444. [CrossRef]

Alsaeed, M. S., & Arabia, S. (2017). Using the internet in teaching algebra to middle school students: A study of teacher perspectives and attitudes. *Contemporary Issues in Education Research*, *10*(2), 121–136. [CrossRef]

Arnawa, I. M., Yanita, Yerizon, Ginting, B., & Nita, S. (2021). Does the use of APOS theory promote students' achievement in elementary linear algebra? *International Journal of Instruction*, *14*(3), 175–186. [CrossRef]

Barkatsas, T., Gialamas, V., & Orellana, C. (2016). Secondary students' attitudes toward learning mathematics with Computer Algebra Systems (CAS). In *Global learning in the 21st Century* (pp. 121–137). SensePublishers. [CrossRef]

Best, J. W., & Kahn, J. V. (2016). *Research in education* (10th ed.). Pearson India.

Biggs, J. B., & Collis, K. F. (1982). *Evaluating the quality of learning—The SOLO taxonomy (structure of the observed learning outcome)*. Academic Press.

Bouhineau, D., Huguet, T., & Nicaud, J.-F. (2002). *Doing mathematics with the APLUSIX-editor.* Available online: https://hal.archives-ouvertes.fr/hal-00962020/document (accessed on 23 April 2021).

Cunico, G., Aivazidou, E., & Mollona, E. (2022). System dynamics gamification: A proposal for shared principles. *Systems Research and Behavioral Science*, *39*(4), 723–733. [CrossRef]

Desmos Studio. (2025). *Desmos graphing calculator and activities*. Available online: https://www.desmos.com/ (accessed on 1 March 2025).

Drijvers, P., Doorman, M., Kirschner, P., Hoogveld, B., & Boon, P. (2014). The effect of online tasks for algebra on student achievement in grade 8. *Technology, Knowledge and Learning*, *19*(1–2), 1–18. [CrossRef]

Fakhar, H., & Hussain, I. (2020). Effectiveness of GeoGebra on the achievement and attitudes of secondary school students towards algebra. *Journal of Educational Research*, *23*(1), 54–63.

Farah, R. N., Amarpreet, K., Zuraida, R. L., Muzirah, M., Ayub, A. F. M., Nida, S. U., Rejeki, S., & Irwan, N. (2021). Algebraic lab: Pedagogical tool to teach and learn algebra through game. *Review of International Geographical Education (RIGEO)*, *11*(4), 951–962.

Fyfe, E. R., & Rittle-Johnson, B. (2016). Feedback both helps and hinders learning: The causal role of prior knowledge. *Journal of Educational Psychology*, *108*(1), 82–97. [CrossRef]

Garrison, D. R., Anderson, T., & Archer, W. (2000). Critical inquiry in a text-based environment: Computer conferencing in higher education. *The Internet and Higher Education*, *2*(2–3), 87–105. [CrossRef]

Goldstone, R. L., Marghetis, T., Weitnauer, E., Ottmar, E. R., & Landy, D. (2017). Adapting perception, action, and technology for mathematical reasoning. *Current Directions in Psychological Science*, *26*(5), 434–440. [CrossRef]

Gürkan, S. (2018). The effect of feedback on instructional behaviours of pre-service teacher education. *Universal Journal of Educational Research*, *6*(5), 1084–1093. [CrossRef]

Han, J.-H., Shubeck, K., Shi, G.-H., Hu, X.-E., Yang, L., Wang, L.-J., Zhao, W., Jiang, Q., & Biswas, G. (2021). Teachable agent improves affect regulation: Evidence from Betty's brain. *Educational Technology & Society*, *24*(3), 194–209.

Hassan, A., & Sulaiman, T. (2018). The effect of GeoGebra software on students' achievement in linear equation. *International Journal of Academic Research in Business and Social Sciences*, *8*(10), 1199–1207.

Hohenwarter, M. (2002). *Geogebra—A software system for dynamic geometry and algebra in the plane* [Master's thesis, University of Salzburg].

Julius, E., Abdullah, A. H., & Suhairom, N. (2018). Attitude of students towards solving problems in algebra: A review of Nigeria secondary schools. *Journal of Research & Method in Education*, *8*(1), 26–31.

Kalonde, G. (2017). Rural school math and science teachers' technology integration familiarisation. *International Journal of Educational Technology*, *4*(1), 17–25.

Karakose, T., Polat, H., Yirci, R., Tülübaş, T., Papadakis, S., Ozdemir, T. Y., & Demirkol, M. (2023). Assessment of the relationships between prospective mathematics teachers' classroom management anxiety, academic self-efficacy beliefs, academic motivation, and attitudes toward the teaching profession using structural equation modelling. *Mathematics*, *11*(2), 449. [CrossRef]

Kersaint, G., Dogbey, J., Barber, J., & Kephart, D. (2011). The effect of access to an online tutorial service on college algebra student outcomes. *Mentoring and Tutoring: Partnership in Learning*, *19*(1), 25–44. [CrossRef]

Khan Academy. (2025). *Khanmigo: AI-powered tutor and teaching assistant*. Khan Academy.

Koedinger, K. R., Anderson, J. R., Hadley, W. H., & Mark, M. A. (1997). Intelligent tutoring goes to school in the big city. *International Journal of Artificial Intelligence in Education*, *8*, 30–43.

Koji, S., Mulenga, H. M., & Mukuka, A. (2016). An investigation into challenges faced by secondary school teachers and pupils in algebraic linear equations: A case of Mufulira District, Zambia. *Journal of Education and Practice*, *7*(26), 99–106.

Kolovou, A., & Van Den Heuvel-Panhuizen, M. (2010). Online game-generated feedback as a way to support early algebraic reasoning. *International Journal of Continuing Engineering Education and Life-Long Learning*, *20*(2), 224–238. [CrossRef]

Kurniawan, H., Budiyono, Sajidan, & Siswandari. (2021). The PINTER learning model to enhance higher order thinking and communication skill in algebra. *International Journal of Instruction*, *14*(3), 359–374. [CrossRef]

Kwelle, C. O., & Charles-Ogan, G. I. (2024). Utilizing MATLAB computing package as a conceptual tool for solving algebraic problems. *FNAS Journal of Mathematics and Science Education*, *5*(4), 102–110.

Li, H. L., & Zulnaidi, H. (2024). Effects of geometer's sketchpad on algebraic reasoning competency amongst students in Malaysia. *Edunesia Jurnal Ilmiah Pendidikan*, *5*(1), 488–499. [CrossRef]

Li, Q., Lemieux, C., Vandermeiden, E., & Nathoo, S. (2013). Are you ready to teach secondary mathematics in the 21st century? A study of preservice teachers' digital game design experience. *Journal of Research on Technology in Education*, *45*(4), 309–337. [CrossRef]

Lian, L. H., & Idris, N. (2006). Assessing algebraic solving ability of form four students. *International Electronic Journal of Mathematics Education*, *1*(1), 55–76. [CrossRef] [PubMed]

Lim, H. L., & Wun, T. Y. (2020). Development of an assessment literacy super-item testfor assessing preservice teachers' assessment literacy. *International Journal of Innovation, Creativity and Change*, *13*(7), 870–889.

Lynn, M. R. (1986). Determination and quantification of content validity. *Nursing Research*, *35*(6), 382–385. [CrossRef]

Mat Dangi, M. R., & Mohamed Saat, M. (2021). Interaction effects of situational context on the acceptance behaviour and the conscientiousness trait towards intention to adopt: Educational technology experience in tertiary accounting education. *Educational Technology & Society*, *24*(3), 61–84.

Mathspace. (2025). *Adaptive math platform*. Available online: https://mathspace.co/ (accessed on 12 October 2025).

Nisbet, J. (2020). *5 irresistible benets of technology in the math classroom*. Prodigy Education. Available online: https://www.prodigygame.com/main-en (accessed on 15 December 2021).

Nyet, M. S., Geofrey, J., & Lee, B. N. (2016). Students' algebraic thinking and attitudes towards algebra: The effects of game-based learning using Dragonbox 12 + App. *The Research Journal of Mathematics and Technology*, *5*(1), 66–79. Available online: http://www.academia.edu/download/46188339/2dragonbox.pdf (accessed on 25 June 2022).

Offenholley, K. H. (2014). Online tutoring research study for remedial algebra. *Community College Journal of Research and Practice*, *38*(9), 842–849. [CrossRef]

Photomath Inc. (2023). *Photomath: Camera calculator app*. Available online: https://www.photomath.com/ (accessed on 25 July 2024).

Polit, D. F., & Beck, C. T. (2006). The content validity index: Are you sure you know what's being reported? Critique and recommendations. *Research in Nursing & Health*, *29*(5), 489–497. [CrossRef] [PubMed]

Prendergast, M., & Treacy, P. (2018). Curriculum reform in Irish secondary schools–a focus on algebra. *Journal of Curriculum Studies*, *50*(1), 126–143. [CrossRef]

Rakes, C. R., Valentine, J. C., McGatha, M. B., & Ronau, R. N. (2010). Methods of instructional improvement in algebra: A systematic review and meta-analysis. *Review of Educational Research*, *80*(3), 372–400. [CrossRef]

Reynolds, C. P., & Joseph, L. M. (2021). Effects of a mathematics app on urban high school students' algebra performance. *Contemporary School Psychology*, *25*(3), 285–294. [CrossRef]

Roschelle, J., Feng, M., Murphy, R. F., & Mason, C. A. (2016). Online mathematics homework increases student achievement. *AERA Open*, *2*(4), 1–12. (Erratum in 2017, *AERA Open*, *2*(4)). [CrossRef]

Roschelle, J., Feng, M., Murphy, R. F., & Mason, C. A. (2021). Effects of ALEKS on mathematics learning in K–12 and higher education: A meta-analysis. *Investigations in Mathematics Learning*, *13*(3), 182–196. [CrossRef]

Schneider, E. (2000). Teacher experiences with the use of a CAS in a mathematics classroom. *The International Journal of Computer Algebra in Mathematics Education*, *7*, 119–141.

Simpson, Z., Janse van Rensburg, N., & van Ryneveld, M. (2010). Developing students as higher-order thinkers: An-alyzing student performance against levels of cognitive demand in a material science course. In *Proceedings of the ASME 2010 international mechanical engineering congress and exposition* (pp. 1–8). American Society of Mechanical Engineers. [CrossRef]

Singh, G., Tuli, N., & Mantri, A. (2021). Issues and challenges in learning foundation linear algebra course with technology: A literature review. In *2021 international conference on advance computing and innovative technologies in engineering (ICACITE)* (pp. 860–865). Institute of Electrical and Electronics Engineers. [CrossRef]

Soft Warehouse. (1995). *DERIVE* (Version 3.0). Soft Warehouse, Inc.

Solfitri, T., Siregar, H. M., Maifa, T. S., & Putra, Y. (2024). Potentials and challenges of technology-based Algebra learning: A classroom experience using Wizer.me. *International Research Journal of Science, Technology, Education, and Management*, *4*(4), 86–98. [CrossRef]

Stenbom, S., Hrastinski, S., & Cleveland-Innes, M. (2012). Student-student online coaching as a relationship of inquiry: An exploratory study from the coach perspective. *Journal of Asynchronous Learning Network*, *16*(5), 37–48. [CrossRef]

Stoelinga, T., & Lynn, J. (2013). Algebra and the underprepared learner. *UIC Research on Urban Education Policy Initiative: Policy Brief*, *2*(3), 1–16.

Subramaniam, S. W. S. M., Norazman, A., & Mazlini, A. (2023). Development and effectiveness of I-algebra module towards Malaysian year five pupils' achievement and motivation. *Journal of Science and Mathematics Letters*, *11*(1), 10–19. [CrossRef]

Ting, J. J., Ahmad Tarmizi, R., Abu Bakar, K., & Aralas, D. (2018). Effects of variation theory approach in teaching and learning of algebra on urban and rural students' achievement and motivation. *International Journal of Mathematical Education in Science and Technology*, *49*(7), 986–1002. [CrossRef]

Vrachnos, E., & Jimoyiannis, A. (2017). Secondary education students' difficulties in algorithmic problems with arrays: An analysis using the SOLO taxonomy. *Themes in Science & Technology Education*, *10*(1), 31–52.

Waddington, A., & Porter, S. (2021). Developing social presence in online learning among nurses: Exploration of the community of inquiry models domain of social using a qualitative descriptive design. *Nurse Education in Practice*, *52*, 103000. [CrossRef] [PubMed]

Waterloo Maple. (2000). *Maple* (Version 6). Waterloo Maple Software, Inc.

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.