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An Analysis of How Technological Advancements Have Shaped Algebraic Thought

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Abstract: *Algebraic thinking is the ability of students to analyse, infer, solve problems, foresee, defend, and illustrate concepts as well as model particular situations. Many contemporary educators advocate using technology in the teaching and learning of algebraic thinking as an alternative to approaches that do not use computers. This research report discusses the ramifications of using technology in education, particularly in higher education, to promote algebraic thinking. It is suggested that more extensive research be conducted, with an emphasis on examining the characteristics of algebraic thinking, on the use of technology to promote algebraic thinking*

Keywords: Algebraic Thinking, Technology-based learning

I. INTRODUCTION

The process of reasoning, notation, and computation of unknowns and numbers is known as algebraic thinking13.The development of algebraic thinking should begin early in order to improve algebra 6 success. Students are expected to think and solve issues using abstractions and logic in a process known as thinking algebraically2,4. Fostering the link between numbers and unknowns that connects to the spatial and structural properties of numbers is one way to improve algebraic thinking13.Arithmetic, also referred to as pre-algebra, is typically taught to younger pupils before algebra.

Much like other mathematical topics, algebra is not without its challenges for students. Basic algebraic skills deficit students often struggle in solving algebraic problems, simplifying equations and algebraic expressions, and deciphering quadratic graphs1. Due to these challenges, they learn by memorisation rather than comprehension, and they carry this learning pattern throughout high school and into further education. Because non-routine questions are beyond their level of conceptual comprehension, pupils who use this method of instruction can only address lower-level thinking problems18.

It seems that the primary resources for learning mathematics, worksheets, exercises, and factual questions, have not been effective in helping pupils think more deeply. When dealing with algebraic operations including variables, objects, functions, and invariable relations or structures, in addition to procedures, students also encounter difficulties5. They often struggle to understand algebra's structure and ideas. A number of strategies might be used to reduce these issues, such as using technology to get beyond non-technological learning environments' constraints, which sometimes overlook the connection between algebraic operations and geometry18.

In classroom environments without technology, students may have challenges in receiving timely feedback and accessing learning resources at their leisure. Furthermore, educators often provide closed-ended questions, which restrict the learning process to algebraic steps and hinder the ability of pupils to think more creatively about mathematics15. When studying mathematics, pupils had trouble visualising what they had learned if they didn't have access to supporting resources. The tools serve as both a visualisation tool and a computational tool. They take the shape of numerous representations, namely graphing symbolic manipulation and numerical calculations, which may be made possible by software technology.

OBJECTIVE

The purpose of this quick overview is to identify the benefits and drawbacks of using various software programmes in educational institutions to improve algebraic thinking. The analyses were split into university and school levels in order to accomplish this.

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METHODOLOGY

A selection of research articles from 2011 to 2016 were obtained from JSTOR, Web of Science, Taylor & Francis Online, ScienceDirect, SpringerLink, and Google Scholar. These well-known databases serve as a multidisciplinary research platform that includes full text or metadata publication forms across several fields in addition to bibliographic records. were used to search the research publications. The analysis's findings were tallied, with the authors' information in Column 1, the kind of software in Column 2, and the intervention's outcomes in Column 3.

ALGEBRAIC THINKING WITH TECHNOLOGY

Technology is being utilised extensively in algebra instruction these days. Several pieces of software were used in earlier research2,9, to aid in the teaching of algebraic thinking. Spreadsheets are a popular tool for teaching algebra and may be used to teach the fundamentals of generalisation. Algebraic thinking is characterised by generalisation. It deals with the accumulation of patterns and successive numerical sums.

Technology facilitates learning by acting as a scaffold. Known for its dynamic mathematics programme, GeoGebra is used to enhance algebraic concepts and visualisation, necessitating a greater number of three-dimensional objects 2,9. In the meanwhile, Group Explorer is a publicly accessible piece of software that offers a variety of capabilities to enhance students' visualisation, including fundamental algebraic structures for mathematics undergraduate students15. Additionally, there are several online algebra learning programmes, like Digital Mathematics Environments and Pearson's My Math Lab by Pearson is a programme that utilises educational material, including videos, assignments, quizzes, and exams with working examples15. In a similar vein, online algebra tasks7 are available via the learning management system DME. Two modules of linear and quadratic equations make up DME algebra, giving pupils the chance to develop their algebraic abilities. Conversely, SimCal is curriculum-related software that can translate students' mathematical concepts into a variety of representations10. Multimedia learning, on the other hand, involves learning via auditory and visual mediums that support spatial abilities, such as the signal principle that links the graph and equations with the use of colors5.

Table 1 displays the results of earlier writers' tertiary-level research projects utilising various tools. Every study that was chosen focused on the use of technology to foster algebraic thinking.

Table.1. The Studies on Algebra with Technology at Tertiary Level.

Author(s)	*Software*	*Impacts*
Salinas et al., (2016)	SimCal	Able to make generalization and conjecture about the derived of invariants
Baltaci and Yildiz, (2015)	GeoGebra 5.0 version	Improvement in justifying the expressions
Krupa et al., (2015)	Pearson"s MyMathLab	Unable to make transitions between algebraic strategies and the meaning of solutions Able to apply known procedures to contextual problems Able to relate between symbols and problem situations Lack of symbol sense Lack of algebraic flexibility reminiscence Performed better on items with radicals, equivalent expressions, and the one circle problem
Schubert et al., (2013)	Group Explorer	Improved algebraic understanding and visual understanding of the concepts of abstract algebra Failed to use variables for the same elements

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Overall, the findings indicate that algebra learning software had beneficial effects. The learning environment has integrated Geo Gebra, Sim Cal, Pearson's My Math Lab, and Group Explorer—all of which are user-friendly software programmes. While using Pearson's My Math Lab does not significantly improve students' ability to think algebraically, it does help them become somewhat procedurally fluent. In contrast to problems involving graphing and polynomials, students received assistance, for instance, in solving proportions, finding equivalent equations, finding function values of radical functions, rationalising two term denominators, and writing the equation of a circle with a given centre and radius.

Despite its advantages, using technology to teach algebra and improve algebraic thinking presents some challenges for students' learning. Notably, they demonstrated a lack of algebraic flexibility in pseudo-structural reasoning, a lack of symbol awareness, and an inability to utilise variables for the same components. According to review9, GeoGebra's various advantages make it a good tool for investigating the traits of algebraic thinking.

Table.2. The Studies on Algebra with Technology at Middle School Level

Author (s)	*Software*	*Impacts*
Heged us et al.,(201 6)	SimCal	Able to construct algebraic expression Make connection or comparison between two or more functions
Heged us et al., (2015)	SimCal	Improvement in identifying patterns of quadratic function Able to present patterns of quadratic function symbols Able to interpret quadratic and exponential relationships, Able to solve and identify solutions of quadratic functions, and systems of quadratic functions
Chui et al.,(201 5)	Multimedia Learning	Improvement in conceptual and procedural knowledge of algebra
Drijver s et al., (2014)	DME Digital Mathematics Environment	Weak performance of retention tasks for both groups Weak achievement in online environment Easy to use the symbolic syntax
Tabach et al., (2013)	Excel	Able to generate multi-variable and recursive expressions. Able to facilitate the transition from arithmetic to algebra.
Tabach et al., (2013)	Excel	Easy to use the symbolic syntax Able to generate multi-variable and recursive expressions. Able to facilitate the transition from arithmetic to algebra.
Bokhove and Drijvers, (2012)	Four digital module (d1-d6)	Improvement in algebraic expertise and recognizing patterns

In the meanwhile, Table 2 presents the results of earlier writers' studies conducted at the middle school level using various software.

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The results of their study showed that there were both beneficial and negative effects on algebra learning from the software employed to foster algebraic thinking. It was discovered via their investigations that the kids were exposed to the ideas and fundamentals of algebra, which may have helped them develop an algebraic way of thinking. Excel, Four Digital Module, Digital Mathematics Environment Sim Cal, and Multimedia Learning were the programmes used. Since they believed arithmetic and algebra were unrelated, most students struggled to make the switch from arithmetic to algebra. However, the use of SimCal has given students cognitive exercises and altered their perspective of the relationships between algebra and arithmetic14. Furthermore, it was discovered that Excel may help with the development of symbol algebra and the move from arithmetic to algebra17. Through the use of multimedia learning5 and four-digital module3, the students' understanding of mathematics and their capacity to identify patterns were improved.

There are still restrictions on the use of online algebra instruction, however. According to research observations, the majority of students improved on retention activities, however they were unable to access online learning resources for the online practice. DME is an online course designed to help those who struggle with fraction and quadratic term issues. Overall, the pupils' performance on the conceptual knowledge exam has improved, demonstrating a comprehension of graphical representations of quadratic equations and relationships5. Particularly when it comes to issues involving quadratic equations, such factoring, recognising, representing, analysing, and solving the connections between them, Sim Cal offers a way to help students perform better. It converts the algebraic forms, tables, graphs, and simulations, among other representations, into the mathematical constructs10,11,14. Sim Calc was also used to encourage scenario-based enquiry and provide deductions and hypotheses14.However, the study focused solely on the impacts of utilising Sim Cal and the influence of accomplishment rather than doing in-depth research on algebraic thinking10.

Despite a number of obstacles and limitations, this research has shown some evidence that students' participation in technology-assisted learning activities may influence the development of algebraic thinking. The writers offered several possibilities to get over the limitations and difficulties after considering them from various perspectives. However, studies of the efficiency of algebraic thinking using technology should include a search of past works. Included articles should be published in Malay, the official language of the area. Actually, to boost the quantity of reviews, try using additional search terms like "algebra and spreadsheet," "algebra and blended learning," "algebra and dynamic mathematics software," or "algebra and digital applications."

II. CONCLUSION

This research has shown the effects of technology on middle school and university students' attitudes as well as their academic performance. This was shown by the gains made in their conceptual understanding and mathematical proficiency18. Digital technology may improve mathematical understanding in three ways: algebraically, numerically, and graphically15. However, a thorough analysis of the technology's use and impact in middle schools should take into account the traits of algebraic thinking. When compared to the other software used in the research, GeoGebra is a free, open-source dynamic programme that is utilised in both higher education and in schools. GeoGebra is made up of three views: spreadsheet, geometry, and algebra. These views are specifically made to link algebra and geometry. More significantly, equations16 and coordinates may be inserted directly. It is used to visualise ideas and make connections between the computer algebra system and other mathematical ideas as well as instructional resources19. It is important to investigate Geogebra's usefulness for learning algebra, paying close attention to algebraic reasoning.

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