



Effectiveness of Applying Deep Learning Strategies on Developing Dimensions of Algebraic Proficiency within Adaptive Learning Systems (ALS) among (8th) Grade Students in Jordan

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ABSTRACT

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The study aimed to identify the impact of applying deep learning strategies and adaptive learning systems (ALS) on enhancing algebraic proficiency among eighth-grade students in the Jerash Directorate of Education. The study tools and materials were prepared, including the development of a proposed instructional unit within the algebra curriculum based on the application of deep learning strategies and adaptive learning systems (ALS), as well as an algebraic proficiency test and verification of its psychometric properties. The study sample consisted of (60) female students selected through purposive sampling. The sample was divided into two groups: an experimental group comprising (30) students who were trained according to the instructional unit, and a control group comprising (30) students who did not undergo training. The study instrument was administered to the sample, and the results were recorded and analyzed, revealing statistically significant differences in favor of the experimental group in enhancing the dimensions of algebraic proficiency in accordance with deep learning strategies and Adaptive Learning Systems (ALS). In light of the study's findings, the researcher recommends the importance of pedagogical and technical diversity in the teaching of mathematical content to enhance algebraic proficiency, thereby contributing to the achievement of the intended outcomes.

KEYWORDS:

Deep Learning Strategies, Dimensions of Algebraic Proficiency, Adaptive Learning Systems (ALS).

INTRODUCTION

Mathematics is the language of science and the perfection of theory expressed mathematically; it is the form towards which scientific knowledge must be directed. Given the importance of mathematics in fostering mathematical proficiency, it has been accorded special importance and regarded as a fundamental outcome that students are expected to possess as a cornerstone of the learning process. To achieve this, it is essential to diversify teaching methods, enhance students' knowledge, and raise their awareness of modern approaches that help broaden their thinking and shift from

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dependency to independence, whilst integrating conceptual and procedural knowledge, and striving for innovation to achieve the desired educational outcomes.

In the context of school algebra, Stacey, Chick and Kendal (2004) discussed the need to understand algebra through strategies that promote the acquisition of school algebra skills, and the importance of these in developing conceptual understanding through mathematical tasks that form a link between algebraic concepts and their conceptual representation.

This is consistent with the view put forward by Kieran (2004) that mathematical theory can be revitalized by providing rich algebraic activities that employ algebraic language to construct meaning, and by employing pedagogical methods that constitute a cognitive dimension based on the context of the tasks presented.

Similarly, Lamb, Warren and Cooper (2007) adopted a learning pathway designed to support mathematical

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generalization through a theoretical framework focused on improving algebraic performance, generalization and representation. Through an experimental study of a group of students, they were able to demonstrate the concept of algebra within patterns, functional (transformational) thinking, equivalence and equations, and arithmetic generalization.

Mason (2008) addressed the definition of algebra through a wealth of mathematical work, paying greater attention to algebraic transformations than to algebraic concepts themselves, and emphasized the importance of spending time generating algebraic ideas. He also highlighted the treatment of algebra as a classroom activity comprising three levels: the formative level, the transformational level, and the post-activity level.

As noted by Radford (2012), algebra acts as a unifying force between physical components (gestures, perception, speech) and symbolic elements; the development of algebraic performance is not linear but rather reorganizes these components into complementary relationships through interaction between the teacher and the student and through purposeful activities.

Given the importance of algebraic dialogue, Luneta and Legesse (2023) highlighted the need to gather information about students' mastery of rules, definitions and algorithms using questions such as: "What do you remember from yesterday's lesson?", "What is the definition of the concept?", and "What are the solution procedures algebraically, graphically and geometrically?" to enable students to understand and practice the procedures by assigning them tasks that provide opportunities to explain ideas, share thinking and resolve conceptual errors.

Although the classification of algebraic conceptual errors, as discussed by Wang (2015), is not exhaustive, it provides a perspective on the errors students encounter when learning algebra within contexts such as: the development of mathematics and curricula, teaching practices and student learning, difficulties in dealing with the unknown, the disconnect between elementary arithmetic and secondary algebra, the lack of teaching of algebra within the concepts of algebraic symbols, the simplification of algebraic expressions, equality, and the treatment of word problems as learning tasks.

However, conceptual errors in algebra, as discussed in (Edo, Tasik, 2022), have led to incorrect and sloppy procedures for solving algebraic problems. A conceptual understanding of the characteristics of the problem—including algebraic concepts such as: the equal sign, variables, like terms, and negative signs, is a type of essential prior knowledge that enables the calculation process, in addition to understanding the purpose of the equation and the effect of changing the position of a term on the problem as a whole. Therefore, students must possess a solid understanding of the fundamental elements of the problem in order to comprehend

and develop in-depth strategies regarding the problematic aspects that make it suitable.

In the same context, Kania et al. (2025) emphasized that students at various educational levels encounter algebraic conceptual errors, including misconceptions in handling symbols and challenges in translating between different representations (symbolic, graphical and verbal). Furthermore, misconceptions arise in the interpretation of abstract mathematical concepts, the translation of real-world problems into mathematical models, and the expression of their reasoning; these errors necessitate teaching strategies that incorporate targeted, evidence-based interventions designed to enhance conceptual understanding and procedural fluency as dimensions of mathematical proficiency.

To achieve mathematical proficiency, as discussed by (Wakhata, Balimuttajjo, Mutarutinya, 2023) appropriate learning strategies should be adapted to address gaps in conceptual and procedural knowledge and understanding, helping students build connections between prior and new knowledge.

The National Research Council (NRC, 2001) defined mathematical proficiency as "a comprehensive concept that goes beyond mechanical calculation and involves deep understanding and flexible application". Mathematical proficiency consists of five interrelated components: "conceptual understanding, procedural fluency, adaptive thinking, mathematical reasoning, and productive engagement".

To enhance strategic competence in mathematics teaching, Suh and Seshaiyer (2014) addressed this by analyzing students' diverse strategies, and by providing time and space for reflection, participation, discussion, justification of their thinking, and engagement in meaningful mathematical dialogue.

Adaptive reasoning, as noted by (Jazby, Widjaja, 2019) takes time for students to grasp the nuances of logical thinking and become able to articulate their understanding of it. This highlights the need to develop teachers' ability to teach and assess this vital mathematical competence, and emphasizes the important role of the teacher in supporting students' mathematical reasoning across four categories: inference, response, facilitation and extension.

Al Mutawah et al. (2019) demonstrated the importance of enhancing students' ability to solve mathematical problems by identifying and formulating problems, determining the consistency of data, applying strategies, data and models, devising procedures, extending and modifying problems, and applying reasoning in new contexts; assessing the plausibility and validity of solutions; and linking concepts, procedures, reasoning skills and communication to solve problems.

With regard to the productive motivation that determines student success, as presented by Cerbito (2020), and the achievement of good results in mathematics learning,

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attitudes influence success and perseverance in mathematics; self-confidence is also a good indicator of success, and successful contexts can lead to the development of a positive attitude towards mathematics in students.

Furthermore, Genareo et al. (2021) called for a balance between conceptual understanding and algebraic procedural fluency within conceptual frameworks that enable students to think more deeply and connect content to prior and future learning. Teachers also require effective teaching methods and materials, as well as assessment techniques, to determine the extent to which students are progressing in enhancing their algebraic proficiency.

Regardless of the teaching method, as discussed by Luneta and Legesse (2023), what is considered an acceptable mathematical explanation and solution in traditional classrooms may not be an elegant and sophisticated one in student-centered classrooms, and specifying the use of precise mathematical terminology, symbols, representations, syntax, rules and notations can help develop proficiency in mathematical language. Questions that can be used to establish mathematical social norms include the following: How can you prove that your answer is correct? Can you prove it in more than one way? How does your solution strategy differ from that of another learner? Do you agree or disagree with another learner's solution? Why does Strategy A work? Why does Strategy B not work?

Deep learning in algebra is a process that goes beyond mere mastery of procedures towards building a relational understanding that enables students to grasp the meanings behind symbols and equations. McGregor (2007) emphasized the importance of developing higher-order thinking skills such as analysis, critical thinking and creativity, and linking learning to everyday contexts. The essence of algebra lies in relationships and change, not in symbols alone. Deep learning occurs when students are allowed to explore their own strategies, discuss their ideas, apply multiple representations, and connect mathematical concepts to real-life experiences; this makes algebra a tool for enhancing learning.

Stacey, Chick and Kendal (2004) outlined the concept of deep learning as falling into two main categories: students' deep learning and teaching efforts aimed at deep learning. In both categories, the focus is on students' prior knowledge or foundational knowledge, their thinking and understanding, interdisciplinary connections, and links to everyday life. With regard to teaching mathematics for deep learning, emphasis is placed on the variety of mediating tools, the variety of teaching approaches, the learning objectives of the lesson, and the importance of applying knowledge.

Fernandes, Flores and Lima (2012) noted that the design of deep learning curricula is linked to learning that stimulates the desire to understand and adopts an inquiry-based approach, which helps students understand the subject matter and acquire skills, and builds a type of learning closely linked

to formative assessment, providing feedback and future guidance to produce objective outcomes.

Perhaps one of the distinctive features of what is termed 'the new science of learning' is the focus on learning accompanied by understanding, which is applied in parallel with deep learning, as mentioned by (Fauskanger, Bjuland, 2018). Nevertheless; students must possess a solid foundation in factual knowledge in order to think critically and solve problems, build new knowledge from existing knowledge, and encourage students to be active and take control of their learning. He emphasized that deep learning helps students to utilize factual information and transform it into knowledge that can be applied in the context of problem-solving by generating arguments and explanations and making comparisons with other problems.

In terms of a pedagogical approach that focuses on understanding, analysis and application, as noted by (Masuku, Jili, Sabela, 2021), deep learning is defined as an alternative to rote memorization or a focus solely on passing exams; it is based on student participation in the educational process through interactive assessment activities such as formative assessment, feedback, group work, the development of critical and creative thinking skills, and the enhancement of the ability to link theoretical knowledge to practical reality; thereby preparing students to be more independent.

Students understand deep learning, as discussed by Liu (2022), based on a deep understanding and the establishment of connections between prior and new knowledge, the study of mathematical knowledge and thinking from a comprehensive perspective, and reliance on solving mathematical problems and transferring knowledge. In this sense, deep learning in mathematics is not limited to merely understanding and mastering knowledge; rather, it places greater emphasis on the students' learning process, focusing on their ability to think, their critical awareness, and their motivation and willingness to learn, which aligns with the pedagogical objective of 'enhancing students' skills in an integrated manner'.

From a cognitive perspective, Yaguarema, Zambrano and Salavarría (2022) incorporated deep learning strategies through the understanding and storage of information in long-term memory; these strategies include metacognitive processes linked to a network of pre-existing elements or schemas. Metacognitive monitoring also involves assessing the ongoing progress or current status of a specific learning activity, pausing during the task and deciding whether to continue with the strategy or change it to improve learning. He noted that these strategies help to monitor and track the crucial connections between prior knowledge and new information more effectively.

Deep learning strategies, as discussed by Suglo (2024), played a key role in enabling the prediction of students' academic success, Deep motivation and deep strategy were

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highlighted as essential components of deep learning. Deep strategy, as he defined it, is the learner's ability to make sense of new material and connect it to their prior experiences or knowledge, noting that the student's interest in learning or the development of their ability to learn stems from deep motivation.

The main areas of application for technological systems, as noted by (Stacey, Chick, Kendal, 2004) lie in supporting the learning of algebra through their ability to support multiple representations, the possibility of dynamic control over variables, and the provision of a structured environment to support the learning of symbolic manipulation. One of the primary objectives is for these systems to provide a bridge to understanding algebraic symbols and concepts, and to support the acquisition of skills; as well as enriching conceptual understanding and algebraic processes. The use of programming and technological environments raises questions about how to address the process/object duality, which is one of the main themes underpinning current thinking on algebra learning.

As one of the systems designed to stimulate deep learning of mathematical content, as described by (Azmy, Fares, Al-Said, Saied, 2017), Adaptive Learning Systems (ALS) by tailoring the system to a specific group of users, where the user profile aligns and adapts to their needs without assistance and offers the advantage of simplified use. It also aids in research and exploration, provides opportunities for communication and interaction amongst learners during the learning process, and stimulates decision-making skills.

The learning pathway within Adaptive Learning Systems (ALS) has been modified, as discussed (Zhao, Wang, 2019) according to students' academic performance and engagement, by collecting in-depth data on their performance. The system continuously generates analyses of learning trends and the effectiveness of learning content, enhances student engagement and motivates them, meets their diverse needs, and promotes accessibility and inclusivity in education. It has also paved the way for a revolution in the traditional education system, which has consequently shifted towards more personalized and interactive learning, with a marked improvement in overall quality, effectiveness and student engagement.

Adaptive learning (ALS) has also been defined by Villegas, Canizares, Alcazar, Pacheco, 2020) as any pedagogical initiative based on the analysis of data generated during the students' learning process within the academic environment. This monitoring is known as learning analytics, and it allows the learning process to be adapted to the educational needs of each student. In this way, adaptive learning enables each student to acquire the knowledge required in each course at their own pace, thereby becoming a pedagogical system capable of providing personalized support to as many students as possible, identifying the topics that need reinforcement, and moves forward in topics that have already

been understood, selecting higher levels if the student is well prepared, and foundational levels if they lack them.

One of the features of Adaptive Learning Systems (ALS) highlighted by Jose et al. (2024) is their ability to provide insights through data analysis, whereby students receive immediate feedback on their efforts, enabling them to identify and correct their mistakes straight away. The information collected in this system is of great value, as it helps teachers identify learning styles, plan teaching methods, predict learning outcomes, and effectively improve students' academic performance, increase their motivation, and enhance their self-efficacy.

With regard to studies focusing on the application of deep learning strategies and Adaptive Learning Systems (ALS), these have varied in terms of implementation approaches, study samples, and methods of analyzing results. They are listed below from the most recent to the oldest:

A study (Boamah, Asemani, Koranteng; Mensah, 2025) examined the impact of the Cognitive Communication (C-C) model as a deep learning strategy in the application of verbal algebra problems. A quasi-experimental design was adopted involving two secondary schools in Ghana, with a sample of (95) first-year secondary school students, comprising 45 in the control group and (50) in the experimental group. Interviews were then conducted with (10) students from this group, and data analysis revealed that the intervention significantly improved the experimental group's ability to solve verbal algebraic problems. The results also showed that the experimental group outperformed the control group in post-test assessments, supporting the application of deep learning strategies.

Kania et al. (2025) adopted the APOS (Action, Process, Object, Scheme) theoretical framework to study conceptual errors in understanding logarithmic functions using a qualitative approach as a case study involving six trainee mathematics teachers with varying levels of mathematical ability (high, medium, and low). Data were collected through written responses, semi-structured interviews, classroom observations, and concept maps. The results showed that most participants were at the action stage, relying on procedural steps without deep conceptual understanding. The main cognitive errors were classified as follows: errors in applying logarithmic properties, difficulties in integrating logarithms with matrices, and an inability to perceive systems of equations as unified entities. The findings also highlight the need to develop diagnostic tools based on the APOS model and innovative instructional designs to address algebraic errors effectively.

Jahudin and Siew (2024) assessed the impact of a teaching method known as problem-solving using Polya's Digital Strip Model (PSDMB) on the algebraic reasoning abilities of grade (7) students in Malaysia. Ralston's framework, which covers general arithmetic, functions and modelling within the topic of linear equations, formed the basis for assessing algebraic

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thinking abilities. A quasi-experimental design with pre- and post-tests and a control group was used. The sample consisted of (90) grade (7) students. The results indicated that the experimental group performed better in general arithmetic, functions and modelling. The results also indicate that integrating the digital strip model into problem-based learning is a successful strategy for improving the algebraic proficiency of grade (7) students.

Suglo (2024) discussed the impact of integrating deep learning strategies into mathematics teaching on students' problem-solving abilities, critical thinking skills, academic achievement, and the development of mathematical skills, using a sample of 162 students in Ghana and applying a quantitative methodology. The study's results showed no significant improvement in students' problem-solving abilities and critical thinking skills when deep learning strategies were integrated into mathematics teaching, and students' attitudes towards deep learning activities in mathematics did not have any effect on their academic achievement. nor did students' levels of engagement in deep learning activities affect the development of their mathematical skills, suggesting that the application of deep learning strategies in mathematics teaching did not result in significant improvements in the specified areas based on the findings.

(Kwangpukieo, Sawangboon, 2024) investigated the effectiveness of the 5E model in altering the learning experience and outcomes in mathematics education and enhancing students' creative thinking abilities in terms of flexibility, originality, fluency and elaboration. The study sample consisted of (40) grade (10) students in north-eastern Thailand. The tools used included lesson plans, a mathematical proficiency test and a creative thinking skills test. The results showed an improvement in mathematical proficiency following the implementation of the inquiry-based (5E) learning methodology with supplementary media, and an improvement in creative thinking skills.

Schulz (2023) distinguished between procedural fluency and the ability to think flexibly about mathematical symbols—such as numbers, operations, procedures, terminology, equations and formulas—in order to use them effectively. He did so by proposing a tool designed to assess prospective teachers' knowledge of numbers and operations involving natural and fractional numbers, place value, calculation strategies, estimation, inverse relationships, mathematical analogies, and word problems, assessing strategic competence in these areas by presenting tasks that require flexible interaction between mental models, strategies, and procedures if the problems are to be solved in a meaningful way.

Weng, Chen, and Ai (2023) outlined the Design-Based Learning (DBL) methodology to promote deep learning among students and improve the quality of teaching in engineering design education in China through the

application of the to three research aspects within a model teaching activity. where the first study examined students' deep learning before and after the application of the Design-Based Learning methodology in terms of their deep learning status and capacity for deep learning; the second study examined the effectiveness of the Design-Based Learning methodology through a comparative study between a control class (traditional teaching method) and an experimental class (design-based learning methodology). The third study examined students' evaluations of the design-based learning methodology. It was found that the design-based learning methodology significantly stimulated students' motivation to learn, making them more engaged in their studies, as well as enhancing their higher-order thinking skills and abilities, such as critical thinking and problem-solving. The results indicate that the design-based learning approach is effective in promoting deep learning among students and improving the quality of teaching and learning.

Identified by (Rahman, Juniati, Manuharawati, 2023) The impact of cognitive autonomy and motivation on mathematical proficiency involved (131) students in Indonesia, and a mixed-methods approach with a sequential explanatory design was applied. The quantitative component was used to determine the impact of cognitive autonomy and motivation on mathematical proficiency using multiple linear regression. Qualitative research was used to examine the effect in depth through in-depth interviews. The results showed that students with high cognitive autonomy are able to process acquired knowledge logically, whilst students with low cognitive autonomy do so in an illogical manner. Students with low motivation applied trial-and-error strategies to enhance their mathematical proficiency, whilst students with high motivation used analytical strategies.

Wakhata, Balimuttajjo and Mutarutinya (2023) investigated the perceptions, misconceptions and errors of grade (11) students when solving mathematical problems using the graphical method. An exploratory descriptive study design was adopted, with a sample of 285 students in Uganda. Students' handwritten and pen-and-paper solution sketches, as well as task-based interviews, were used to identify students' prior conceptions, misconceptions and errors in linear programming. The results indicated that students lacked proficiency in applying incorrect algebraic concepts, and they also faced difficulties in interpreting and writing correct inequalities from verbal linear programming problems, and extremely weak conceptual understandings regarding the graphical representation of equations and inequalities and their relationship to feasible regions.

The aim of (Sari, Kurniawan, Sutiarsa, 2023) was to determine the effect of cognitive autonomy and motivation for mathematical proficiency on a sample of (131) students in Indonesia. A mixed-methods approach with a sequential explanatory design was applied, the quantitative component was used to determine the effect of cognitive autonomy and

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motivation on mathematical proficiency, whilst the qualitative research examined the effect in depth through in-depth interviews. The results showed that students with high cognitive autonomy were able to process the knowledge they had acquired logically, whereas students with low cognitive autonomy did so in an illogical manner. Students with low motivation applied trial-and-error strategies to maximize their mathematical proficiency, whilst students with high motivation applied analytical strategies.

Al-Otaibi (2023) investigated the effectiveness of a learning environment based on expert systems and artificial intelligence in improving the five dimensions of mathematical proficiency (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive motivation) in a sample of 68 first-year secondary school students. An experimental design was used, applied to an experimental and a control group, and included a test of mathematical proficiency skills and a scale measuring productive motivation towards mathematics. The results showed a significant difference in favor of the application of Adaptive Learning Systems (ALS), as they helped students overcome procedural errors and focus on deep conceptual understanding.

Edo and Tasik (2022) analyzed students' conceptual understanding of algebra in relation to their modelling competence when solving a modified mathematical problem within a qualitative study involving a sample of (244) students at vocational colleges in Indonesia. The data used were collected through students' worksheets, video recordings and interviews with some students to obtain information about their thought processes. The data was analyzed and interpreted, and the results revealed a weakness in conceptual understanding, with many students relying on rote memorization of laws and algorithms without a deep understanding of variables, the equal sign, or the structure of the equation.

Genareo et al. (2021) examined the mathematical proficiency of secondary school students in algebra using three procedural measures and two conceptual measures, assessing students taught by 31 teachers in the United States. The assessments included both procedural and conceptual measures, as well as teacher assessment criteria for algebraic proficiency. The results of the procedural measures indicated that they are suitable for use as screening tools, and these findings contributed to the design of measures to enhance their application as assessments of algebraic proficiency.

Wong and Wong (2021) investigated the effects of applying adaptive learning systems on students' motivation towards mathematics in a technology-enhanced learning environment using Geometer's Sketchpad. The motivational adaptive instructions were designed in accordance with the Attention, Relevance, Confidence, and Satisfaction (ARCS) motivational model. An unequal control group design with pre- and post-tests was adopted following a two-week

intervention period. Two intact grade (2) classes were randomly selected and assigned to two groups: an experimental and a control group, each comprising (20) students in Malaysia. The results showed that the intervention did not significantly improve the experimental group's motivation towards learning mathematics, although their average motivation scores improved from the first time period to the second. The results also showed that motivation and mathematics performance were not strongly correlated in this group of students.

Junpeng et al. (2020) validated a digital tool for diagnosing mathematical proficiency in numeracy and algebra among (1,504) students in Thailand. A multidimensional approach, which is an extension of the Rash model, was applied. A design-based research approach was used to create the diagnostic tool, which consists of four components: a scoring system, input data, a processing system, and a diagnostic feedback report. The diagnostic framework comprises (18) tasks, including (11) tasks in the mathematical procedures dimension and (7) tasks in the observed learning outcome's structure dimension. The results revealed evidence of the validity of the internal structure based on a comparison of model fit, and the results also indicated that the reliability and item validity evidence are consistent with the quality of the digital tool among the selected sample.

Hartati et al. (2020) addressed the limited proficiency of university students in Indonesia in algorithm programming and identified the most influential factor in algebra learning by applying a quantitative approach to a sample of 54 students. The tests included mathematical reasoning in linear algebra, basic calculus, and mathematical logic. The results showed that mathematical reasoning has a positive effect on the ability to program algorithms, and that the most influential variable among mathematical reasoning abilities is algebra.

Sabilah, Siswono, Masriyah (2018) investigated the strategic competence of grade (6, 7 and 8) students in solving open-ended problems in Indonesia. They adopted a qualitative research approach with a sample of (25) students with varying mathematical abilities; three students with high mathematical competence were selected to represent each year group. Interview-based tasks were used to explore the students' strategic competence. The results showed that the students understood the problems by reading and drawing/graphing them, formulated solutions by drawing on their prior knowledge of quadrilaterals, and used numerical and visual strategies to solve the open-ended problems.

Egodawatte and Stoilescu (2015) investigated the difficulties faced by grade (11) mathematics students in Canada in applying conceptual knowledge, procedural skills, strategic competence and algebraic thinking to solve routine algebraic problems, using a sample of (30) students. The results showed that the majority of students were in the transition phase from arithmetic to algebra, and one of the prominent features of their difficulties was the overuse of procedures without the

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ability to assess whether these procedures would succeed or not; they also demonstrated a lack of relational, applied and constructive abilities when solving educational problems.

Floyd, Harrington, and Santiago (2009) explored the relationships between perceived course value, student engagement, deep learning strategies, and surface learning strategies in the United States with a sample of (191) students. The study drew on concepts from previous research to measure perceived course value, engagement, surface learning strategies and deep learning strategies. Statistically significant results were observed between the perceived value of the course, student engagement, and deep learning strategies. The results showed that the perceived value of the course has a greater positive impact on deep and surface learning strategies than engagement; by understanding and enhancing perceived value and engagement, the ultimate goal of promoting deep learning can be achieved.

A review of previous studies reveals a scarcity of research integrating the pedagogical aspect (deep learning) with the interactive technical aspect (adaptive learning systems) specifically in the context of enhancing mathematical proficiency. Most studies have focused on general academic achievement rather than the five dimensions of algebraic proficiency. Hence the need for the present study, which integrates three dimensions (pedagogical, technical and subject-specific) to enhance the dimensions of algebraic proficiency.

Significance of the study

Evidence from the field suggests that, although many students graduate from primary education having learnt and acquired the ability to store and retrieve information, they lack the ability to apply this information to make informed choices or decisions—or, more broadly, to utilize mathematical skills in problem-solving. Therefore, teaching students how to think has become an urgent requirement imposed by the current era on educational systems. Furthermore, factors that increase the difficulty of learning—such as students' 'abilities and levels of cognition'—where their speed of learning and understanding of the same subject varies, serve as a theoretical basis for developing educational practices, as discussed by (Zhang, Stylianides, Stylianides, 2024), which enables informed decisions to be made regarding how to shape and organize specific aspects to enhance mathematical proficiency and students' ability to formulate mathematical problems, The study included an activity-based exercise that participants were required to try out, and method-based assistance that helped with problem formulation, as support for these practices.

The current study derives its significance from being a continuation of the work advocated by Abu Zeina and Ababneh (2007), who emphasized the need to move away from traditional teaching towards a focus on building mathematical proficiency across its five dimensions, whereas

the present study seeks to provide a practical framework that integrates deep learning strategies and adaptive learning systems (ALS) to achieve this proficiency. This also responds to recommendations in Jordan, including those of Abu Zeina and Ababneh (2007), who highlighted the urgent need to develop teaching models that enhance students' procedural fluency and conceptual understanding. Accordingly, this study provides a proposed teaching unit in algebra that mathematics teachers may utilize to enhance learning outcomes in line with national standards.

Research Problem

The researcher considers the eighth-year stage to be crucial in the educational continuum, as it is during this stage that students acquire the fundamental skills enabling them to acquire knowledge and develop diverse ways of thinking. Given the importance of this stage, the researcher has proposed the design of a teaching unit within the algebra curriculum based on deep learning strategies and Adaptive Learning Systems (ALS), with the aim of enhancing mathematical proficiency. Furthermore, the prescribed curriculum tends to focus on providing students with necessary information and facts without paying attention to training them in thinking skills or providing them with learning opportunities or situations. The current era requires the preparation of learners with a level of mental ability that enables them to use and practice different types of thinking—analyzing, synthesizing, distinguishing, modifying and adding—thereby enabling them to interact with a changing and evolving reality. The promotion of cognitive acceleration has become a focus of educational development, and the development of thinking in general has become a subject of interest to many educators worldwide, as it is not possible to reconcile the demands the times and the changes surrounding the individual without their behavior being characterized by organization and awareness of all aspects of the educational situation or the task set for the student.

Based on the researcher's findings, the problem lies in the observed low level of algebraic proficiency among grade (8) students, where learning often tends towards the rote memorization of rules without a deep understanding of logical connections or the ability to model mathematical concepts, With the rapid development of educational technology, there has been a growing need to integrate deep learning strategies that focus on connection, analysis and evaluation within smart technological environments, such as Adaptive Learning Systems (ALS), which tailor content to the needs of each learner. The research problem is defined by answering the following main question "What is the impact of an adaptive learning environment based on deep learning strategies on the development of algebraic proficiency among students?" Consequently, the following two questions were posed:

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- "What is the performance level of grade (8) students when implementing a proposed teaching unit based on deep learning strategies and Adaptive Learning Systems (ALS) in enhancing algebraic proficiency?" The following hypothesis emerged from this question: There are no statistically significant differences at the significance level ($\alpha \leq 0.05$) between the mean scores of the 'control' and 'experimental' groups of eighth-grade female students in the post-test of algebraic proficiency, attributable to the implementation of the teaching unit based on deep learning strategies and Adaptive Learning Systems (ALS) to enhance the dimensions of algebraic proficiency among eighth-grade female students."
- How do eighth-grade students describe the development of their cognitive processes and their ability to provide mathematical justification whilst engaging with the proposed teaching unit?

Procedural definitions

- Deep learning strategies are defined procedurally by the researcher as: "a set of cognitive activities and complex mathematical tasks aimed at enabling students to reach higher levels of thinking (analysis, synthesis, evaluation), implemented via an Adaptive Learning System (ALS) to enhance students' ability to link prior algebraic knowledge with new concepts."
- Adaptive Learning Systems (ALS) are defined procedurally by the researcher as: "a digital learning environment based on intelligent algorithms that personalize algebraic content, learning pathways and feedback based on the student's immediate performance and level of algebraic proficiency."
- The researcher defines algebraic proficiency operationally as: "an integrated combination of five dimensions (conceptual understanding, procedural fluency, strategic competence, adaptive reasoning, and productive engagement), measured by the overall score the student achieves in a test designed for this purpose."

METHOD AND PROCEDURES

Study Sample

The study participants were purposively selected from grade (8) students at Jabal al-Sheikh Musleh Co-educational Primary School for the first term of the (2025/2026) academic year, comprising a sample of (60) female pupils divided into two groups: a control group of (30) students who did not undergo the intervention, and an experimental group of (30) students who underwent the teaching unit in accordance with deep learning strategies and Adaptive Learning Systems (ALS), with pre- and post-tests on algebraic problems.

Research Tool

The algebraic proficiency test consisted of (10) questions distributed according to the dimensions of algebraic proficiency. The test items were designed to measure the student's level within the dimensions of algebraic proficiency (conceptual understanding, procedural fluency, mathematical reasoning, adaptive thinking, productive motivation). The test was presented to experts to ensure its reliability and suitability for its intended purpose. It was administered to a pilot sample of 25 female students from the eighth-grade cohort in Jerash Governorate to verify the test's validity and reliability. Internal consistency was calculated using Cronbach's alpha, which yielded a value of (0.87) a statistically significant result. The test's objective and duration were defined, and a marking scheme was developed to align with the objectives of the current study.

The Guide

The guide was developed in accordance with the Mathematical Proficiency Framework established by the National Council of Teachers of Mathematics (NCTM, 2001) and in line with the national standards discussed in the study by Abu Zeina and Ababneh (2007) on the development of algebra learning at the primary level. It also drew upon the scope and sequence matrix issued by the Jordanian National Centre for Curriculum Development within the National Curriculum Framework (2019), where activities were designed to achieve a balance between the five dimensions (understanding, fluency, proficiency, reasoning, and motivation) and to measure these dimensions among Year 8 students to ensure the quality of learning. Reference was also made to the study by Yaguarema et al. (2022), which adopted deep learning strategies focusing on analysis and deep engagement with the learning material and its role in fostering deep understanding.

The study by Wong and Wong (2021) was also drawn upon in formulating learning pathways regarding the impact of adaptive, motivation-based teaching in technology-enhanced learning environments, and the presentation was designed to allow the pace of the educational content to be adjusted based on the student's immediate responses. With regard to strategic proficiency exercises, and with reference to the study by Al Mutawah et al. (2019), students were guided to formulate algebraic problems themselves as a means of deepening mathematical proficiency and linking concepts to communication skills.

With regard to programmers and platforms that adopt the concept of Adaptive Learning Systems (ALS), most of which use artificial intelligence algorithms, these include: The ALEKS platform, which conducts a thorough pre-test to identify gaps in the student's knowledge and then provides a learning pathway that adapts to the student's pace; and the PheT platform, which provides an excellent interactive

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environment for fostering a productive desire to learn and making algebra enjoyable and less abstract.

With regard to the procedural integration steps between deep learning strategies and Adaptive Learning Systems (ALS) these included the following stages: The adaptive diagnostic phase (input), where the module begins with a pre-test via the adaptive system; if the student demonstrates weakness in basic algebraic skills, the system provides ‘warm-up exercises’ before introducing deep learning concepts, thereby ensuring procedural fluency; The task design phase according to deep learning levels, where tasks requiring research and inquiry were integrated, and the adaptive system acts as a guide; if the student encounters difficulty with the skill of ‘adaptive reasoning’, the system presents her with educational media and interactive models explaining ‘why’ we use this rule and not just ‘how’; and the personalization and branching stage, where the Adaptive Learning System (ALS) has been integrated to allow high-achieving students to progress to higher-order thinking applications as one of the pillars of deep learning, thereby enhancing their intrinsic motivation. The Adaptive Learning System (ALS) also includes prompts that help students correct their own thought processes, which serves to enhance strategic proficiency in algebraic reasoning.

Study methodology

The researcher adopted a descriptive approach; analyzing previous research and studies to determine the content of the teaching unit in accordance with deep learning strategies and Adaptive Learning Systems (ALS), and testing algebraic problems to enhance algebraic proficiency, and an observation sheet was used during the implementation of the teaching unit and the development of research processing tools and measurement instruments, as well as to contribute to the interpretation and discussion of the results. To measure the impact of implementing the teaching unit in accordance with deep learning strategies and Adaptive Learning Systems (ALS), a quasi-experimental design was used, which involved dividing the sample into two groups: a control group (G1) and an experimental group (G2), and administering a pre-test of algebraic problems, The experimental group was

then treated by implementing the proposed teaching unit, after which the researcher compared the two groups’ results in the post-test for algebraic problems and discussed the findings.

| | | | |
|----|-------|----|----|
| T1 | _____ | T1 | G1 |
| T1 | O | T1 | G2 |

Study procedures

The study involved administering an algebra test based on mathematical proficiency dimensions. The sample was divided into an experimental and a control group, and the teaching unit was implemented using deep learning strategies and Adaptive Learning Systems (ALS). The teaching processes for the unit were recorded as they were delivered in their natural context during the lesson. Observations were recorded on the lessons included in the Programme, numbering five, which comprised the explanation and teaching of algebraic concepts, the solving of exercises, and classroom discussions. The experimental group was allocated 15 lessons to implement the proposed teaching unit in accordance with deep learning strategies and Adaptive Learning Systems (ALS) within the algebra curriculum, with the aim of enhancing algebraic proficiency. Upon completion of the teaching unit, students were given a post-test to determine the extent to which the dimensions of algebraic proficiency had been enhanced in the study sample. Furthermore, during the delivery of the teaching unit and based on classroom observations focused on the cognitive and organizational aspects of the application levels of algebraic proficiency, observation sheets were used to measure the effectiveness of the teaching unit in fostering positive attitudes. A tool was developed to monitor students’ progress during the delivery of the teaching unit, and a record was kept for each student participating in the Programme to study their development whilst exposed to the proposed unit. The teaching unit and the outcomes formulated for each sub-skill were also introduced to the experimental group in a simplified and understandable manner for the fifth-year science students, as shown in Table (1).

Table (1): Key elements of the deep learning strategy and Adaptive Learning Systems (ALS) within the teaching unit

| Indicator | Deep learning |
|-------------------------|---|
| Asking questions | Can identify mathematical problems from real-life situations and ask high-quality questions |
| Knowledge discovery | Independently discovers knowledge and demonstrates initiative |
| Understanding knowledge | Focuses on transferring knowledge and applying it flexibly to solve different types of problems |
| Problem-solving | Focuses on training the mind and applying methods; understands ‘what’ and ‘why’ |

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| | |
|---------------------------------|---|
| Indicator | Deep learning |
| Summarizing knowledge | Uses classification, connection and logical criticism to build an accurate and comprehensive knowledge system |
| Applying knowledge | Uses knowledge flexibly to solve a variety of problems |
| Motivation to learn | Engages actively in learning to meet intrinsic needs |
| Engagement in learning | High concentration, significant investment, able to plan tasks and progress independently |
| Thinking characteristics | Comprehensive, interconnected, critical |
| Scope of learning | Broader and deeper than superficial learning |
| Memory characteristics | Memory based on understanding, diverse in approach and practical |
| Learning format | Rich content, varied methods, an enjoyable experience, collaboration and independent exploration |

degree of organization in the presentation of ideas and the logic applied to construct mathematical arguments. Participants in the teaching unit were provided with an observation sheet for each sub-task they completed to assist them in assessing their performance in the individual sub-task and the tasks as a whole, as shown in Table (2).

The table above illustrates the translation of the deep learning strategy and Adaptive Learning Systems (ALS) applied within the proposed teaching unit that was implemented with the experimental group, The sub-tasks include producing arguments and demonstrating evidence of language knowledge; students' performance in the tasks will reveal the

Table (2): Student performance observation sheet based on deep learning strategies

| Performance Indicator | Sub-indicator |
|--|--|
| Prior knowledge | Establishing and linking prior knowledge at the start of the topic |
| Student thinking (their strategies, discussions, misconceptions) | Exploring their own strategies for rejecting ineffective ones and adopting effective ones. |
| Students' relational understanding (understanding connections and concepts) | Identifying new concepts and linking them to their prior knowledge. |
| Interdisciplinary integration / links to everyday life | Applying knowledge across multiple subjects and linking the topic to their daily lives to make it clearer, and understanding topics and problems across areas of knowledge and linking them to daily life. |
| Diversifying teaching aids (books, number lines, concrete materials, etc.) | Applying skills (drawing, visualizing, and using concrete materials) |
| Diversifying teaching methods | Apply different strategies: station work, learning partners, teaching from the blackboard, student participation in activities, watching a film. |
| Learning outcomes for the lesson | Practicing describing the learning objective verbally: what we are supposed to learn. |
| Applying knowledge | Applying practical situations and other materials where it is natural to use them. |

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RESULTS

The first research question aimed to investigate the impact of implementing the teaching unit in accordance with deep learning strategies and adaptive learning systems (ALS) by identifying statistically significant differences between the mean scores of grade (8) students in the algebra test. To answer this question, the hypothesis derived from it was tested, namely: “There are no statistically significant

differences ($p \leq 0.05$) between the mean scores of eighth-grade female students on the post-test of algebraic proficiency attributable to the implementation of the teaching unit in accordance with deep learning strategies and Adaptive Learning Systems (ALS).” To achieve this, the arithmetic means and standard deviations of the eighth-grade students’ scores on the algebraic problems test were calculated for both the pre-test and post-test, as shown in Table (3).

Table (3): Arithmetic means and standard deviations for the algebra test according to the study groups * Total marks (30)

| Group | No. | Pre-test | | Post-test | | Balanced mean | Standard error |
|-------------|-----|----------|--------------------|-----------|--------------------|---------------|----------------|
| | | mean | Standard deviation | mean | Standard deviation | | |
| Empirical | 30 | 23.34 | 7.37 | 26.35 | 8.16 | 24.85 | 1.5 |
| The Officer | 30 | 19.89 | 6.65 | 23.78 | 7.03 | 21.83 | 1.3 |

Table (3) shows an apparent difference between the arithmetic means of the sample scores in the algebra test according to the proposed teaching unit, to determine whether the apparent difference in the overall post-test scores is statistically significant, a one-way ANCOVA was used for the post-test of the algebraic problems according to the implementation of the proposed teaching unit, and Table (4) shows these results.

Table 4: Analysis of covariance (ANCOVA) for the post-test on algebraic problems according to the implementation of the proposed teaching unit

| Source of variation | Sum of squares | Degrees of freedom | Mean of Sum of Squares | F | Sig. | Effect size |
|---------------------|----------------|--------------------|------------------------|--------|---------|-------------|
| Hypothesis test | 0.232 | 1 | 0.232 | 0.004 | | |
| Training | 1708.49 | 1 | 1708.49 | 38.449 | 0.0001* | 0.62 |
| Error | 1410.88 | 27 | 44.753 | | | |
| Total | 26,592.00 | 59 | | | | |

Table (4) shows a statistically significant difference ($P < 0.05$) between the mean scores of grade (8) students in the two study groups on the algebra test, where the F-value was 38.449 and the P-value was 0.0001, in favor of the experimental group that was trained using the proposed teaching unit based on deep learning strategies and adaptive learning systems (ALS). Table (4) shows that the training has an effect on enhancing the dimensions of algebraic proficiency among primary school students, and the Eta-squared value (η^2) explained 62% of the explained (predicted) variance in the enhancement of algebraic proficiency, with the remainder attributed to other factors.

This result is attributed to the pivotal role played by deep learning strategies in shifting the student from the role of a passive recipient to that of a meaning-seeker, as the rich

algebraic tasks included in the teaching unit provided opportunities for comparison, analysis and connection between different representations, The Adaptive Learning System (ALS) also contributed to enhancing proficiency through Personalized Paths. Whilst the system provided immediate feedback to low-performing students to correct their conceptual errors, it provided advanced students with mathematical challenges that enhanced their adaptive reasoning and strategic competence. This is consistent with studies confirming that adaptive technology increases student motivation and the construction of deep mental schemas.

With regard to the second research question: "**How do grade (8) students describe the development of their cognitive processes and their ability to provide mathematical justification whilst engaging with the proposed teaching**

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unit?" changes in the students' behavior and discourse during implementation were observed as follows:

"The shift from procedural memorization to logical understanding" where the students described the development of their cognitive processes by moving away from asking "What is the rule?" and starting to ask "Why do we use this rule?", with one student discussing: "Previously, I used to memorize the steps to solve the equation without understanding; now, I visualize the equation as a set of scales and understand that any action on one side must be followed by a similar action on the other to maintain balance."

"The ability to provide evidence-based mathematical justification" Instead of merely giving final answers, the student has become able to formulate mathematical arguments. One student described her abilities as follows: "I can explain my steps to my classmates, not just because I found them in the book, but by saying, 'Since the variable (x) represents an unknown value and since we have substituted, the result makes sense because the product of the substitution on both sides of the equation is equal.' This reflects a development in mathematical reasoning."

"Confidence in dealing with unfamiliar situations" where students describe an improvement in adaptive thinking. Thanks to the Adaptive Learning System (ALS), which presents progressive challenges, one student says: "I no longer feel confused when I see a new algebraic problem; the system has taught me how to break the problem down into small parts and try different strategies until I reach the solution."

"Awareness of mental processes (beyond knowledge)" During interaction with the module, students begin to describe how they think. One student says: "I've become more aware of my mistakes as soon as they happen, because the adaptive system gives me a prompt that makes me review my thinking at that moment, and this has helped me organize my thought processes before starting the written solution."

"Enhancing productive motivation (perseverance)" The students describe a shift in their attitudes towards algebra content, where the feeling changes from "algebra is complicated and boring" to "algebra is a challenge and fun". One student says: "I used to give up quickly, but the new strategies made me feel capable of discovering things, which made me try again and again without getting bored."

"Development of mental representations of abstract concepts" describes the students' shift in how they view algebraic symbols. Instead of seeing variables (x, y) as mysterious letters, they begin to describe them as "changing quantities or dynamic relationships". One student says: "I used to see the equation as a rigid template that had to be filled in; now I see it as a story or a relationship between the variables. Adaptive technology has allowed me to see the change in the number on the graph or the result immediately, which has made the abstract concept tangible in my mind."

"Practicing backward reasoning" in deep learning means the student doesn't just move from the data to the solution; she learns how to work backwards from the solution to examine the logic," says the student: "The adaptive system didn't just say 'wrong'; it asked questions that helped me discover where my logic had gone astray. This helped me develop the ability to reason backwards – that is, to examine every step I had taken to ensure it was consistent with the rules I had learnt."

"Enhancing Cognitive Flexibility" This aspect relates to the ability to solve a problem in more than one way, which is the essence of algebraic proficiency. The student says: "Previously, I would stick to one method, and if I forgot it, the solution was lost. Now, deep learning strategies have taught me that there are multiple ways to arrive at an answer. I would describe my thinking as flexible; I can try substitution, simplification or graphing, and I know why I choose one method over another."

"The Transition to Cognitive Autonomy" The students describe a shift in the source of confidence from relying on the teacher to relying on their own mathematical reasoning. The student says: "My sense of competence stems from the fact that I have become the judge of the validity of my solutions. When I provide a mathematical justification, I do not wait for the machine to correct me; rather, I feel the strength of the logic upon which my answer is built. This kind of confidence has made my thinking bolder in proposing hypotheses."

"Integrating mathematical language into everyday discourse" The students' reasoning evolves from general language to precise mathematical discourse. The student says: "Instead of saying 'we moved the number to the other side', I started using terms such as 'adding the opposite to both sides to maintain equality'. Does this shift in language reflect a deeper understanding of the underlying structure, where the reasoning is based on the properties of the operations rather than mere mechanical movements?"

The students thus describe this development as a journey from being 'passive recipients' of information to becoming 'active explorers', where algebraic symbols become, for them, a comprehensible language with its own logic, rather than merely concepts and rules to be memorized. Furthermore, integration is the optimal approach to teaching algebra to primary school pupils, where the adaptive system acts as an engine whilst deep learning serves as a methodology for achieving algebraic proficiency.

DISCUSSION OF RESULTS

The researcher observed a correlation between the application of deep learning strategies and adaptive learning systems (ALS) in enhancing the dimensions of algebraic proficiency. This includes applying relationships between content and situations, visualizing or imagining the situations referred to, and cognitive processes to link acquired information to prior

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knowledge structures. It also involves a thorough review of Adaptive Learning Systems (ALS) instructions to ensure their understanding. With regard to differences in educational level, the researcher notes that primary school pupils use fewer visual strategies for explanation and summarization. Furthermore, the available evidence on this subject indicates that primary school pupils rely more heavily on direct instruction and may therefore be better able to self-regulate.

The results of the current study are consistent with those reported by Zhang et al. (2024) and Yaguarema et al. (2022), which indicated that deep learning strategies shift the student from the role of a passive recipient to that of an active processor of information, This may be consistent with deep learning's focus on linking prior knowledge with new knowledge, which helped eighth-grade students understand the logical structure of algebra, thereby enhancing conceptual understanding as one dimension of algebraic proficiency.

The findings of the current study also corroborate those of a study by Wong and Wong (2021) on the impact of adaptive teaching on enhancing motivation and achievement in mathematics, as the current study provided a safe environment for the students to make mistakes and try again, thereby fostering a "productive disposition" in them This technical support reduced achievement gaps and increased the stability of algebraic performance in the experimental group.

The results of the present study demonstrated an improvement in the dimensions of algebraic proficiency outlined in the definition by the NRC (2001), as evidenced by the nature of the proposed integrated teaching unit, given that mathematical proficiency is not achieved through procedural fluency alone. and the integration of pedagogical depth and technical adaptation allowed the students to practice adaptive reasoning by solving non-routine algebraic problems within the adaptive system, which explains the significant improvement in the post-test results.

The results of the current study showed a significant improvement in problems requiring reasoning (not merely the application of rules), which is consistent with a study (Wibowo, Suryaningsih, 2020), which emphasized the close link between logical ability and algebraic proficiency. The application of deep learning strategies in the current study helped the students to justify their solution steps, thereby improving their performance on algebraic problems.

Thus, the present study provides empirical evidence that integrating Adaptive Learning Systems (ALS) with sound pedagogical strategies such as 'deep learning' represents the optimal solution for overcoming traditional difficulties in learning algebra, which supports the modern trends advocated by contemporary educational literature. Furthermore, the successful application of the Adaptive Learning System (ALS) within the algebra content in the present study is due to the fact that algebra relies on abstraction; the Adaptive Learning System helped bridge the gap between the concrete

and the abstract by progressively presenting examples based on students' responses.

The findings of the present study align with those of Al-Otaibi (2023) in that the delivery of educational content via intelligent and adaptive learning systems (ALS) has directly contributed to enhancing mathematical proficiency and providing specialized learning pathways tailored to the pace and ability of female students, thereby strengthening conceptual understanding and overcoming traditional learning barriers, as it provides them with the opportunity for self-correction and learning from mistakes in an interactive environment.

The study also provides findings for researchers seeking to enhance mathematical proficiency in primary education, as learning outcomes in general education curricula increasingly reflect learning pathways that go beyond procedural competence. It is important to continue efforts to develop assessment strategies that provide teachers with data on the achievement of learning outcomes. Future research should focus on studying dimensions of mathematical proficiency in classroom settings where the teaching process explicitly focuses on developing students' understanding beyond a procedural focus.

RECOMMENDATIONS

The study examined the impact of applying deep learning strategies and Adaptive Learning Systems (ALS) through the design of a teaching module and an instrument to measure the extent to which algebraic proficiency is enhanced among primary school pupils. This was accompanied by the design and implementation of sound assessment methods, tools and techniques, characterized by quality, validity and reliability. Accordingly, the researcher recommends focusing on providing guidance and feedback to achieve learning outcomes. Furthermore, the aim of instructional design should be to help students enhance their mathematical proficiency in general, and their algebraic proficiency in particular, as highlighted in the study, whilst enabling them to construct knowledge and identify weaknesses in their learning process.

The researcher also emphasizes the importance of structuring instructional design in a way that allows for the measurement of the cognitive effort required of students, encourages accompanying tasks to foster a deeper approach to learning, increases objectivity in student assessment, and provides timely feedback. Assessment tasks should always align with the specified learning outcomes, and instructional designs should be meaningful to ensure the promotion of deep learning and its impact on enhancing mathematical proficiency. Emphasis should also be placed on designing an assessment tool that utilizes deep learning strategies as an educational tool to measure understanding of processes and content standards, whilst involving students in the process. The researcher recommends conducting further future studies

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addressing the impact of ALS systems on the development of metacognitive skills among students at other educational levels.

STUDY LIMITATIONS

The scope of this study is limited to eighth-grade female students at Jabal al-Sheikh Musleh Co-educational Primary School, the reason for selecting this grade level is the completion of the basic concepts, facts and theories included in the proposed Programme. Furthermore, the study is limited to the dimensions of algebraic proficiency and mathematical concepts and facts within a specific educational Programme; it is important to note the possibility of using pre- and post-tests to assess the extent of development achieved by students participating in the implementation of the teaching unit. The pre-test is linked to measuring or assessing aspects of mathematical proficiency, such that the tool used is characterized by reliability and validity to provide realistic results, Furthermore, the post-test is aligned with the skills of the proposed teaching unit and reflects the effectiveness the researcher expects from its application to the study sample, comprising grade 8 pupils.

Furthermore, the current study is limited to the application of Adaptive Learning Systems (ALS), which were implemented with the study sample on a limited basis; this is a vital aspect requiring logistical support, such as the availability of devices and internet speed. The study also incorporated a combination of deep learning and Adaptive Learning Systems (ALS) to enhance mathematical proficiency; from the researcher's perspective, it is difficult to determine which has the greater impact on enhancing proficiency: the teaching method or the technical tool.

REFERENCES

1. Abu Zeina, Farid; and Ababneh, Abdullah. (2007). The level of mathematical proficiency among eighth-grade students in Jordan. *Journal of Studies: Educational Sciences, University of Jordan*, 34(2), 244–261
2. Al Mutawah, M. A., Thomas, R., Eid, A., Mahmoud, E. Y., & Fateel, M. J. (2019). Conceptual understanding, procedural knowledge and problem-solving skills in mathematics: Analysis of high school graduates' work and perspectives. *International Journal of Education and Practice*, 7(3), 258–273
<https://doi.org/10.18488/journal61..2019.73.258.273>
3. Al-Otaibi, Bandar bin Shabib. (2023). The impact of using AI-based smart learning systems on the development of mathematical proficiency skills among secondary school students. *International Journal of Educational and Psychological Sciences*, 74(3), 115–152
4. Azmy, N. G., Fares, N. M., Al-Said, S. M., & Saied, M. A. A. (2017). Adaptive learning systems and their relation to learning styles, foundations and associated educational theories. The 1st International Scientific Conference of the Faculty of Specific Education in Qena, South Valley University, entitled "Specific Education and the Quality of Community Work: A New Vision", 161–176
<https://www.academia.edu/97079951>
5. Boamah, S., Asemani, E., Koranteng, E. K., & Mensah, R. O. (2025). Effect of cognitive-communicative model on senior high school students' proficiency in solving algebraic word problems. *Discover Education*, 4(188).
<https://doi.org/10.1007/s44217-025-00619-y>
6. Cerbito, A. F. (2020). Comparative analysis of mathematics proficiency and attitudes toward mathematics of senior high school students. *International Journal of Scientific and Research Publications*, 10(5), 125
<https://files.eric.ed.gov/fulltext/ED605013.pdf>
7. Edo, S. I., & Tasik, W. F. (2022). Investigation of students' algebraic conceptual understanding and the ability to solve PISA-like mathematics problems in a modelling task. *Mathematics Teaching Research Journal*, 14(2), 44–60
<https://files.eric.ed.gov/fulltext/EJ1350638.pdf>
8. Genareo, V. R., Foegen, A., Dougherty, B. J., DeLeeuw, W. W., Olson, J., & Karaman Dundar, R. (2021). Technical Adequacy of Procedural and Conceptual Algebra Screening Measures in High School Algebra. *Assessment for Effective Intervention*, 46(2), 121–131
<https://doi.org/10.1177/1534508419862025>
9. Fauskanger, J., & Bjuland, R. (2018). Deep learning as constructed in mathematics teachers' written discourses. *International Electronic Journal of Mathematics Education*, 13(3), 149–160.
<https://doi.org/10.12973/iejme/2705>
10. Fernandes, S., Flores, M. A., & Lima, R. M. (2012). Students' Views of Assessment in Project-led Engineering Education: findings from a case study in Portugal. *Assessment & Evaluation in Higher Education*, 37(2), 163–178
<https://doi.org/10.1080/02602938.2010.515015>
11. Floyd, K. S., Harring, S. J., & Santiago, J. (2009). The effect of engagement and perceived course value on deep and surface learning strategies. *The International Journal of an Emerging Transdiscipline*, 12, 181–190
12. Jazby, D.; Widjaja, W. (2019). Teacher noticing of primary students' mathematical reasoning in a problem-solving task. In G. Hine, S. Blackley, & A. Cooke (Eds.), *Mathematics education research:*

Nabeela A. O. Effectiveness of Applying Deep Learning Strategies on Developing Dimensions of Algebraic Proficiency within Adaptive Learning Systems (ALS) among (8th) Grade Students in Jordan

- Impacting practice (Proceedings of the 42nd annual conference of the Mathematics Education Research Group of Australasia, 380–387. Perth: MERGA. <https://files.eric.ed.gov/fulltext/ED604495.pdf>
13. Hartati, S. J., Vitianingsih, A. V., Kurniati, N., Sulistyowati, & Muhajir. (2020). Identifying the factors of mathematical reasoning that affect the ability to Programme algorithms. *International Education Studies*, 13(5), 44–56. Canadian Centre for Science and Education. <https://doi.org/10.5539/ies.v13n5p44>
 14. Hatisaru, V., Chick, H., & Oates, G. (2022). Developing proficiency with teaching algebra in teacher working groups: Understanding the needs. In N. Fitzallen, C. Murphy, V. Hatisaru, & N. Maher (Eds.), *Mathematical confluences and journeys* (Proceedings of the 44th Annual Conference of the Mathematics Education Research Group of Australasia, 3–7 July) (pp. 250–257). MERGA. Retrieved from <https://files.eric.ed.gov/fulltext/ED623705.pdf>
 15. JAHUDIN, J.; SIEW, N. (2024). The effects of Polya's problem solving with digital bar model on the algebraic thinking skills of seventh graders, *PROBLEMS OF EDUCATION IN THE 21st CENTURY*, 82(3), 390–409 <https://doi.org/10.33225/pec/24.82.390>
 16. Jose, J., Joseph, A., Abraham, P., Varghese, R., Beenamole, T., Varghese, S. M., & Oommen, S. E. (2024). Transformative pedagogies: A bibliometric journey through adaptive learning systems. *Journal of Theoretical and Applied Information Technology*, 102(6), 2308–2322. Little Lion Scientific. <https://files.eric.ed.gov/fulltext/ED650379.pdf>
 17. Junpeng, P., Marwiang, M., Chiajunthuk, S., Suwannatrai, P., Chanayota, K., Pongboriboon, K., Tang, K. N., & Wilson, M. (2020). Validation of a digital tool for diagnosing mathematical proficiency. *International Journal of Evaluation and Research in Education (IJERE)*, 9(3), 665–674 <https://doi.org/10.11591/ijere.v9i3.20503>
 18. Kania, N., Saepudin, A., & Gürbüz, F. (2025). Assessing cognitive obstacles in learning number concepts: Insights from pre-service mathematics teachers. *Journal of Research and Advances in Mathematics Education*, 10(3), 146–166 <https://doi.org/10.23917/jramathedu.v10i3.8638>
 19. Kieran, C. (2004). The core of algebra: Reflections on its main activities. In K. Stacey, H. Chick, & M. Kendal (Eds.), *The future of the teaching and learning of algebra: The 12th ICMI Study* (pp. 21–33). Dordrecht: Kluwer Academic Publishers. https://doi.org/10.1007/1-4020-8131-6_3
 20. Kwangpukieo, C., & Sawangboon, T. (2024). Fostering mathematical proficiency and creative thinking skills in 10th grade students through the 5E inquiry-based learning approach with supplementary media. *International Education Studies*, 17(3), 1–8. <https://doi.org/10.5539/ies.v17n3p1>
 21. Lamb, J., Warren, E., & Cooper, T. (2007). Combining teaching experiments and professional learning: Conflicts between research and teacher outcomes. *Mathematics Education Research Journal*, 19(3), 73–92. <https://files.eric.ed.gov/fulltext/EJ788379.pdf>
 22. Liu, Y. N. (2022). Rational Analysis of Deep Learning in Mathematics. *Creative Education*, 13, 854–861 <https://doi.org/10.4236/ce2022.133056>
 23. Luneta, K., & Legesse, M.Y. (2023). Discourse-based mathematics instruction on Grade 11 learners' mathematical proficiency in algebra topics, 44(1), a686. <https://doi.org/10.4102/pythagoras.v44i1.686>
 24. Mason, J. (2008). Making use of children's powers to produce algebraic thinking. In L. English (Ed.), *Handbook of International Research in Mathematics Education*, Routledge, 169–190
 25. Masuku, M. M., Jili, N. N., & Sabela, P. T. (2021). Assessment as a pedagogy and measuring tool in promoting deep learning in institutions of higher learning. *International Journal of Higher Education*, 10(2), 274–283. <https://doi.org/10.5430/ijhe.v10n2p274>
 26. McGregor, D. (2007). *Developing thinking, developing learning: A guide to thinking skills in education*, 7–25. Maidenhead: McGraw-Hill Education. https://archive.org/details/isbn_9780335217809
 27. McGuinness, S. (2014). *Developing and Assessing Thinking Skills Project, Final Report Part 1 February with all appendices*
 28. National Research Council (NRC). (2001). *Adding it up: Helping children learn mathematics*. J. Kilpatrick, J. Swafford, & B. Findell (Eds.). Mathematics Learning Study Committee, Center for Education, Division of Behavioral and Social Sciences and Education. Washington, DC: National Academy Press. <https://doi.org/10.17226/9822>
 29. Ottmar, E., Lee, J.-E., Vanacore, K., Pradhan, S., Decker & Woodrow, L., & Mason, C. A. (2023). Data from the Efficacy Study of From Here to There! A Dynamic Technology for Improving Algebraic Understanding. *Journal of Open Psychology Data*, 11: 5, pp. 1–15. DOI: <https://doi.org/10.5334/jopd87>.
 30. Pane, J.; Griffin, B.; McCaffrey, D.; Karam, R.; Daugherty, L.; & Phillips, A. (2013). Does an

Nabeela A. O. Effectiveness of Applying Deep Learning Strategies on Developing Dimensions of Algebraic Proficiency within Adaptive Learning Systems (ALS) among (8th) Grade Students in Jordan

- Algebra Course with Tutoring Software Improve Student Learning? (RB-9746-DEIES), RAND Corporation
https://www.rand.org/pubs/research_briefs/RB9746.html
31. Radford, L. (2012). Early algebraic thinking: Epistemological, semiotic, and developmental issues. In Tso, T. Y. (Ed.), *Proceedings of the 12th International Congress on Mathematical Education (ICME-12)*, 487–502. https://www.luisradford.ca/pub/5_2012ICME12RL312.pdf
 32. Rahman MS, Juniati D, Manuharawati. The Quality of Mathematical Proficiency in Solving Geometry Problems: Differences in Cognitive Independence and Motivation. *Pegem Journal of Education and Instruction*, 13(3), 255–266. <https://orcid.org/0000-0002-5352-3708>
 33. Sabilah, I.; Siswono, T. Y. E.; Masriyah. (2018). Students' Strategic Competence Towards Open-Ended Problems Before and After the Transition to Junior High School. In *Journal of Physics: Conference Series*. 1108 (1). <https://iopscience.iop.org/article/10.1088/1742-6596/1108/1/012017/pdf>
 34. Sari, D. P., Kurniawan, H., & Sutiarso, S. (2023). The quality of mathematical proficiency in solving geometry problems: Differences in cognitive independence and motivation. *Pegem Journal of Education and Instruction*, 13(1), 1–12. <https://doi.org/10.47750/pegegog13..01.01>
 35. Schulz, A. (2023). Assessing student teachers' procedural fluency and strategic competence in operating and mathematising with natural and rational numbers. *Journal of Mathematics Teacher Education*, 27, 981–1008. <https://doi.org/10.1007/s10857-023-09590-7>
 36. Stacey, K., Chick, H., & Kendal, M. (Eds.). (2004). *The future of the teaching and learning of algebra: The 12th ICMI study*, 8. Kluwer Academic Publishers.
 37. Suglo, E. K. (2024). Exploring the impact of deep learning activities in the mathematics classroom on students' academic performance: A comprehensive study [Preprint]. Preprints.org. <https://doi.org/10.20944/preprints202403.1551.v1>
 38. Villegas, W.; Canizares, M.; Alcazar, A.; & Pacheco, X. (2020). Data Analysis as a Tool for the Application of Adaptive Learning in a University Environment. *Applied Sciences*, 10(20), 7016; <https://doi.org/10.3390/app10207016>
 39. Wakhata, R., Balimuttajjo, S., & Mutarutinya, V. (2023). Building on students' prior mathematical thinking: Exploring students' reasoning interpretation of preconceptions in learning mathematics. *Mathematics Teaching Research Journal*, 15(1), 127–142. <https://files.eric.ed.gov/fulltext/EJ1391459.pdf>
 40. Wang, X. (2015). The Literature Review of Algebra Learning: Focusing on the Contributions to Students' Difficulties. *Creative Education*, 6, 144–153. <http://dx.doi.org/10.4236/ce2015..62013>
 41. Warren, E., & Cooper, T. (2007). *Generalizing the pattern rule for visual growth patterns: Actions that support 8-year-olds' thinking*. Springer Science Business Media.
 42. Weng, C., Chen, C., & Ai, X. (2023). A pedagogical study on promoting students' deep learning through design-based learning'. *International Journal of Technology and Design Education*, 33(6), 1653–1674. <https://doi.org/10.1007/s10798-022-09789-4>
 43. Wibowo, A., & Suryaningsih, Y. (2020). The correlation between mathematical logic ability, algebra ability, and basic calculus ability with algorithm programming ability. *International Education Studies*, 13(7), 44–52. <https://files.eric.ed.gov/fulltext/EJ1254684.pdf>
 44. Wong, S. L., & Wong, S. L. (2021). Effects of motivational adaptive instruction on student motivation towards mathematics in a technology-enhanced learning classroom. *Contemporary Educational Technology*, 13(4), ep326. <https://doi.org/10.30935/cedtech/11199>
 45. Yaguarema, M.; Zambrano R J.; Salavarría, M. (2022) Analysis of the Deep Learning Strategies Questionnaire with Ecuadorian students. *Front. Educ.* <https://doi.org/10.3389/FEDUC2022..1004874>
 46. Zhang, L., Stylianides, G. J., & Stylianides, A. J. (2024). Enhancing mathematical problem posing competence: A meta-analysis of intervention studies. *International Journal of STEM Education*, 11(1), Article 507. <https://doi.org/10.1186/s40594-024-00507-1>
 47. Zhao L, Wang H. (2019). Research on adaptive learning system based on three core modules [Internet]. *Proceedings - 10th International Conference on Information Technology in Medicine and Education, ITME*, 447–452. <https://doi.ieeecomputersociety.org/10.1109/ITME2019..00106>