# The Impact of AI-Based-Mathway Software on Obtaining the Concepts of Quadratic Equations and the Mathematical Self-Concept among Tenth-Grade Female Students

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***Abstract*—This investigation examines the impact of teaching with Artificial Intelligence (AI)-based math software on the understanding of quadratic equations and the mathematical self-concept among tenth-grade female students. The study implemented the quasi-experimental approach and included a sample of female students distributed into two groups: an experimental group (32 students) who were taught the subject of quadratic equations and their solution using Mathway software, and a control group (31 students) who were taught using the traditional method. To achieve the objectives of the study, a test on the concepts of quadratic equations and a scale of the mathematical self-concept were applied after verifying their validity and reliability. The results of the study showed remarkable progress in acquiring the concepts of quadratic equations ($F = 49.39$, $p < 0.05$) and enhancing the mathematical self-concept ($F = 29.62$, $p < 0.05$) among the students of the experimental group who studied the subject of solving quadratic equations using the Mathway software compared to the control group who studied using the traditional method. The study also recommended using the Mathway software in the educational process to acquire mathematical concepts and develop the mathematical self-concept. The study also recommended providing a special integrated laboratory for mathematics by providing modern computers and tablets to facilitate the implementation of classes and lessons for students and teachers, in addition to developing curricula to keep pace with modern technological means, computerized techniques, and software, and including their use in the educational process.**

***Keywords*—Artificial Intelligence (AI)-powered software, education, Mathway, self-concept, learning mathematics**

## I. Introduction

Societies are living in an era of scientific and technological revolution that has invaded various aspects of life, resulting in a progressive and prosperous life in several aspects. However, these societies have become dependent on technologies and innovations, with the attempt to keep pace with these developments, which imposes several challenges on educational systems, and brings about changes and developments in educational environments. Their search for new horizons and ways to improve the quality of the educational process continues through technological innovations and investments into their capabilities in serving the educational process. Education that generates enthusiasm and love of knowledge is the best type of education, making it more enjoyable and livelier, and develops the ability to create, innovate, and think, which requires educational systems to keep pace with this accelerating technological era and expand their capabilities and advance their potential more effectively to improve the outcomes of the educational process.

The trend towards modern technological means, computerized techniques and software are in line with the rapid and successive developments in the technical and technological field, and given its importance in improving the quality of learning outcomes and achieving the desired goals, and with the integration of the use of modern technological means, computerized techniques and software in the educational process; and the increasing calls for their use to improve the quality of the educational process, the number of teachers wishing to teach their students using these computerized software that play the role of an educational mediator that helps achieve learning has increased, which contributes to shifting attention from mere education to learning, where learning becomes the active agent. Through the keyboard or mouse, the student can simulate some things that he cannot see directly, such as moving the circumference of a circle on a straight line to measure the length of the circumference [1].

Students face several difficulties in learning mathematics at different educational levels, the most important of which is their view of it. Some scholars consider it a subject that cannot be understood, while others consider it a riddle of symbols and equations that are difficult to understand. Many students do not have the desire or motivation to learn it because there are no real applications in their lives for what they learn. Rather, the student fails to perceive mathematics as part of the comprehensive scientific fabric that constitutes life [2]. Perhaps the reason behind this perspective is the failure to teach the subject in a way that simulates real contexts and the failure to integrate mathematical issues within purposeful models so that the student can see the applications of mathematics in physics, science, engineering, and economics. Therefore, there is great importance in paying attention to teaching models and strategies that will build bridges for the student that connect him to mathematical concepts smoothly and spontaneously [3–5].

For example, when a teacher asks a student to solve a quadratic equation using the general law method, completing the square method, common factor method, etc., or when he solves two quadratic equations graphically, by elimination, or by substitution, this does not indicate that the student has a complete understanding of solving quadratic equations. Rather, he must be able to describe or explain how to solve them algebraically or geometrically, express this in different formulas and symbols, and understand the relationships

between them, and the ability to link these concepts and integrate them in his conceptual map, and thus he has acquired a correct conceptual understanding of solving quadratic equations. Accordingly, after studying the educational literature and previous studies that addressed the topic of acquiring mathematical concepts and surveying the opinions of mathematics teachers and supervisors in the educational field, the idea of this study came to exploit these efforts and place them in a specific and clear framework. It was suggested to teach using the Mathway software to acquire the concepts of quadratic equations and the concept of the mathematical self among tenth-grade female students.

The spread of technology, information technology, and modern computerized educational software created effective roles in the educational process. Based on our analysis of the document evaluating mathematics curricula adopted by the Ministry of Education in Jordan, and with the keenness of educational experts to raise and train students to use and employ computerized educational software in the educational process, and via the knowledge of researchers in the educational field as mathematics teachers and supervisors of mathematics student teachers - pre-service - and as a result of repeated meetings with mathematics teachers, researchers noticed that there is a gap in the use of educational means and computer software in teaching and learning mathematics in general, and in the subject of algebra and equations in particular, in addition to what students feel of boredom while studying the subject of algebra and equations and low achievement and anxiety about mathematics and negative attitudes towards it and lack of motivation towards learning.

Although those in charge of the educational process emphasize the importance of students acquiring basic mathematical concepts at various educational levels, there is still a general weakness in acquiring mathematical concepts, in addition to the fact that the method of building current mathematics curricula is not consistent with the modern view of teaching mathematics that relies on technology and computerized educational software. Moreover, studying the notion of self in general and the concept of the mathematical self, in particular, have received great attention from researchers and specialists. Several studies have been carried out on the relationship between the concept of the mathematical self and some variables. In addition, interest in studying the concept of the mathematical self has increased recently to include multiple aspects of the factors affecting it. From this standpoint, this study highlights the importance of employing computerized educational software, such as the Mathway software, in teaching mathematics and demonstrating its impact on acquiring the concepts of quadratic equations and the concept of mathematical self among tenth-grade students. Based on what has been established, this study answers the following two questions:

1) What is the impact of teaching using Mathway software on acquiring the concepts of quadratic equations among tenth-grade female students?
2) What is the impact of teaching using Mathway software on the mathematical self-concept of tenth-grade female students?

The theoretical significance of this study lies in the importance of the subject itself and in its response to contemporary educational trends that call for the necessity of using artificial intelligence applications, technology, and computer software in the educational process, and enhancing the use of Mathway software in teaching by teachers due to its advantages that help improve the quality of the educational process. The applied position of the study lies in the practical benefit it provides to all parties involved in the educational process. This research may urge mathematics teachers to use Mathway software in solving mathematical problems and encourage students to use it to verify the correctness of their solutions. This study may also provide a procedural model for how to use Mathway software and employ it in teaching quadratic equations. This study may also be useful in directing researchers to study the impact of using Mathway software on other variables, such as mathematical achievement, motivation towards learning, attitudes towards mathematics, and others.

Most studies in any field of educational sciences seek to achieve a set of objectives, and specifically, this study seeks to explore the impact of teaching using the Mathway software on acquiring the concepts of quadratic equations among tenth-grade female students. The study also aims to explore the effect of teaching using the Mathway software on the mathematical self-concept among tenth-grade female students.

Mathway was selected over other AI tools, such as, Photomath and Wolfram Alpha because it aligns closely with the pedagogical aims of the study. It provides organized, step-by-step solutions with clear explanations, making it effective for strengthening conceptual and procedural understanding in quadratic equations. The tool is also easy to use, available in Arabic and English, and accessible across various devices, which supports its integration into classroom activities. Moreover, Mathway accommodates all major methods of solving quadratic equations, directly serving the content of the targeted instructional unit. Its features immediate feedback, error detection, and comparison between student and system steps create a low-anxiety learning environment that reinforces mastery and supports self-efficacy development. These advantages made Mathway a more suitable choice than tools that offer only final answers or are less adaptable for classroom use.

## II. Literature Review

### A. Theoretical Foundation

Technology-enhanced math education often relies on constructivist and cognitivist theories, and technology can now enhance this process by offering instantaneous, individualized, and multi-representational approaches for the same mathematical objects because of AI technology [6–9]. Such a strategy is especially relevant in algebra, considering the large number of learners who experience difficulties moving from procedural understanding towards a conceptual understanding of a mathematical problem [10, 11].

From a discipline perspective, mathematics education standards explicitly position technology as an essential support for student learning. The National Council of Teachers of Mathematics (NCTM) identifies technology as a core principle that can help learners visualize mathematical ideas, organize and analyze data, and perform accurate operations efficiently, thereby enabling deeper engagement

with mathematical reasoning and problem solving [12]. This theoretical stance implies that digital tools may strengthen conceptual acquisition when they are used to explain processes, reveal relationships, and support exploration rather than to replace thinking.

In parallel, the affective dimension of learning mathematics is often explained through Bandura's self-efficacy theory, which links students' beliefs about their capabilities to their motivation, persistence, and performance [11]. Self-efficacy develops through four sources: mastery experiences, vicarious experiences, social (verbal) persuasion, and emotional or physiological states [11]. Because mathematical self-concept is closely related to these efficacy beliefs, interventions that increase successful problem solving, provide supportive feedback, and reduce anxiety are expected to strengthen students' mathematical self-perceptions.

Accordingly, the present study conceptualizes Mathway as an AI-based scaffolding environment that may support (a) conceptual acquisition of quadratic equations through structured, step-by-step explanations and error diagnosis, and (b) mathematical self-concept by strengthening efficacy sources during learning. Building on this foundation, the next section reviews generalized empirical evidence on technology-supported mathematics learning.

### B. General Empirical Evidence on Technology-Supported Mathematics Learning

A substantial body of research indicates that technology-supported instruction can enhance mathematics achievement, mathematical thinking, and attitudes when integrated pedagogically. For example, Alharbi and Aboloum [3] reported statistically significant gains in mathematical thinking skills for students taught geometry using computerized instructional software compared with traditional instruction. Hussein [6] likewise found that structured training improved mathematics teachers' competence and attitudes toward interactive mathematics software, which is important because teacher readiness often determines the quality of classroom technology integration.

Studies across diverse contexts also suggest positive academic effects of educational software. In Jordan, Muflehe [7] found statistically significant differences in ninth-grade students' achievement favoring computerized educational software over traditional methods. Fadlee [8] reported higher post-test achievement for students learning with Adobe Flash-based instruction, accompanied by generally positive attitudes toward mathematics. Large-scale classroom practice studies further show that students frequently use computer algebra systems and similar tools for checking solutions and tackling difficult problems, while teachers use them more selectively depending on grade level and topic [9].

In sum, the generalized evidence provides two conclusions that are core to this study. Firstly, technology has been found to positively impact learning outcomes in mathematics subjects and the degree of impact depends entirely on how the instructional process has been carried out. Secondly, for maximum productivity of the learning tools in the classroom, the tools should be used for explanation and verification of solutions rather than for coming up with solutions. These conclusions motivate closer attention to AI-based tools that provide intelligent, stepwise feedback in algebra.

### C. Focused Specialization: AI-Based Problem Solvers and Mathway in Mathematics Education

In general, in the larger field of education technology, mathematics problem solvers using Artificial Intelligence have caught attention as effective and easily available learning tutors. However, unlike the substantial amount of research in education technology and mobile learning, relatively fewer studies are focused entirely on Mathway within school mathematics environments.

Available evidence nevertheless suggests that Mathway can influence achievement-related outcomes when used in structured instructional settings. Alqashanin and Faqihi [10] reported that secondary school students who learned with Mathway outperformed peers who received traditional instruction. In Oman, Al-Blushi [2] found that Mathway-based teaching improved students' acquisition of equation and function concepts and enhanced mathematical self-concept compared with conventional instruction. These studies indicate promise, but they also highlight the need to examine Mathway in other educational contexts, grade levels, and mathematical topics, with attention to how the tool is integrated into teaching.

Importantly, Mathway's educational value appears to depend on implementation. When students rely on AI solvers only to obtain final answers, the tool may reduce productive struggle and limit conceptual growth. In contrast, when the solver is used for verification, error analysis, and exploration of alternative methods, it can support conceptual clarity and metacognitive monitoring. This focused specialization therefore leads to an in-depth analysis of the two focal variables in the present study: acquiring the concepts of quadratic equations and mathematical self-concept.

### D. Acquiring the Concepts of Quadratic Equations

Quadratics are a basic algebra topic that requires that students integrate different modes of thought, including symbolic, graphic, and model-based, to understand the connections among different solutions, including factoring, completing the square, or the quadratic formula, among others. Proficiency in this area requires more than the ability to solve problems: it means recognizing crucial attributes, choosing strategies, understanding the meaning of roots, as well as recognizing connections among algebraic solutions, graphic solutions, and models.

Technology is frequently argued to support this type of conceptual acquisition by making procedures transparent, enabling repeated practice with feedback, and helping learners compare multiple methods and representations. In the context of Mathway, the step-by-step solution display can serve as a cognitive scaffold: students can compare their own reasoning with the software's reasoning, identify misconceptions at specific steps, and refine their conceptual map of how and why solution methods work. Such structured feedback is particularly relevant for quadratic equations, where students may know a method but struggle to justify it or to decide when it is appropriate.

### E. Mathematical Self-Concept

Mathematical self-concept refers to students' perceptions

of their competence, interest, and confidence in mathematics and is associated with motivation, persistence, and achievement. Definitions in the literature emphasize students' self-evaluations of their mathematical abilities and their feelings toward learning and performing mathematical tasks [13]. Because self-concept is shaped by repeated experiences of success or difficulty, classroom feedback, and emotions such as anxiety, interventions that improve learning experiences and perceived competence are expected to strengthen students' mathematical self-concept.

Bandura's self-efficacy framework provides a mechanism-based explanation for how an AI-supported learning environment may strengthen mathematical self-concept [11]. Mathway can impact mastery experiences in terms of successfully completing questions in guided steps, vicarious experiences in terms of allowing students to see solutions and other methods, social persuasion in terms of immediate feedback, and reducing VAE in terms of providing a non-threatening environment in which to check solutions and correct errors [14]. All of these provide a theory of how the intervention (teaching through Mathway) affects the affective outcome (mathematical self-concept).

With these variable-specific links established, the literature can be synthesized to identify the most pressing research gaps that the current study addresses.

### F. Research Gaps and Justification for the Current Study

Although technology-supported mathematics instruction has been widely studied, several gaps remain in relation to AI-based solvers and the specific outcomes examined in this manuscript. First, the empirical base on Mathway in school settings is still limited compared with the broader literature on educational software, and only a small number of studies have examined Mathway's effects using controlled or quasi-experimental comparisons [2, 15]. Second, existing Mathway studies have tended to focus on general achievement or on topics other than quadratic equations, leaving uncertainty about its effectiveness for strengthening students' conceptual understanding of quadratic equations and their ability to connect multiple solution methods within this unit.

Third, while mathematical self-concept has been studied extensively, fewer studies have examined how AI-based tools influence self-concept alongside conceptual outcomes within the same intervention, despite strong theoretical reasons to expect joint effects through feedback, mastery experiences, and reduced anxiety [11]. Fourth, within the Jordanian context, prior work indicates ongoing challenges in integrating computerized educational software into mathematics instruction and in addressing students' negative perceptions and low motivation toward algebraic topics [7]. This context-specific need further supports investigating an AI-based approach that is feasible for classroom integration.

Therefore, this study is designed to fill these gaps by evaluating, within a quasi-experimental framework, the effect of teaching with the AI-based Mathway software on two linked outcomes among tenth-grade female students: (1) acquiring the concepts of quadratic equations and (2) mathematical self-concept. By progressing from theoretical foundation to generalized empirical evidence, then to Mathway-specific evidence, and finally to variable-level mechanisms, the review clarifies the gaps that this research needs to fill and directly motivates the study questions and hypotheses.

## III. Methodology

### A. Study Design

This investigation adopted the quasi-experimental approach with two groups, where the study sample was divided into two groups: the first was an experimental group that was taught using the Mathway software, and the second was a control group that was taught according to the traditional method.

### B. Participants

The study population consisted of all tenth-grade female students who were enrolled in the first semester of 2023/2024 in all schools in the second Irbid district in Jordan. The study sample consisted of 63 tenth-grade female students in one of the government schools that had the necessary capabilities. The school administration and the teaching staff cooperated with the researchers to conduct the study. Two groups were chosen intentionally, with the first representing an experimental group of 31 students who were trained and taught using the Mathway software, and the second representing a control group of 32 students who were taught using the traditional method. Table 1 represents the distribution of the study sample.

Table 1. Distribution of study sample

| Group | No | % |
|---|---|---|
| Experimental Group | 31 | 49.2% |
| Control Group | 32 | 51.8% |
| **Total** | **63** | **100%** |

### C. Instruments

#### 1) Concepts of quadratic equations test

After reviewing the theoretical and research literature and studies that dealt with teaching using computer software [16–22], a Concepts of Quadratic Equations Test was prepared, which aims to measure the mathematical knowledge and skills acquired by female students in the subject of solving quadratic equations through the (Solving the Quadratic Equation Unit). The test consisted of 25 multiple-choice items, with 4 points allocated to each item, so the final score for the test ranged between 0 and 100. The Solving the Quadratic Equation Unit was also analyzed to determine the mathematical concepts contained therein, and a specifications table was prepared for the Solving the Quadratic Equation Unit to determine the relative weight of the topics included in the unit and to determine the number of questions in Each cognitive level according to the TIMSS cognitive levels (Knowledge, Application, Inference). Table 2 represents the findings.

Table 2. Test specifications table

| Knowledge Level | Percentages Wight | Number of Questions | Degree |
|---|---|---|---|
| Knowledge | 35% | 9 | 36 |
| Applied | 40% | 10 | 40 |
| Inference | 25% | 6 | 24 |
| **Total** | **100%** | **25** | **100** |

The exam was administered to a panel of math educators

and supervisors, as well as an arbitrator panel consisting of university academics, to ensure its validity. They were asked to provide their consultations in terms of the clarity of the questions and test instructions, the validity of the study content, the extent to which the questions were appropriate to the study objectives, their comprehensiveness, and their inclusion of the mathematical concepts included in the unit (Solving the Quadratic Equation). Based on the sentiments and recommendations of the arbitrators, the necessary modifications were made to the Quadratic Equations Concepts Test until it reached its final form.

To verify the test's reliability, it was applied to a survey sample of 26 female students from outside the study sample, and the stability coefficient was calculated using Cronbach's alpha equation. The stability coefficient reached 0.862, which is an acceptable value to conduct this study.

*2) Mathematical self-concept scale*

After revising the theoretical and research literature and studies that dealt with mathematical self-concept scales [23–28]; a mathematical self-concept scale was prepared, which aims to know the extent of change in female students' perception of themselves and enhance their self-confidence when studying the topic of solving the quadratic equation through situations that express the mathematical self-concept of female students. The scale consisted of 20 item according to the five-point Likert scale, which was formulated in two directions, positive and negative, and five gradations were set for each paragraph (strongly agree, agree, neutral, disagree, strongly disagree), and for each gradation, the measurements were given (5, 4, 3, 2, 1) in order, thus the minimum value of the scale reached 20 and the maximum value of the scale as a whole 100.

To verify the validity of the scale, it was presented to a group of arbitrators to obtain their comments in terms of the extent to which the scale paragraphs achieved the study purposes, the soundness of the linguistic formulation, clarity, accuracy, and comprehensiveness. The necessary amendments were made in light of the arbitrators' opinions, as some paragraphs were deleted and some were reformulated to produce the scale in its final form. To verify the stability of the tool, it was applied twice to the survey sample with a time difference of two weeks between the two applications. The stability coefficient values were calculated using Cronbach's alpha equation, which reached 0.924. This value confirms that the test has stability indications that allow it to be used to conduct this study.

The independent sample t-test was applied to measure the equivalence of the two groups. The test was based on measuring the groups' knowledge on the Concepts of Quadratic Equations Test and the Mathematical Self-Concept Scale. The results are presented in Table 3.

Table 3. The *t*-test for the equivalence

| Instrument | Group | *N* | df | Mean | SD | *t*-value | *p*-value |
|---|---|---|---|---|---|---|---|
| Concepts of Quadratic Equations Pre-Test | Experimental | 31 | 61 | 5.68 | 2.85 | –0.27 | 0.786 |
| | Control | 32 | 61 | 5.49 | 2.82 | | |
| Mathematical self-concept scale Pre-Test | Experimental | 31 | 61 | 13.84 | 71.05 | –0.06 | 0.956 |
| | Control | 32 | 61 | 13.76 | 70.86 | | |

Significance Level ($\alpha = 0.05$)

Table 3 above reveals the equivalence of the control and experimental groups before initiating the study, which created a baseline for the analysis after the implementation of the instruments to show the post-differences.

*3) The educational material*

The educational material was prepared through a set of strategies, methods and activities that aim to enable students to acquire the concepts of quadratic equations and the concept of the mathematical self, in addition to a set of classroom lessons, a detailed description and explanation supported by classroom activities, exercises and homework that were prepared using the Mathway software. The educational material was also selected through the (Solving the Quadratic Equation Unit), which consists of eight lessons: (Solving the Quadratic Equation by the Analysis Method in the Form of the Product of Two Factors, Solving the Quadratic Equation by the Common Factor Method, Solving the Quadratic Equation by the Difference of Two Squares Method, Solving the Quadratic Equation by the Completing the Square Method, Solving the Quadratic Equation by the General Law Method, Solving Two Quadratic Equations: Graphically, by Elimination, by Substitution). The teaching of the educational material took six weeks, with 24 class periods, each lasting 45 min. The researchers also prepared a user guide for using the Mathway software, which explains to the teacher an overview of the software, how to use it, an explanation of its main elements, and a simplified explanation of some of its features and tools that the teacher needs when using it. A teacher guide was also prepared to guide the teacher in teaching the (Solving the Quadratic Equation Unit) using the Mathway software, which explains the proposed time plan for teaching, preparing lessons, the lesson plan, and evaluation.

The educational material was reviewed by a group of arbitrators with backgrounds in mathematics education and teaching methodologies to ensure its validity and to assess if it was appropriate for the study's aims. They were requested to provide their thoughts and recommendations on the educational validity of the goals and the mathematical abilities covered in the course materials. The committee's views informed the subsequent revisions and recommendations.

*4) Integrating Mathway into instruction*

The researchers designed instructions that are student-centered and based on the integration of the Mathway software into the material. The duration of the experiment extended for six weeks, and the following procedures were used for each lesson:

- Teacher-Led Introduction: The teacher presents a new solution method to the students in a conventional manner.
- Exploratory Practice: the students attempt to solve the problem manually and try to utilize the Mathway to review the solution the software provides step-by-step, while understanding the rationale behind each step.
- Verification & Error Analysis: The students benefit from the software's solution to double-check their work. If the students' answers are different from those of the software, they compare each step they did with Mathway's to identify and understand their mistakes.

- Teacher's Role: The role of the teacher in this instruction is focused on facilitating and guiding the process rather than mere lecturing.
- Students' Role: The students play an interactive role of investigating and exploring using the Mathway rather than merely extracting answers.

*5) Teacher training in using Mathway*

The subject teacher had undergone the required structured training as prepared by the researchers so as to ensure effective and uniform integration of Mathway into the instructional plan before the actual experiment. The training included three major components:

- Technical Training: The teacher was taught to navigate independently within the application environment-entering problems, reading solutions via step-by-step analysis, and scanning problems using the scanning feature of the application. Important tools for quadratics and classroom management strategies for controlling students' usage of the application in the learning environment were also discussed.
- Pedagogical Integration: Mathway was to be fitted into the lesson sequence from introduction, through direct instruction to guided practice and solution verification. The training also paid attention to formative assessment using Mathway and for emphasizing a shift from a solution generator to an explanation, conceptual understanding, and error analysis tool.
- Training on Timeline and Classroom Activities: The teacher was trained on the proposed six-week (24-session) instructional timeline and on designing class activities and homework assignments in line with Mathway's step-by-step procedures. The training equally addressed strategies for individual and group work and for leading classroom discussions after comparing the solutions of students with those generated by Mathway.

Through this comprehensive training, the teacher was now able to use Mathway in a structured way pedagogically, keeping it as a tutor supporting the learning process rather than as a mere digital answer provider.

### D. Statistical Analysis

To answer the study questions, the data were entered into the computer and analyzed using the SPSS program, where the mean scores and standard deviations of the students' scores on the Quadratic Equations Concepts Test and the Mathematical Self-Concept Scale were extracted. The Analysis of Covariance (ANCOVA) was also used, and the effect size was calculated using Eta square ($\eta^2$) for the two study tools.

## IV. Result and Discussion

The first study question aimed to reveal the effect of teaching using the Mathway software on acquiring the concepts of quadratic equations among tenth-grade female students. To answer this question, the mean scores and standard deviations of the students' scores on the quadratic equations' concepts test were extracted in the pre-and post-applications. Table 4 shows the results.

Table 4. Means and SDs for concepts of quadratic equations test

| Group | No | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| Experimental | 31 | 5.68 | 2.85 | 14.62 | 1.88 |
| Control | 32 | 5.49 | 2.82 | 7.95 | 2.68 |

Table 4 shows an improvement in the performance of the study sample in the post-application of the quadratic equation concepts test for the two study groups. It was clear that there are apparent differences in the arithmetic means and standard deviations of the performance of the study sample individuals in the post-application of the quadratic equation concepts test, as the arithmetic mean of the test for the experimental group reached 14.62, while the arithmetic mean for the control group reached 7.95, while the standard deviation for the experimental group reached 1.88 and for the control group 2.68.

To ascertain if these observed differences were statistically significant, a one-way Analysis of Covariance (ANCOVA) was employed, and the effect size was computed to evaluate the concepts of quadratic equations in the post-application between the two study groups (experimental and control) after controlling for the influence of the pre-measurement (the covariate). The results are presented in Table 5.

Table 5. ANCOVA analysis and effect size for the concepts of quadratic equations test

| Source of Variance | Sum of Squares | df | Mean of Squares | $F$ | Sig. | $\eta^2$ | Effect Size |
|---|---|---|---|---|---|---|---|
| ANCOVA | 752.65 | 1 | 752.65 | 105.41 | 0.00 | 0.375 | Large |
| Teaching Method | 352.69 | 1 | 352.69 | 49.39 | 0.00 | 0.478 | Large |
| Error | 428.63 | 60 | 7.14 | - | - | - | - |
| Corrected Error | 562.17 | 62 | - | - | - | - | - |

Significance Level ($\alpha = 0.05$)

Table 5 shows that there are statistically significant differences at the significance level ($\alpha = 0.05$) between the mean scores of the two study groups in the quadratic equation's concepts test attributed to the effect of the teaching method (teaching using the Mathway software versus the traditional method). All differences were in favor of the experimental group that was taught using the Mathway software. The impact of utilizing Mathway software on the comprehension of quadratic equations among tenth-grade female students was assessed, yielding an effect size of 0.478 as determined by eta squared ($\eta^2$). The utilization of the Mathway program accounts for 47.8% of the variance in enhancing the performance of the research sample (The quasi-experimental design and controlled nature of extraneous variables such as teacher influence on students, motivation of learners, and previous experience with technology affect the variance: much of it is contextual rather than just an effect of the software. Effect size therefore is an estimate given these constraints of the study, rather than an absolutely causal effect of Mathway), whilst the remaining 52.2% of the variance remains unexplained, maybe attributable to external influences or other variables.

The second study question aimed to reveal the effect of teaching using the Mathway software on the mathematical self-concept of tenth-grade female students. To answer this question, the mean scores and standard deviations of the students' scores on the mathematical self-concept scale were

extracted in the pre- and post-applications. Table 6 shows the results.

Table 6. Means and SDs for the mathematical self-concept scale

| Group | No | Pre-test | | Post-test | |
|---|---|---|---|---|---|
| | | Mean | SD | Mean | SD |
| Experimental | 31 | 71.05 | 13.84 | 80.42 | 9.93 |
| Control | 32 | 70.86 | 13.76 | 73.52 | 12.66 |

Table 6 shows an improvement in the performance of the study sample in the post-application of the mathematical self-scale for the two study groups, as it is clear that there are apparent differences in the arithmetic means and standard deviations of the performance of the study sample members in the post-application of the mathematical self-scale. The arithmetic mean of the scale for the experimental group was 80.42, while the arithmetic mean for the control group was 73.52. The standard deviation for the experimental group was 9.93 and for the control group 12.66.

To determine if the observed differences were statistically significant, a one-way Analysis of Covariance (ANCOVA) was employed, and the effect size of the mathematical self-scale was computed post-application between the experimental and control groups, after controlling for the pre-measurement (the covariate). The results are presented in Table 7.

Table 7. ANCOVA analysis and effect size for the mathematical self-concept scale

| Source of Variance | Sum of Squares | df | Mean of Squares | F | Sig. | $\eta^2$ | Effect Size |
|---|---|---|---|---|---|---|---|
| ANCOVA | 1313.75 | 1 | 1313.75 | 44.97 | 0.00 | 0.393 | Large |
| Teaching Method | 865.33 | 1 | 865.33 | 29.62 | 0.00 | 0.418 | Large |
| Error | 1752.65 | 60 | 29.21 | - | - | - | - |
| Corrected Error | 8095.62 | 62 | - | - | - | - | - |

Significance Level ($\alpha = 0.05$)

Table 7 shows that there are statistically significant differences at the significance level ($\alpha = 0.05$) between the mean scores of the two study groups in the mathematical self-concept scale attributed to the effect of the teaching method (teaching using the Mathway software versus the traditional method). All differences were in favor of the experimental group that was taught using the Mathway software. To reveal the effect of teaching using the Mathway software on the mathematical self-concept of the study sample members, the effect size was found using Eta square ($\eta^2$), which was found to be equal to 0.418. This indicates that the use of the Mathway software explains about 41.8% of the variance in improving the mathematical self-concept of female students, while the remaining variance (58.2%) is unexplained and may be due to external influences or other factors.

The results of the study show that most of the experimental group members obtained high scores on the quadratic equation concepts test, with a mean score of 14.62 in the post-application test, which indicates the presence of significant progress in the performance of the study sample members. Perhaps the reason behind this is due to the smart capabilities provided by the Mathway software that improved the process of teaching and learning mathematics in general and acquiring the concepts of quadratic equations in particular, and as a result of the ease of using the Mathway software by female students in solving quadratic equations, in addition to the nature of the Mathway software, which was designed according to organized scientific steps that aim to develop mathematical concepts and activate the role of students and allow them to practice various learning activities. Given the nature of the activities and exercises provided to female students using the Mathway software, the software stimulated motivation to learn and gave sufficient space for all female students to participate in these activities, which led to better acquisition of quadratic equation concepts among female students.

The repeated practice in solving exercises using the Mathway software contributed to the acquisition of experience and skills that enabled students to apply them in other similar situations and link them, rebuild and develop them, and that correcting errors and overcome difficulties in a comfortable atmosphere and without embarrassment or fear led to the availability of the elements of interest and self-motivation for learning. This practice enhanced the positive impact of using the Mathway software, which made students feel comfortable and reassured when they were exposed to solving quadratic equations that were diverse in their ideas and different in their patterns. These results are consistent with the results of many previous studies [29], which confirmed that the use of teaching methods and strategies based on modern technological means, computerized techniques, and software enhances the acquisition of mathematical concepts, achievement, and motivation towards learning mathematics.

In addition, Mathway software enabled students to work in groups to accomplish many tasks, such as finding solutions to quadratic equations in different ways, such as the factorization method in the form of a product of two factors, the common factor method, the difference between two squares, completing the square, or the general law, which helped students to deduce the relationship between them through trial and error, and choose the best method to solve the quadratic equation, which led to a deep understanding of the concepts of quadratic equations and retaining these concepts for a longer period. This confirms what many previous studies have indicated [9, 12, 24].

It is clear from the results related to the second question that most of the members of the experimental group obtained high scores on the mathematical self-concept scale, as the arithmetic mean of their scores in the post-application reached (80.42), which indicates the students' mastery of the concepts of quadratic equations and the acquisition of skill in methods of solving them and the various elements of knowledge. Since there is a mutual need to acquire mathematical concepts and self-realization, this contributes to developing their academic achievement and making them feel successful, proud, and self-esteem, high social status, and raising their level of ambition and their sense of high efficiency, which leads to improving the student's view of herself and her understanding of herself. Several studies indicated that the students who achieve the most and acquire mathematical concepts are the students with an advanced and positive level in achieving the mathematical self-concept, and this indicates the great impact of the software Mathway in enhancing the mathematical self-concept of the study sample individuals [30–34].

Analyzing the mechanisms Mathway uses to strengthen students' mathematical self-concept deepens our analysis of the results. Bandura [11] argued that self-efficacy is formed by the primary sources of mastery experiences, vicarious experiences, social persuasion, and physiological and emotional states. Using Mathway promotes the mastery experiences when student solve equations, get immediate feedback, and observe their own progress, which strengthens their mathematical capacities. Students are exposed to solved examples and alternative options to different equations, which strengthen their vicarious experiences. Moreover, the ability of the Mathway software to mimic teachers in providing feedback and reinforcing students promotes the social persuasion skills indirectly. This process, eventually, enhances the students' ability to reduce their anxiety in solving mathematical problems and creates an interactive environment. The integration of all these mechanisms provides a window for Mathway to promote students' achievement and strengthen their self-belief.

Given the abstract nature of mathematics, working in an environment that encourages independence and is full of challenge and curiosity enhances students' self-confidence and makes them more confident in their knowledge, skills, and previous experiences. This makes using ready-made software such as Mathway a pleasure for self-realization, overcoming challenges, and feeling self-confident. These results are consistent with the results of some previous studies [14, 19, 26].

The superiority of the experimental group students over the control group students in the mathematical self-concept scale can also be attributed to the Mathway software's reliance on the use of mathematical symbols and equations in different formats that require conversion from images to mathematical symbols and equations. The ease of use and dealing with its vocabulary and providing clear explanations for each step of the solution, in addition to sequential and extra explanatory answers that are beloved by the students deepened their image of the concept and contributed to organizing and consolidating the concepts of quadratic equations and delving into them, which enabled them to practice expressing the concept in their language and reaching the characteristics and features of the concept and analyzing them. Moreover, working in an atmosphere of activity and motivation towards using the Mathway software and listening to the teacher's directions and instructions enabled them to achieve self-confidence and eliminate feelings of anxiety and a sense of success and overcome challenges. All of these reasons may have led to strengthening the mathematical self-concept, and this is consistent with what some previous studies have indicated [8–10, 35–37].

Apart from the improvements in the statistical sense, the enhancement in mathematical self-concept can be described via many mechanisms beyond simple feedback. This software provided the student with numerous mastery experiences, where he or she was able to successfully solve quadratic equations through clear guided steps. Success after success has bolstered their self-perception of competence, which is a key element in self-concept. In addition, the program helped alleviate cognitive load by presenting solution methods in an organized and coherent format, thus promoting student understanding of how the different methods were related. The program also helped develop metacognitive skills, as students would compare their solution with the stepwise output of the software, thus encouraging self-monitoring and error analysis. In addition, the low-anxiety environment established by the software facilitated emotional regulation and a sense of autonomy. Thus, these factors explain why Mathway improved students' mathematical self-concept past the immediate effect of having received feedback.

Although this study witnessed clearly positive findings for the use of Mathway, it should be noted that other researchers have sometimes obtained contradictory results in assessing the efficacy of technology in math instruction. While some studies found minimal gains when students relied too much on automated solutions or teacher guidance was low, it remains possible that the improvements alleged in this study were dependent on other variables such as novelty in using AI tools, enhanced motivation, or the teachers' active support during implementation. More importantly, such considerations present a more balanced interpretation of the results and connect them to the overall literature.

## V. Conclusion

The effects of teaching quadratic equations with the AI-based Mathway Software on tenth-grade female students' achievement of mathematical concepts and their mathematical self-concept were studied here. It was found that teaching quadratic equations with Mathway significantly improved students' learning of quadratic equations, as shown by significant differences in post-test scores of experimental and control groups. Stepwise guidance, instant feedback, and a structured environment for solving problems within the software helped achieve conceptual clarity, along with reinforcing procedural fluency by enabling students to identify and rectify misconceptions with assurance.

Another notable finding was an increase in students' mathematical self-concept. AI-based learning experiences promoted students' confidence, reduced anxiety, and helped them realize the sense of mastery. These findings are in accordance with Bandura, who laid stress on mastery experiences, vicarious learning, performance feedback, and emotional regulation, all of which can enhance positive self-beliefs. Placing Mathway as an app to generate a friendly, interactive, and low-anxiety learning environment built students' self-confidence and motivation in mathematics.

The study recommends employing teaching methods and strategies based on modern technological means, computerized techniques, and software, such as using Mathway software to enhance the acquisition of various mathematical concepts and develop the concept of the mathematical self, and working to provide a special integrated laboratory for mathematics by providing modern computers and tablets to facilitate the implementation of classes and lessons for students and teachers. The study also recommends conducting professional development courses to help teachers understand the usage and benefits of the Mathway software. Such training programs should focus on the pedagogical features of AI tools. The study also recommends using modern technological means, computerized techniques, and software such as Mathway

software and benefiting from its multiple capabilities and advantages in teaching algebra in general and employing it in teaching quadratic equations and solving them in particular. It is also recommended to conduct periodic development of curricula to keep pace with modern technological means, computerized techniques, and software, while emphasizing the need to include the use of computerized software in the educational process. It is also important to conduct more studies and research that address the impact of teaching using technological means and computerized software, such as Mathway software, on various mathematical subjects, and on other variables such as motivation towards learning mathematics, academic mathematical enthusiasm, mathematical sense, and other variables.

Future research into this topic can tackle different related aspects. The sample demographics for the studies could be expanded to cover larger samples of students from both genders. Future studies can explore other mathematical topics and investigate the uses of AI tools in teaching different mathematical topics. Other variables can also be explored to uncover the impact of using such software in terms of promoting knowledge retention, students' motivation, and critical thinking skills. Moreover, future studies can compare the different available AI-powered software in teaching mathematics, such as Mathway, Photomath, and Wolfram Alpha.

This study focused on the unit "Solving the Quadratic Equation" in the student book for the tenth grade. The application of this study was limited to female students of one of the public schools in the second Irbid region, which has the necessary capabilities and the cooperation of the school administration and the teaching staff with the researchers. The application of this study was limited during the first semester of 2023/2024 through a test on the concepts of quadratic equations and a scale in the concept of the mathematical self, which was developed to accomplish the aims of the study. The sample size of the study was limited to female students only on one public school. Therefore, the researchers acknowledge the limitations of the results and their representation for the whole population of the study. The study also focused on one unit from the tenth-grade mathematics curriculum, which limited the results of the study and their generalization.

## APPENDIX: THE INSTRUMENTS OF THE STUDY

### A. *Concepts of Quadratic Equations Test*

#### 1) *Knowledge level*

1. Which of the following is a quadratic equation?
   a) $x + 2 = 0$ b) $x^2 + 3x + 2 = 0$
   c) $3x = 6$ d) $x^3 + 2x = 0$
2. The standard form of a quadratic equation is:
   a) $ax + b = 0$ b) $ax^2 + bx + c = 0$
   c) $ax^3 + bx + c = 0$ d) $a/x + b = 0$
3. The discriminant ($\Delta$) of a quadratic $ax^2 + bx + c = 0$ is:
   a) $b^2 - 4ac$ b) $2a + b$
   c) $b^2 + 4ac$ d) $a^2 - 4b$
4. The quadratic formula is used to find:
   a) Roots of linear equations
   b) Roots of quadratic equations
   c) Factors of polynomials
   d) Graph intercepts
5. If a quadratic equation has $\Delta = 0$, it has:
   a) Two real roots b) One real repeated root
   c) No real roots d) Complex roots
6. The vertex form of a quadratic equation is:
   a) $y = ax^2 + bx + c$ b) $y = a(x + h)^2 + k$
   c) $y = (x - a)(x - b)$ d) $y = a/x^2 + b$
7. Which method can be used to solve all quadratic equations?
   a) Factorization b) Completing the square
   c) General formula d) Substitution
8. When a quadratic equation is factorable, it can be solved by:
   a) Using the quadratic formula
   b) Factoring into two binomials
   c) Dividing by x
   d) Multiplying both sides by zero
9. The graph of a quadratic equation is always a:
   a) Line b) Parabola
   c) Circle d) Hyperbola

#### 2) *Application level*

10. The roots of the equation $x^2 + 5x + 6 = 0$ are:
    a) 2, 3 b) 2, −3 c) −2, −3 d) −2, 3
11. The roots of the equation $x^2 - 9 = 0$ by the difference of two squares method are:
    a) −3, 3 b) 9, −9 c) −9, −3 d) −9, 3
12. The roots of the equation $x^2 + 4x + 3 = 0$ using factorization are:
    a) 1, 3 b) −1, −3 c) –1, 3 d) −1, 2
13. If the roots of the equation $ax^2 + bx + c = 0$ are 2 and 3, then the equation is given by:
    a) $x^2 + 5x + 6 = 0$ b) $x^2 - 5x + 5 = 0$
    c) $x^2 + 6x + 5 = 0$ d) $x^2 - 5x + 6 = 0$
14. The roots of the equation $2x^2 + 3x - 2 = 0$ using the quadratic formula are:
    a) 1/2, −2 b) −1/2, −3 c) −1/2, 2 d) −1/2, −2
15. The axis of symmetry for $y = x^2 + 6x + 5$ is:
    a) $x = -3$ b) $x = 3$ c) $x = -2$ d) $x = -1$
16. The vertex of $y = x^2 - 4x + 3$ is:
    a) (2, −1) b) (−1, −2)
    c) (−2, −1) d) (−1, −1/2)
17. A ball is thrown upwards. Its height after t seconds is $h = -5t^2 + 20t + 1$. Then the time when it reaches maximum height is:
    a) 3 b) 4 c) 1 d) 2
18. The intercepts the quadratic equation $y = x^2 - 2x - 3$ are:
    a) x-intercepts −1, 3 and y-intercept −3
    b) x-intercepts −1, −3 and y-intercept −3
    c) x-intercepts −1, −3 and y-intercept 3
    d) x-intercepts 1, 3 and y-intercept −3
19. The real roots of the equation $x^2 + 2x + 5 = 0$ are:
    a) 0 b) 1 c) 2 d) No roots in R

#### 3) *Inference level*

20. Which one is the graph of $y = -x^2 + 4$:
    a) Parabola opening downward with vertex (1,4)
    b) Parabola opening downward with vertex (0,2)
    c) Parabola opening downward with vertex (-2,4)
    d) Parabola opening downward with vertex (0,4)
21. How the value of 'a' in $y = ax^2$ affects the shape of the parabola:
    a) a controls direction
    b) a controls direction and width
    c) a controls width

d) None of these

22. If the product of the roots of a quadratic equation is 3 and the sum is −4, then the equation is:
    a) $x^2 + 3x - 4 = 0$ b) $x^2 - 3x - 4 = 0$
    c) $x^2 + 4x + 3 = 0$ d) $x^2 - 3x + 4 = 0$
23. A quadratic equation has roots that differ by 2. If the sum of the roots is 10, then the equation is:
    a) $x^2 + 8x - 12 = 0$ b) $x^2 - 12x - 24 = 0$
    c) $x^2 + 24x + 48 = 0$ d) $x^2 - 10x + 24 = 0$
24. If one root of $2x^2 + kx - 3 = 0$ is 1, then the value of k is:
    a) $k = -1$ b) $k = 2$ c) $k = 1$ d) $k = 0$
25. How the discriminant (Δ) determines the nature of the roots of a quadratic equation.
    a) If Δ>0 then one distinct real roots, If Δ=0 then two real repeated root, If Δ<0 then no real roots.
    b) If Δ>0 then two distinct real roots, If Δ=0 then one real repeated root, If Δ<0 then no real roots.
    c) If Δ>0 then one distinct real roots, If Δ=0 then two real repeated root, If Δ<0 then no real roots.
    d) If Δ>0 then two distinct real roots, If Δ=0 then one real repeated root, If Δ<0 then no real roots.

### B. *Mathematical Self-Concept Scale*

The questioner of the mathematical self-concept is shown in following Table A1:

Table A1. The questioner of the mathematical self-concept

| No | Item | Strongly Agree | Agree | Neutral | Disagree | Strongly Disagree |
|---|---|---|---|---|---|---|
| 1 | I feel confident when solving mathematics problems. | | | | | |
| 2 | I enjoy learning new mathematical concepts. | | | | | |
| 3 | Mathematics is one of my favorite subjects. | | | | | |
| 4 | I find it difficult to understand mathematics lessons. | | | | | |
| 5 | I am proud of my ability in mathematics. | | | | | |
| 6 | I feel anxious when asked to solve a math problem in class. | | | | | |
| 7 | I believe I can get good grades in mathematics. | | | | | |
| 8 | I avoid mathematics whenever possible. | | | | | |
| 9 | I can solve challenging mathematics problems if I try hard enough. | | | | | |
| 10 | I learn mathematics faster than most of my classmates. | | | | | |
| 11 | I feel nervous before mathematics tests. | | | | | |
| 12 | Mathematics makes me feel confident and capable. | | | | | |
| 13 | I think I am good at mathematics. | | | | | |
| 14 | I find mathematics boring. | | | | | |
| 15 | I can understand math concepts without much help from others. | | | | | |
| 16 | I feel proud when I solve difficult math problems. | | | | | |
| 17 | I usually need help to solve mathematics problems. | | | | | |
| 18 | I enjoy discussing mathematics with others. | | | | | |
| 19 | I can apply mathematics in real-life situations. | | | | | |
| 20 | I believe I can improve in mathematics with practice. | | | | | |

## Institutional Review Board Statement

The Ethical Committee of the Deanship of Scientific Research, King Khalid University, Saudi Arabia approved this study on 20/02/2024 (Ref. No. RGP. 2/384/46).

## Transparency

The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

## Conflict of Interest

The authors declare no conflict of interest.

## Author Contributions

M.A.T. conceptualized the manuscript, designed the study, and analyzed the data. M.A.K. contributed to the methodology, particularly in applying the Mathway framework, and assisted with the validation process. N.H.S. oversaw the implementation of the model in the classroom and managed the student assessments. All authors contributed to the final manuscript, ensuring the accuracy and integrity of the research. All authors had approved the final version.

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