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Proposed Educational Program Predicated on Gamification for Teaching Mathematics as Required by TIMSS and Its Effect on Developing Strategic Competence among Fourth-grade Male Students

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Research Article

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Abstract

Background/purpose. This research aimed at designing an educational program based on gamification for teaching mathematics as required by the Trends in International Mathematics and Science Study (TIMSS) to determine its impact on advancing strategic competence among fourth-grade male students in the first semester of Academic Year 1445AH in elementary schools in Arar City. The experimental method was utilized in the current research and based on two equivalent control group designs.

Materials/methods. This research utilized the experimental approach to determine the effect of the educational program on advancing strategic competence among fourth-grade students. This approach is based on the design of two equal groups (pre-measurement, application of the experiment, post-measurement) for the experimental and control groups. The study's purposive sample was selected using a simple random method, in which 61 male students were divided into two groups: control and experimental groups, which comprised 30 and 31 students.

Results. Research findings led to the design of an electronic educational program predicated on gamification to teach mathematics based on the requirements of TIMSS for fourth-grade male students of elementary schools and the preparation of a teacher's guide for the program. Moreover, findings show statistical differences at the 0.01 level between the rank averages of students' grades in the experimental and control groups in favor of the experimental group in the strategic competence test.

Conclusion. On the bases of the results, a gamification strategy was recommended for teaching mathematics to fourth-grade male students, thereby promoting teachers' awareness of the significance of problem-solving lessons in mathematics courses and benefiting from the teacher's guide in developing the strategic competence of fourth-grade students.

1. Introduction

The education sector ranks as one of the most important fundamental sectors that communities and governments aspire to build and develop. By supporting this sector, countries and people rise, and generations are molded capable of sustaining the developments of the modern and sustainable era, providing opportunities, and addressing challenges. Consequently, renderings of the development and advancement of civilization and peoples are echoed, and its objectives are achieved. Societies, resulting in scientific development in various cultural, economic, industrial, and health fields, and so on.

The vision of the Kingdom of Saudi Arabia (2030 AD) accentuates the concern for the education system and its advancement in a manner that supports the development of the national economy, participates in varying its sources, and attains economic sustainability for Saudi society. The Ministry of Education aspires to understand the concepts, values, and provisions of the contemporary and subsequent stages; identify the actuality of education through homogeneous standard instruments predicated on the best worldwide involvement and practices; develop and advance educational attainment and progress; and enhance the outcomes and improve the competitiveness of general education in the Kingdom given the requirements of the 21st century (Ministry of Education, 2019).

International tests are regarded among the most eminent international indicators through which students' levels of educational achievement or academic progress in basic subjects, such as reading, science, and mathematics, are recognized. International tests seek to evaluate and assess various education systems culturally, economically, and socially under the leadership of institutions with extensive experience and peak and extreme efficiency in the education domain and its evaluation and assessment. The most important of these institutions are the Organization for Economic Cooperation and Development (OECD), which oversees the Program for International Student Assessment (PISA) and Teaching and Learning International Survey (TALIS), and the International Organization for the Evaluation of Educational Achievement (IEA), which supervises the Trends in International Mathematics and Science Study (TIMSS). TIMSS is an assessment of the mathematics and science knowledge of fourth- (or fifth-) and eighth- (or ninth-) grade learners in various countries. Meanwhile, the Progress in International Reading Literacy Study (PIRLS) is an international assessment monitoring trends in reading achievement.

TIMSS tests and studies are extremely important tests offering credible evaluation and accurate assessment of student academic performance in science and mathematics for fourth- and eighth-grader students. TIMSS was launched in 1964 when it was initiated in its initial form. Since 1995, the tests have been held regularly every four years, helping provide a 24-year database of trends in mathematics and education achievement.

The tests are developed by utilizing methodical procedures for mathematics and science contents in participating countries. At the end of the tests, numerous reports are released on the performance evaluations of students, and pertinent data on mathematics and science education policies are issued to reap the benefits and obtain results that will enhance and advance educational processes and boost students' performance in the future (International Association for the Evaluation of Educational Achievement [IEA], 2021).

Requirements for the TIMSS test in mathematics for fourth-grade students comprise three key areas. (1) The numbers domain encompasses arithmetic operations on numbers and fractions and represents 50% of the evaluation. (2) Measurement and mathematical engineering include topics associated with the properties of geometric shapes and angles and their operations. This area represents 30% of the evaluation. (3) Lastly, data analysis includes topics related to graphs and tables and their classification and analysis, representing 20% of the evaluation. The three test areas are measured according to three levels: knowledge (40%), application (40%), and reasoning (20%)

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(Education and Training Evaluation Commission, 2018). Strategic skill is associated with conceptual comprehension and procedural fluency. The three dimensions form a unified system that improves learners' problem-solving skills. Meanwhile, improving strategies to address new problems relies on a profound understanding of the information given and the nature of the problems; the ability to relate the notions, knowledge, and competence acquired; and fluency in resolving stereotyping problems (Al-Tuwaijri & Al-Khader, 2022).

The importance of strategic competence arises from the significance of resolving issues and problems in mathematics because it is the outcome of the educational process. Knowledge, skills, abstractions of mathematics, and all other scholarly subjects are not regarded as strict objectives, but as media and instruments helping students resolve real problems, they encounter (Al-Qarni & Al-Khabti, 2023).

Strategic competence is defined as "mastery of problem-solving strategies." That is, this competence to interpret, formulate, represent, and solve mathematical problems. Strategic competence can be developed among students through the frequent presentation of practical mathematical problems from the physical world, in which problems are interpreted, data are decided, mathematically represented, and solved. (MacGregor, 2013). Meanwhile, strategic competence derived its name from the mental ability to apply strategies to formulate, represent, and solve mathematical problems (Sabilah et al., 2018, p. 1). Strategic competence is also defined as understanding that comprises formulating and solving problems and representing them mathematically, numerically, symbolically, verbally, or graphically (Nugraheni et al., 2018, p.2)

The US National Research Council (NRC, 2001) determined that the constituents of strategic competence include understanding, probing, formulating, and structuring a problem; representing the problem mathematically, symbolically, verbally, or graphically; identifying valuable information and disregarding superfluous information; and formulating a suitable strategy to address the problem, applying methods and strategies to solve it, and verifying the validity of the corresponding solution formulated.

In general, the extent of strategic competence can be determined in three core skills, which is compatible with Sabella et al. (2018), Al-Qarni and Al-Khabti (2023), and Hilal (2021). These skills are (1) representing, (2) solving, (3) formulating and composing the mathematical problem.

Representing a mathematical problem is the competence of students to analyze problems and situations in life, represent them using mathematics, and express them using drawings, pictures, tables, simple equations, and charts. This skill comprises linking heterogeneous representations and precisely selecting the adequate representation for the mathematical problem (Al-Qarni & Al-Khabti, 2023). Representing a mathematical issue incorporates the ability to determine the mathematical principles and relationships accessible in an issue, determine variables and constants in it, and discern between critical and superfluous information (Hilal, 2021).

Solving a mathematical problem is represented by students' familiarity with the corresponding steps and procedures, therefore enabling them to utilize notions and skills they have acquired from previous experiences to find the solution. This step comes after the perception of the mathematical problem, specifically knowing the relationships between the problem's components, identifying what is required, selecting the correct plan for the solution and implementing it, arriving at the conclusion, and verifying the conclusion's validity (Al-Qarni & Al-Khabti, 2023).

Lastly, formulating and composing a mathematical problem is represented by students' capability to transform a life problem into a mathematical formula or problem, illustrate its meaning, restate it in their own words, form a meaning for the issue, analyze it to identify the data and what is required, search for missing data, and disregard superfluous information (Al-Qarni & Al-Khabti, 2023).

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Hilal (2021) explained that the skill of formulating a problem or creating a similar problem is higher than the skill of solving the problem because training students to formulate the problem comes after they have gone through reading, understanding, analyzing, and solving it.

Strategic competence among elementary school students is demonstrated through various indicators. The most important indicators are the abilities to represent issues and problems mathematically, identify important mathematical data, disregard further information, cope with data and numbers without difficulty, and solve mathematical problems in various ways. A method and the ability to link similar mathematical problems to solve them. The ability to generate multiple models of mathematical problems, the ability to formulate mathematical problems akin to a previously posed problem, the ability to formulate mathematical problems based on the given solution, and the ability to suggest other possible solutions to incorrect solutions (Al-Jundi & Khalil, 2019).

Students' strategic competence can be advanced through the frequent presentation of mathematical problems that show and mirror their real situations and exposure to mathematical problems. This situation demands that students interpret the problem, distinguish between relevant and additional information, represent the problem mathematically, be trained to handle several problems, and select strategies to solve these problems. Thus, students must have an array of strategies and a comprehension of these strategies in solving problems. An environment must be created that enables students to logically and mathematically interpret what they find. Feedback must be provided to enable students to learn how to apply acceptable strategies to a mathematical position and improve participation, discuss solutions, and confirm the validity or make corrections (Zidan, 2018).

Hilal (2021) indicated that students' strategic competence could be advanced through training in representing the problem, guiding them to read the problem carefully, determining the concepts, relationships, and variables incorporated, training in connection with various problems, selecting the correct strategies to solve the problem; and discussing solutions with others. Naming the causes for its utilization, equipping a relevant environment for resolving issues, and presenting problems of variable difficulty. Offering individual and activity groups to stimulate their thinking, improve participation, and guide them to the proper solution, and train students in linking and interpretation to find what is needed logically and mathematically, then give feedback, discuss solutions, and verify their accuracy or correct them.

Meanwhile, strategic competence among fourth-grade students could be advanced by providing a secure environment appropriate for solving mathematical problems, presenting problems of variable difficulties at various levels related to everyday life, and offering individual and group activities stimulating their thinking and motivating them to participate and interact through additional points, rewards, and leaderboards. These factors constantly boost their contributions and guide them to the right solution, as well as offer critique, discuss solutions, and verify their validity. This situation demands mathematics teachers to depend on current strategies and methods meeting these requirements, such as the gamification strategy.

Gamification is regarded as one of the new strategies utilized to stimulate students to learn, specifically by taking some gamification elements and introducing and integrating them into the education environment. This strategy represents a motivational philosophy integrating conventional game elements and game design techniques in contexts irrelevant to gaming to attain the highest amount of learning in appealing surroundings; this strategy provides purposive activities for students, improves their communication skills, stimulates them to participate and interact, and enhances their interest to continue learning (Al-Zein, 2021).

Gamification motivates students to engage in activities in the form of fractional work, participate, interact, and compete among themselves, and collaborate in developing their abilities to solve

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problems they encounter. The strength of this method lies in arranging its learning process components by individual tracks and rules. Depending on the use of points and rewards, the progression of stages and levels of challenges helps boost students' behavioral needs and increase their sense of control over educational situations, satisfy their behavioral needs with respect to the use of badges and titles, enhance their self-confidence, motivate them to interact, and reduce stress and anxiety while learning occurs (Abdel-Malak, 2022). Moreover, this method satisfies students' behavioral and psychological needs with recognition through the use of insignia and titles, raise their self-reliance, stimulate them to cooperate, and alleviate pressure and distress while learning takes place (Abdel-Malak, 2022).

Gamification offers miscellaneous benefits to education, making it one of the beneficial practical classroom. This strategy includes the following aspects: giving students full freedom to manage their learning, stimulating them for continuous self-learning, expanding the threshold of freedom to make mistakes and try again without causing negative consequences, the opportunities to enhance enjoyment and fun in the classroom and the diversity of educational tools in learning, connecting education to students' real-life experiences, offering proper and unrestricted range of tasks for children, motivating them to determine their inspiration to learn, enhancing their spirit of participation and collaboration, and attaining the most significant cognitive, emotional, and skill facets of learning (Al-Qayed, 2015, Albahiri, M.H. et al., 2024)

Al-Sayed (2017) emphasized that gamification is one of the best strategies utilized in teaching mathematics skills to children within the virtual learning environment. The benefits of this strategy lie in its appropriateness with the traits of children's development at this stage, motivating their inherent tendencies and innate development toward playing and providing them with opportunities to learn through practice and experiment without feeling pressured or anxious. Thus, this strategy contributes to boosting children's joy and gratification while learning and underscores the formation of idealistic attitudes and positive outlooks toward mathematics.

Therefore, gamification as a strategy arguably helps in stimulating learners' role and integrating them with the academic content in an environment that motivates progress in learning. This method is implemented by carrying out activities, resolving problems by earning points, enhancing rank, and students engaging in contests and challenges with one another in an atmosphere of fun and joy without feeling bored.

Gamification is compatible with the principles of behavioral theory by stimulating and motivating students toward progress in learning. By gaining points and receiving rewards in contests and challenges, resulting in boosting answers and offering critique, gamification is appropriate with the principles of constructivist theory. Gamification particularly activates students' roles and confidence in learning. The reason is that this strategy helps students connect their new experiences with previous experiences and integrating them into the cognitive structure in a way that is easy to introduce and utilize in new situations. Moreover, gamification helps students interact with their peers in groups through simulation, dialogue, and discussion.

Given that education platforms can be utilized in using gamification strategies in teaching mathematics, the Quizizz platform has been found to be among the best electronic educational environments for gamification. This platform enables teachers to conduct educational or learning assessments of students' progress in a manner that is fun and appealing to students of all ages. Moreover, quizzes enable teachers to develop their activities and tests or use many of the activities and tests they have previously prepared for various subjects and courses. Quizizz utilizes effective assessments because it enables students to participate in activities or tests in a synchronized contest format or use them for assignments within a specified time frame, during which their progress is

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measured while they are playing; feedback is immediately provided for teachers and students (Iqraa, 2023; Albahiri & Alhaj, 2020).

Evidently, gamification can positively influence advancing strategic competence among fourth-grade students, thereby motivating the researchers to design an electronic educational program predicated on gamification to teach mathematics based on the requirements of TIMSS. Moreover, this study attempts to determine the ramifications of this program on developing strategic competence among fourth-grade students.

1.1. Research Problem

The Ministry of Education in the Kingdom of Saudi Arabia gained interest in participating in international tests and studies, such as TIMSS, because they are scientific tools that are credible in evaluating and assessing education. Moreover, these tests serve as critical standards and important indicators for attaining educational quality and education standards. Accordingly, the results enable the advancement and enhancement of science and mathematics curricula and amplify professional development programs to train and qualify teachers (Ministry of Education, 2019).

Reports of performance results in early sessions revealed a decrease in fourth-grade students' skill levels in mathematics according to global performance standards. This finding indicates the need to address and raise the quality of education, given that many students lack fundamental mathematics knowledge. In most cases, their limited knowledge will prevent them from continuing their education and fully participating in a modern society where technology and a knowledge-based economy dominate. Therefore, all education stakeholders, such as schools, teachers, families, and students, must intensify their effort to improve the level of education, particularly assuring that students are substantially trained at the earliest stages (Education and Training Evaluation Commission, 2021).

Bhuth (2022) noted the relationship between TIMSS requirements and components of mathematical prowess. The elements of conceptual comprehension and procedural fluency encompass the cognitive dimension level in the test requirements. Components of procedural fluency and strategic competence include the applied dimension, and the adaptive reasoning component includes the inferential dimension of the test. He added that attention to the components of mathematical prowess and their development in Arab educational institutions will have a positive influence on enhancing students' academic performance, progress, and competition at the international level.

O'Connor (2022) revealed that the interests of research and studies are often about the two elements of conceptual comprehension and procedural fluency, and that strategic competence is connected to solving mathematical problems. However, these aspects have not received adequate attention in mathematics education research. Al-Hanafi (2019) highlighted that the poor performance of students in international tests is due to weak strategic competence. Evidently, students commit errors, especially when using symbols and terminologies and applying them correctly when solving problems. Moreover, students merely memorize the steps in solving problems without adequate understanding, thereby preventing them from formulating the correct solution when changing the given data.

1.2. Research Objectives

This research attempted to achieve the following objectives:

1. Build an electronic educational program predicated on gamification to teach mathematics based on the requirements of TIMSS and

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- 2. Identify the influence of an electronic educational program contingent upon gamification based on the requirements of TIMSS in improving the strategic competence in mathematics of fourth-grade students.

1.3. Research Questions

This research presents the following questions:

1. What is the nature of an electronic educational program predicated on gamification to teach mathematics given the requirements of TIMSS?

2. What is the effect of an electronic educational program based on gamification, given the requirements of TIMSS, in developing strategic competence in mathematics of fourth-grade students?

1.4. Significance of the Research

The scientific significance of this research is in compliance with the Kingdom of Saudi Arabia's Vision 2030, which aspires to develop the levels of students in the Kingdom in international tests and to offer a vision for writers of educational books or authors of instructional materials on the effect of gamification in advancing strategic competence in mathematics among fourth-grade students in the Kingdom. This research can also elucidate the relationship between the strategic competency component and the requirements of TIMSS in mathematics. Moreover, the current study paves the way for researchers to conduct studies on gamification and explore its influence on enhancing the achievement levels of fourth- and second-grade students in TIMSS.

The practical significance of this research lies in determining strategic competency skills and their accessibility among fourth-grade students and offering gamification-based activities in light of the requirements of TIMSS. This study can play a part in offering models for teachers to develop students' strategic competence skills. The current research can also support mathematics teachers at the primary level in enhancing teaching practices and varying evaluation methods that conform to course contents and student development traits.

1.5. Research Limitations

This research is confined to the following aspects.

Objective limits: This research was limited to building a proposed educational program for teaching mathematics in the field of numbers in TIMSS by utilizing the Quizizz platform to activate learning through gamification, and determining the influence of this program in advancing strategic competence among fourth-grade students.

Strategic competence was assumed from the constituents of mathematical prowess. Owing to the interest in mathematics education research bounded to the first elements of mathematical proficiency (conceptual comprehension and procedural fluency), strategic competence has not received ample research focus. Moreover, developing strategic competence can assist in interpreting, representing, and solving mathematics problems covered in TIMSS at the cognitive and applied levels. This aspect concerns 80% of test skills.

Human limit: This research was limited to fourth-grade students in elementary schools in Arar city in the northern border region of the Kingdom of Saudi Arabia.

Spatial boundary: The research was limited to elementary schools (for boys) in Arar city in the northern border region of the Kingdom of Saudi Arabia.

Time limit: The research was conducted during the first semester of Academic Year 1445 AH.

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2. Literature Review

2.1. Educational Program

An educational program is defined as “a coordinated set or series of designed and organized educational activities to attain previously established educational objectives or to accomplish a specific set of educational tasks over a prolonged period” (United Nations Educational, Scientific and Cultural Organization [UNESCO], 2011, p. 79). This program is also defined as “a list of modern educational activities that the teacher offers the learner to gain assorted educational goals, which are developing behavior and personality and advancing the learner's ability to manage his life within this complex tech-driven world, comprising risk management” (Bahjat, 2013, p. 15, Albahiri et al., 2023). The current researchers define an educational program procedurally as a set of activities and procedures predicated on gamification in light of the requirements of TIMSS, with the aim of developing strategic competence in mathematics among fourth-grade students.

2.2. Gamification

Gamification is defined as “an educational strategy involved in stimulating students to learn, using game components in educational spaces, to attain greatest enjoyment and participation and resolving problems in other fields outside the context of games, by attracting their interest to continue learning” (Al-Juhani, 2018, p. 648).

In addition, gamification is defined as "a strategy in which the characteristics of the game are applied, comprising motivations levels, and competitors, controlled by particular conditions and rules, to attain a certain level of achievement, to obtain the goals of the educational unit" (Al-Otaibi & Al-Nafie, 2022, p. 505).

The current researchers define gamification procedurally as a strategy predicated on activating play components using the Quizizz platform in teaching mathematical skills to stimulate and motivate fourth-grade students to obtain the maximum amount of learning.

2.3. Mathematics requirements for TIMSS

The requirements of TIMSS for fourth-grade students are defined as "The basic structure in its two dimensions: the content dimension and the cognitive dimension that must be incorporated in the content of mathematics curriculum at the elementary level in light of the Study of International Trends in Mathematics and Science (TIMSS)" (Al-Habib & Al-Jundi, 2019, p. 540).

It is defined as a set of topics covered by TIMSS in the content areas of numbers (50%), measurement and geometry (30%), and data analysis (20%) through items measuring knowledge, application, or reasoning (Philpot et al., 2023, p. 8)

The researchers define it procedurally as the basic mathematics skills that must be acquired by fourth-grade students in the field of numbers in the dimensions of thinking (i.e., knowledge, application, reasoning) in light of the requirements of TIMSS.

2.4. Strategic Competence

Strategic competence in mathematics is defined as "the ability to formulate, represent, and solve a mathematical problem" (NRC, 2001, p. 5). Moreover, strategic competence is defined as "the ability to interpret and formulate mathematical problems, and the ability to represent and solve them, and requires theoretical understanding to assess the nature of the problem, as well as procedural fluency to solve the problem precisely and successfully" (MacGregor, 2013, p. 5)

The researchers procedurally define strategic competence as the ability of students in the fourth grade to interpret and represent mathematical problems, simulating the problems presented by

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TIMSS in the domain of numbers, solving them, and reformulating them. Lastly, strategic competence can be measured by the scores the students obtain in the strategic aptitude test.

2.5. Previous Studies

Previous studies that aimed to determine the levels of strategic competence have revealed the weaknesses and insufficient levels of strategic competence in mathematics among students. Al-Munoufi and Al-Muatham (2019) revealed weak levels of strategic proficiency among second-year students in Qassim City, given that their average correct answers did not exceed 30.5%. Al-Mallouhi (2020) demonstrated weak levels of strategic competence among sixth-grade female students in Riyadh. They found that the students' average answers did not exceed 22.05%. Lastly, Al-Mutairi and Al-Khader (2021) showed that fourth-grade female students are incapable of mastering strategic competence.

Many previous studies that concentrating on developing strategic competence among students have identified the efficiency of educational programs and teaching strategies in advancing them. Al-Shalhoub (2019) found a significant influence of a proposed enhancement program predicated on incorporating the principles of TRIZ theory with skill activities for TIMSS in developing strategic competence and adaptive reasoning among middle school female students in the Kingdom of Saudi Arabia.

Bani Yassin and Abu Loom (2021) presented the influence of utilizing mathematics software in solving mathematical problems among tenth-grade students in Jordan. Al-Tuwaijri and Al-Khader (2022) showed the efficiency of the scientific station's strategy in advancing the strategic competence of second-grade female students in the Qassim region. Their results demonstrated that the differences between the averages of the experimental and control groups may be caused by the exposure of the female students of the experimental group to recurrent and various mathematical problems.

The application of the strategy competence enables female students to interpret the problems, distinguish between relevant and irrelevant information, present the problem mathematically, and select the appropriate strategies for solving them without the assistance of teachers. In particular, applying the strategy enables students to offer immediate feedback, discuss the solutions for the mathematical problems, and present viewpoints in a classroom environment characterized by cordiality, assurance, cooperation, and discussion, as well as working in collaborative teams.

Numerous studies have proven the effect of gamification in teaching mathematics, particularly using digital tablets and educational tech platforms. Al-Batnin (2019) revealed a significant influence of utilizing gamification using tablet devices in teaching and enhancing operations on ordinary fractions among elementary students. Al-Ghamdi (2019) indicated that the impact of learning through gamification in advancing stimulus toward learning mathematics is immense for challenge, enjoyment, confidence, and self-assuredness. Al-Khuzaim (2021) indicated the efficiency of digital course material based on gamification in developing academic performance in mathematics for third-grade female students in Riyadh. Abdul Malak (2022) discovered the significant effect of applying gamification in mathematics by way of the class craft platform in developing creative intelligence and in progressing academic feelings toward mathematics.

Regional and global scientific conferences and symposia also recommended the necessity of focusing on gamification. The 14th Scientific Conference of the Egyptian Society for Educational Technology (2014) recommended focusing on websites and electronic courses by applying a gamification strategy to improve learning. The Arab Society for Educational Technology Conference (2017) recommended modernizing syllabi and curricula, utilizing new technology in them, and benefiting from them in gamification. The International Conference on Technology in Education

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(ICTE) in Hong Kong recommended utilizing competitive digital games as a current trend in educational progress (Huang et al., 2018). Lastly, the Game-based Learning Conference 2017 in Vienna recommended exploring virtual competitive games with experimental research (Ortiz et al., 2017).

The experiences of one of the current researchers as a primary level mathematics teacher are invaluable, including his awareness of cutting-edge strategies for teaching mathematics, understanding of the terms of TIMSS, knowledge of exonerated problems from early versions of the test and the problems simulating them, and his explanation of electronic educational platforms and their advantages. Accordingly, gamification can be utilized as a strategy to train students to solve the problems included in the test and problems and activities that motivate them. Using the Quizizz platform can set challenges and competitions, as well as use points and disciplinary councils to develop students' emotional maturity toward learning mathematics.

Overall, this research aims to build an electronic educational program predicated on gamification to teach mathematics based on the terms of TIMSS. The effect of this program on advancing strategic competence among fourth-grade students is apparent.

3. Methodology

This research utilized the experimental approach to determine the effect of the educational program on advancing strategic competence among fourth-grade students. This is approach is based on the design of two equal groups (pre-measurement, application of the experiment, post-measurement) for the experimental and control groups.

3.1. Research Sample

To specify the research sample, previous studies were used as reference, indicating that selecting the sample using a randomized sampling method was most suitable. The schools were cataloged with numbers. By drawing randomly, one of the public sector schools was selected, and the research sample consisted of (61) students from the fourth grade. The sample members were divided into two groups: experimental and control groups consisting of 31 and 30 students, respectively. Given the random assignment of the sampling items, this research sought to control all factors influencing the experiment. The research population comprised all fourth-grade students in schools in Arar city in the northern border region of the Kingdom of Saudi Arabia, including general education and private school students (total of 2055 students). (General Administration of Education in the Northern Border Region, 2023E.C).

3.2. Research Materials

The electronic educational program predicated on gamification was prepared and designed based on the requirements of TIMSS and formulated on the general design model ADDIE. The reason is that it incorporates the fundamental earliest stages, apart from being flexible and capable of modification and development.

1. Analysis stage: The content of the second unit (addition and subtraction) in the mathematics book for fourth-grade students for the first semester was analyzed and developed in light of the skills

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targeted by the field of numbers in TIMSS, with its three dimensions (i.e., knowledge, application, reasoning).

2. An electronic educational program was designed predicated on gamification to teach mathematics based on the requirements of TIMSS via the Quizizz platform according to the following steps:

a.Identifying the general objectives of the educational program;

b.Identifying the sample members; studying their mental, emotional, and social characteristics; and considering them when designing the program;

c.Discerning lesson topics and educational objectives based on the requirements and time plan for TIMSS;

d.Considering the feelings of users while practicing gamification;

e.Formulating special instructions for using the program and engaging in the activities;

f.Establishing progress metrics, such as questions or tests, through which users can advance to the next activity or higher level;

g.Identifying the mechanisms that will be used to design gamification, such as determining gain or loss points;

h.Detecting incentives to move to a higher level if a certain number of points are obtained;

i.Providing the necessary, thereby enabling users to continue gamification and correcting their path; and

j.Deciding on an appropriate time for each activity; if the activity is completed in a short time, then a certain number of points will be obtained.

3. An electronic educational program was advanced based on gamification for teaching mathematics on the bases of the requirements of TIMSS through its presentation and arbitration by teaching specialists.

4. An electronic educational program was used experimentally based on gamification in light of the requirements of TIMSS on a group of fourth-grade students outside the research sample.

5. The e-learning program was assessed based on gamification in light of the requirements of TIMSS.

3.3. Instruments

To achieve the research objectives, the testing tool was utilized and applied in the form of pre- and post-tests. This study also aims to determine the influence of experience and change on the strategic competence of fourth-grade students when solving mathematical problems.

3.4. Strategic Competency Test

The strategic competency test was prepared as follows.

- Determining the purpose of the test

The test aimed to gauge the levels of strategic proficiency among fourth-grade students before and after the experiment to determine the effect of the educational program on their advancement.

- Defining a list of strategic competency skills

After examining previous studies on mathematical prowess in general and the development of strategic competence in particular, such as Hilal (2021), Al-Tuwaijri and Al-Khader (2022), and Al-

Qarni and Al-Khabti (2023), a list was prepared incorporating strategic competence skills adequate for fourth-grade students. Accordingly, a conceptual picture was prepared.

- Verifying the validity of the test

To validate the seeming credibility and general aspect of the test and to verify the acceptability of the item contents, how to frame them, their linguistic purity, their clarity, and their aptness to the levels of students, the test was presented to several experts and specialists in teaching mathematics methods, researchers in the research domain, and several esteemed professionals in teaching mathematics. Given the modifications and suggestions of experts and specialists, some phrases were rewritten and some options were changed and rearranged to align with the students' experiences and age phases.

To verify internal consistency, the test was applied to a survey sample of students from one of the schools in the research population. The research purposive sample consists of 30students, and the correlation coefficient (Pearson) was calculated between each item of the test and its total score (see Table 1).

Table 1. Pearson's Correlation Coefficient between Items with the Total Score

Question numbers	Correlation coefficients	Question numbers	Correlation coefficients
1	.585**	2	.539**
3	.031**	4	.663**
5	.538**	6	.616**
7	.495**	8	.616**

**Statistically significant at.01

Table 1 shows that the correlation coefficient values for each of the items with the total score of the test are positive and significant at a level below.01, except for item number 3. For this item, the correlation coefficient was weak and there was no statistical significance. Accordingly, the answer alternatives for this item have been modified to align with the other items in the test.

To verify the construct validity of the tool, the correlation coefficient was calculated between the scores of the main skills of strategic competence and the overall score. The results are presented in Table 2.

Table 2. Pearson correlation coefficient between the scores of the main skills of strategic competence and the overall score

Standards	Correlation coefficients
First skill: representing the mathematical problem	.714**
Second skill: solving the mathematical problems	.812**
Third skill: formulating and forming the mathematical problem	.617**

**Statistically significant at.01

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Table 2 shows that the values of the correlation coefficient of the basic skills with the total score of the test are positive and significant at a level below.01. This result indicates that the basic skills comprising the test are marked by construct validity.

3.5. Checking the Test Stability

After confirming the validity of the test, reliability was calculated from the results of its application to the explorative sample using the Cronbach's alpha coefficient. The value was 0.736, indicating that the tool is stable and can be used for measurement.

3.6. Checking the Difficulty Factor

The difficulty coefficients for each test item were calculated from the results of the application to the poll samples, particularly by calculating the percentages of students' incorrect responses over the total number (see Table 3).

Table 3. Difficulty factor for testing strategic competence

Item Numbers	Difficulty factors	Item Numbers	Difficulty factors
1.	45.16	2.	80.64
3.	70.96	4.	58.06
5.	48.38	6.	48.38
7.	61.29	8.	29.03

Table 3 shows that the values of the difficulty coefficients for the items ranged between approximately 29% (i.e., somewhat easy) and approximately 80% (i.e., difficult), with an overall average for the test estimated at approximately 54%. This result reveals that the test is medium difficult and balance in the test items in terms of ease and difficulty.

3.7. Checking the Discrimination Coefficient

To verify the discrimination coefficient, the coefficient for the test items was calculated from the results of the application to the exploratory sample according to the following steps.

1. The test results are arranged in descending order according to the scores.

2. The results were divided into two groups: (e.g., high and low). Thereafter, the discrimination coefficient was calculated according to the following equation:

$$\text{Discrimination coefficient} = \frac{\text{Sum of the high scores} - \text{Sum of the low scores}}{\text{Number of students in one of the two groups}}$$

The coefficient results appear as shown in Table 3.

Table 4. Discrimination coefficient for testing strategic efficiency

Item numbers coefficients	Discrimination coefficients	Item numbers	Discrimination
1.	0.46	2.	0.26
3.	−0.06	4.	0.46

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5.	0.53	6.	0.4
7.	0.4	8.	0.6

Table 4 shows that the discrimination coefficients were positive between (0.26) and (0.60), except for item number 3, which has a negative value. The answer alternatives to the item were changed, and the approximate average of the discrimination coefficient reached 0.38. This result signifies differences between the students' performance in favor of the higher group, thereby indicating discrimination in the test.

3.8. Determining the Test Time

To decide the time limit to answer test questions, the average was calculated between the time when the first student finished answering the questions and the time when the last student finished answering them. Accordingly, the time was determined as follows: (25 + 45) ÷ 2 = 35 minutes.

3.8.1. Final test preparation

After ascertaining the psychometric properties of the strategic aptitude test, the test was developed in its final form.

3.9. Procedures

1. Creating gamification-based content on the Quizizz platform.

2. Choosing a research sample and dividing it into experimental and control groups.

3. Pre-application of the research tools on the experimental and control groups on 04/07/1445 AH.

4. To verify the equality of the two groups, a t-test was conducted to identify the differences in the average scores of students in the experimental and control groups in the strategic proficiency test (see Table 5).

5. Registering the experimental group students on the platform.

6. Instructing the students on how to use the platform.

7. Determining the conditions for earning points and distributing rewards.

8. Relying on gamification while teaching the unit, and training in solving mathematical problems.

9. Post-application of the research tools on the experimental and control groups on 04/28/1445 AH.

10. Analyzing data and monitoring results.

Table 5 shows the arithmetic mean, standard deviation, and t-test for the two independent samples of the scores of students in the experimental and control groups in the strategic proficiency test in the pre-application.

Table 5. Skills group arithmetic mean standard deviation t-test significance level

Skills group arithmetic mean standard deviation t-test significance level					
1. Rep. Math. Problem	controlled	1.23	.774	.682	.498
	Experimental	1.10	.790		
2. Sol. Math problem	control	1.40	1.037	.076	.940

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	Experimental	1.42	.958		
3. F.&c.m. problem	controlled	.57	.626	.427,671	
	Experimental	.65	.798		
Total	controlled	3.17	1.793	1.58	.875
	Experimental	3.10	1.680		

Table 5 shows no statistically significant differences at the 0.05 level between the average scores of the experimental and control groups in the pre-application of the strategic competency test.

3.3.1 Statistical Methods

The following statistical methods were used to achieve the aims of this research, analyze data, and present the research results.

1. Arithmetic Mean: to calculate the average scores of students in the control and experimental groups in applying the pre-and post-tests of strategic proficiency

2. Standard deviation.

3. Ease and difficulty factor: to determine the ease and difficulty of the test

4. Discrimination coefficient: to identify the differences in students' grades

5. Pearson correlation: to calculate the internal and constructive validities of the strategic efficiency test.

6. Cronbach's alpha: to measure the stability of the research tool

7. Test One Sample Kolmogorov–Smirnov: to check the normal distribution of data

8. T-test for independent samples: to determine the significance of the differences between the means of the experimental and control groups in the strategic aptitude test in the pre-application

9. Mann-Whitney test for independent samples: to determine the significance of the differences between the median placement of the experimental and control groups in the strategic proficiency test in the post-application.

10. Eta Square η2 (Eta Squared): to determine the extent of the impact of the independent variable on the dependent variable in the case of two independent samples, indicating the effectiveness of the independent variable on the dependent variable among members of the experimental group by understanding the value of (U) and its statistical significance for the differences between the average scores of the members of the two samples.

4. Results and Discussion

4.1. Results related to the first question

To answer the first question: What is an e-learning program based on gamification for teaching mathematics on the bases of the requirements of TIMSS?

We reviewed previous research that depended on gamification in mathematics, such as Al-Hananfi (2018), Al-Shalhoub (2019), Al-Ghamdi (2019), Al-Khuzaim (2021), Al-Olayan (2022), and Al-

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Otaibi and Al-Nafi'i (2022). From this perspective, the educational program was prepared according to the following steps.

First: Determining the general objective of the program

The proposed educational program for teaching mathematics aims to develop strategic competence among fourth-grade students.

Second: Identifying the sample members and studying their mental, emotional, and social traits

The research sample comprised students in the fourth grade. The students are often 10 or 11 years old. The most important traits of this age group are as follows (Faraj, 2008).

• Mental development: Intelligence continues to develop until the age of 12. Reading skill improve, the ability to innovate progressively becomes markedly evident, abstract thinking continues to improve, and attention span, duration, and sharpness increase. Children's memory enhances steadily from age 7 to 11. At this stage, they tend to remember the path of understanding.

• Emotional development: At this stage, children clearly tend to have fun, like to feel secure and successful, and for the adults around them to appreciate and encourage success on various occasions.

• Social development: Children's communication with adult groups increases and the former acquires their standards, attitudes, and values. Given that the impact of cohorts increases, social interaction with peers becomes considerably zealous, and children take pride in their membership in peer groups.

Third: Determining the content of the educational program

- Introduction to the educational unit: The educational unit is Chapter: Addition and Subtraction, which is included in the mathematics textbook for fourth-grade students in the first semester of Academic Year 1445 AH.

- Determining the general goals and objectives of the unit: The unit aims to develop students' mathematical abilities in addition and subtraction by providing the following skills:

• Using the properties of addition and subtraction for addition and subtraction;

• Estimating the sum of numbers and estimating their difference;

• Determining when they will estimate answers, and when they find the accurate answer;

• Adding numbers consisting of several digits;

• Subtracting numbers, each of which consists of several digits;

• Subtracting numbers, each of which consists of several digits, with the presence of zeros;

• Developing the skills of solving, representing, reformulating, and composing a mathematical problem;

• Explaining the importance of mathematics and its role in life and other sciences;

• Developing positive attitudes toward mathematics; and

• Determining lesson topics and educational objectives based on the requirements of TIMSS and the time plan (see Table 4).

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Table 6. Mann-Whitney U test for two independent samples, and Eta square η2 for the scores of .students in the experimental and control groups

Number of periods	Page numbers	Target level in light of TIMSS			Educational objectives	Lesson topics
		inference	application	knowledge		
2	49-47	*	*	*	Using the properties of addition and subtraction for addition and .subtraction	Algebra: properties of addition and rules of subtraction
2	53-50	*	*	*	Estimating the sum of . numbers and estimating their difference	Estimate the sum and difference
2	55-54	*	*	*	Determining when estimating the answer, and when finding the exact answer	Skill of solving an estimation problem or giving an accurate answer
2	59-56	*	*	*	Adding multi-digit .numbers	Addition
2	65-63	*	*	*	Subtracting numbers each consisting of several digits.	Subtraction
2	70-67	*	*	*	Subtracting numbers, each consisting of several digits, .including zeros	Subtraction with zeros

-Adding enrichment activities based on the requirements of TIMSS to develop strategic competence.

- Preparing the teacher's guide

Fourth: Determining teaching strategies

The strategies of cooperative learning, dialogue, discussion, and pair learning were utilized in presenting the lessons. In addition, the gamification strategy was used in solving mathematical problems.

Fifth: Determining educational techniques

Interactive screens were used, and the features of Quizizz were activated to display lessons and educational tools, provide enrichment activities, and enhance responses.

Sixth: Determining the evaluation methods for the program

Pre-evaluation: Students' levels of strategic competence were verified by applying the testing tool before implementing the educational program.

Formative evaluation: The activities and issues included in the educational program were evaluated immediately and continuously.

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Final evaluation: The students' levels of strategic competence were verified by applying the testing tool after implementing the educational program.

4.2. Results related to the second question

To answer the second question: What is the impact of an electronic educational program based on gamification in light of the requirements of TIMSS in developing strategic competence in mathematics among fourth-grade students?

Testing the validity of the following hypothesis: No statistically significant differences exist at the 0.05 significance level between the average scores of students in the experimental and control groups in the post-application of the strategic proficiency test owing to the proposed educational program based on gamification.

The conditions of the t-test for two independent samples were verified on the performance results of the students of the two groups: experimental and control groups. In the post-application of the strategic aptitude test and using the Kolmogorov-Smirnov test, that the condition of easing was not met in the results of the students of the experimental group. Therefore, the alternative Mann-Whitney (U) test was utilized to determine the differences in the ranks of the average scores of the students of the experimental and control groups. Moreover, for the statistical significance in the test skills for each test separately and in the test as a whole, the "eta square η2" was calculated to determine the size of the effect of the independent variable on the dependent variable, given that the effect size is considered small if the value is between 0.01 and below 0.06. In addition, the effect size is considered medium if the value is above 0.06 and below 0.14, Lastly, the effect size is considered significant if it is above 0.14 (Bahash, 2019). The results are presented in Table 7.

Table 7. Mann-Whitney U test for two independent samples, and Eta square η2 for the scores of students in the experimental and control groups for the strategic proficiency test in the post-application.

Effect size	Eta square η2	Degree of freedom	significance level	U value	Total ranks	Average rank	group	Skills
big	.212	59	.000	227.500	692.50	23.08	Control	Representing the mathematical problem
					1198.50	38.66	Experimental	
simple	.013	59	.391	408.500	873.50	29.12	Control	Solving the mathematical problem
					1017.50	32.82	Experimental	
big	.358	59	.000	158.000	623.00	20.77	Control	Formulating and composition of the mathematical problem
					1268.00	40.90	Experimental	
big	.237	59	.000	183.000	648.00	21.60	Control	Total
					1243,00	40,10	Experimental	

**Statistically significant at 0.01

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Table 7 shows that the value of (U) for the Mann-Whitney test for two independent samples is statistically significant at the 0.01 level between the ranks of the average scores of the experimental and control group students in the skills of representing the mathematical problem and rephrasing and forming the problem, in favor of the experimental group. Apparently, significant differences are observed. Statistically significant at the level of (0.05) between the ranks of the average scores of the students of the two groups in the problem-solving skill. Moreover, Table 5 shows that the value (U) of the Mann-Whitney test in the strategic aptitude test is statistically significant at the 0.01 level. This result shows statistically significant differences between the average scores of students in the experimental and control group students in the post-application in favor of the experimental group.

Table 7 also shows that the value of "eta square η2" was above 0.14 in the two skills: representing and formulating the problem. This finding shows a significant effect of the independent variable in the two skills. Apparently, the value of the "Eta square η2" was between 0.01 and 0.06 in the skill of solving the mathematical problem, indicating the presence of a simple effect of the independent variable in this skill. Table 4 also indicates that the value of "eta square η2" was generally above 0.14 in the strategic proficiency test. That is, a significant effect of the independent variable exists on the dependent variable, indicating that the difference in students' scores in the strategic proficiency test between the experimental and control groups is due to the suggested tutorial.

The researchers attribute the results in the skill of representing the problem to the following factors: impact of the proposed educational program on students' strategic competence through presenting various mathematical problems and issues related to the students' real lives, training the students of the experimental group to represent the mathematical problem in identifying the important mathematical data in it, determining what is required of it, and training students read the problem and convert sentences into mathematical formulas and symbols.

The preceding results confirm those of MacGregor (2013) and Hilal (2021), who indicated the possibility of developing students' strategic competence through the repeated presentation of various mathematical problems, especially situations related to real life and training students to convert verbal expressions into mathematical formulas using mathematical symbols. This finding confirms what Hilal (2021) indicated about the possibility of developing strategic competence through training in representing the issue, encouraging students to read it carefully, and defining the concepts, relationships, and variables involved with it.

The researchers attribute the results in the problem-solving skill to the exposure of the control group students to training in solving mathematical problems, as in the experimental group, through the activities and examples of the textbook on the subject of (problem-solving). In particular, the lesson subject deals with identifying appropriate strategies for solving mathematical problems and explains the steps in solving them and verifying the validity of the solution.

The researchers attribute the results in the skill of rephrasing and composing the problems to the effect of the proposed educational program on the strategic competence of students by training students to repeatedly attempt to rephrase mathematical problems and create new and similar models in a safe and appropriate environment.

5. Conclusion

This study aimed at planning a proposed educational program predicated on gamification for teaching mathematics according to the requirements of TIMSS to identify its impact on developing strategic competence among fourth-grade male students in the first semester of Academic Year 1445AH in elementary schools in Arar city.

The following important factors led to a significant impact of the proposed educational program based on gamification in developing strategic competence: motivating students to participate in

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solving mathematical problems; setting individual and group challenges and competitions in solving competitions and activities; providing immediate feedback by clarifying, interpreting, and correcting errors; and providing a safe learning environment. This finding confirms Abdel-Malak's (2022) idea that gamification helps in breaking the stagnation of mathematics teaching methods by engaging students, stimulating their internal motivation, and engaging them in learning without feeling bored, thereby leading to their improved performance and raising their achievement levels. Using gamification in mathematics improves problem-solving skills and creates a safe learning environment that ensures fun in learning. This result confirms Al-Zein's (2021) conclusion that gamification helps students acquire concepts and information related to mathematics and language and for the learning effect to remain for a long period.

The results of this research agreed with the results of Al-Shalhoub (2019), who showed the impact of a proposed enrichment program based on integrating the principles of TRIZ theory with skills activities for TIMSS in developing strategic competence among female middle school students in the Kingdom of Saudi Arabia. Moreover, the results of the current research agreed with that of Bani Yassin and Abu Loom (2021), who showed a statistically significant effect of using the Microsoft Mathematics software in solving mathematical problems among tenth-grade students in Jordan.

The results of this study also agreed with those of Al-Tuwaijri and Al-Khader (2022), who revealed the effectiveness of the scientific station's strategy in developing the strategic competence of female second-year intermediate students in the Qassim region.

5.1. Recommendations

Given the research results, this study presents the following recommendations:

• Utilize the gamification strategy in teaching mathematics to fourth-grade students;

• Teachers maximize the features provided by electronic platforms to motivate students to participate and interact in learning mathematics;

• Educate teachers on the importance of problem-solving lessons in mathematics courses because of their impact on developing strategic competence among fourth-grade students;

• Benefit from the activities of the educational program in developing strategic competence among fourth-grade students; and

• Maximize the teacher's guide in developing strategic competence among fourth-grade students

6. Suggestion

The following suggestions emerged in this research:

• Educational program for teaching mathematics based on gamification as required by TIMSS and its impact on developing strategic competence and productive desire among second-year intermediate students;

• Educational program for teaching mathematics based on gamification as required by TIMSS and its impact on developing adaptive reasoning among fourth-grade students;

• Educational program for teaching mathematics based on gamification as required by TIMSS and its impact on developing adaptive reasoning among second-year intermediate students.

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Declarations

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