The level of information technology achievement among students and their practice of innovative problem-solving strategy (TRIZ)

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ABSTRACT

In today's rapidly advancing digital landscape, equipping students with strong competencies in information technology (IT) and innovative problem-solving strategies is essential to meet market demands, foster lifelong learning, and engage with emerging technologies such as artificial intelligence. Theory of Inventive Problem Solving (TRIZ) has been applied in educational contexts to enhance students' creativity and technical skills, yet prior research has produced mixed results regarding its effectiveness in robot construction and programming. This study investigated the impact of TRIZ-based instruction on IT achievement among 7th-grade students, examining differences between pre- and post-intervention performance and gender-related variations in robot assembly, programming, and strategy use. This aspect uniquely distinguishes the present study from prior investigations. Employing a descriptive correlational design, the sample comprised 329 7th-grade students and 65 IT teachers. Results indicated significant improvement in IT achievement from pre-test to post-test, favoring the post-intervention outcomes. However, no significant gender differences were found in post-test scores or in the application of TRIZ strategies. The findings highlight the value of integrating TRIZ-based approaches into IT curricula and diversifying problem-solving activities to cultivate innovation, technical proficiency, and adaptability among school students in preparation for future technological challenges.

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1. INTRODUCTION

Moreover, in the educational robotics aspect, a systematic review of ERIC, Scopus, and Web of Science confirms the increasing use of robotics in education to support individual learning outcomes, yet highlights that its collaborative potential for developing teamwork skills remains largely untapped [1]. For example, Sánchez-Rivas *et al*. [2] identified significant gaps in teachers' digital competence in robotics and block programming in primary education, despite their familiarity with active pedagogies, underscoring the importance of targeted upskilling initiatives. Similarly, the Organisation for Economic Co-operation and Development (OECD) Digital Education Outlook 2023 stresses that digital competences have become essential for all teachers, prompting many countries to adopt formal guidelines and standards for both pre-service and in-service training [3]. Recent teacher digital competence (TDC) reviews corroborate that competence levels remain low, particularly in ICT innovation and integration, highlighting the urgent need for structured professional development to strengthen teachers' digital readiness [4].

In contemporary education, the cultivation of 21st-century competencies—encompassing communication, creativity, critical thinking, collaboration, and advanced problem-solving—has become a central priority to ensure students can effectively engage with emerging educational technologies [5], such as educational robotics, robot assembly, and programming activities. Consequently, curriculum design is increasingly aligned with graduation benchmarks that mirror labor market demands, thereby ensuring that learning outcomes are both relevant and transferable to real-world contexts. In this regard, several scholars have employed the innovative problem-solving strategies methodology as a foundational framework for curriculum development, leveraging its systematic innovation principles to enhance instructional design and promote higher-order cognitive skills [6].

The integration of the Theory of Inventive Problem Solving (TRIZ) into educational contexts has gained considerable attention for its potential to enhance learners' problem-solving abilities and creative thinking. Recent research has examined various applications of TRIZ in teaching and learning. For instance, Park [7] developed a TRIZ-based innovation program for preservice teachers and evaluated its effects on creativity, beliefs about creativity, and teaching self-efficacy. Implemented through a quasi-experimental design with hands-on activities, the program was incorporated into an innovation course. Findings demonstrated notable increases in teachers' creativity, creative beliefs, and instructional confidence, with differential impacts observed across creativity sub-dimensions.

In parallel, design thinking (DT) has emerged as a widely utilized pedagogical framework that prioritizes empathy, ideation, and iterative prototyping. A systematic review by Razali *et al*. [8] assessed the application of DT in higher education, highlighting its capacity to foster collaborative learning and address authentic, real-world challenges. Nonetheless, the study also identified limitations regarding the scalability and consistency of problem-based approaches across varied educational settings.

Problem-based learning (PBL) is another influential student-centered approach that emphasizes inquiry-driven learning and the cultivation of critical thinking through engagement with real-world problems. Hallinger [9] investigated the use of PBL in medical education and reported enhanced student engagement and improved problem-solving competencies. The study, however, underscored the necessity for effective facilitation and robust assessment methods to fully realize the benefits of PBL.

Teachers guide students toward innovation by applying higher-order thinking skills based on analysis, synthesis, and evaluation that affect their students' skills. Accordingly, Park study [7] showed that training teachers to teach TRIZ to their students increased their innovation beliefs and innovation teaching effectiveness, as well as the sub-dimensions of innovation among these teachers; this was reflected in their students. Additionally, diversifying teaching strategies and methods helps students apply various activities that stimulate their thinking within the curriculum, encouraging them to find appropriate solutions to the problems they face, ultimately leading to improved academic achievement [10].

The Ministry of Education's Strategy 2040 aims to diversify the teaching methods and strategies educators use to achieve emerging educational objectives. These objectives include stimulating students' thinking, developing their interests and abilities, improving academic achievement, fostering self-learning and lifelong learning, promoting sustainability, and promoting innovation [11]. Therefore, it is necessary to update curricula to align with the principle of lifelong learning and enhance their skills [6].

Additionally, the Ministry is paying close attention to anticipated changes in the fields of robot assembly and programming. These changes aim to empower the educational system with modern robotics trends. Such empowerment is achieved by developing the components of the educational system and by offering teacher-training programs at higher education institutions that align with the evolving needs of educational robotics [11].

In constructivist learning theory, learning is achieved by building cognitive structures that represent activities students can engage in in the learning environment. This can be observed when students assemble and program an educational robot, because as Soori *et al*. [12] remark, AI in robotics enables robots to identify different tasks. Tasks are divided among students to achieve specific educational goals. Through their implementation, they learn to confront problems, encounter them, and investigate appropriate solutions themselves through practical application [13]. According to constructivism, students learn best when they use tangible parts to assemble components of a system, giving them the opportunity to design and program, such as assembling and programming an educational robot.

Students' desire to improve their academic achievement deepens their understanding and fosters a competitive spirit, encouraging a love of learning. When students engage in assembling and programming self-propelled robots and educational robotics, they are exposed to mathematical, scientific, and technical concepts from complementary curricula [14]. The findings revealed that integrating educational robotics into lessons led to a marked improvement in students' academic performance, accompanied by heightened engagement and enjoyment of the subject. Compared to traditional instructional approaches, this technology-enhanced method fostered a more interactive and stimulating learning environment. Such outcomes highlight the potential of robotics-based pedagogy to enrich subject comprehension while simultaneously enhancing learners' achievement [15].

Communication, collaboration, critical thinking, and creativity are essential elements of 21st-century skills, and the application of innovation strategy tools by male and female students works to develop them in both, according to the nature and activity of each [16]. Also, it can stimulate students' thinking if they have been taught by an urged method such as TRIZ. The TRIZ strategy consists of 39 criteria, identified through patent analysis using the technical contradiction detection matrix. This led to the deduction of 40 principles of inventive invention to resolve contradictions, in which solutions are reached by matching the contradiction with the relevant principle [17].

According to Chen *et al.* [18], "TRIZ, abbreviation in Russian of *Teoriya Resheniya Izobretatelskikh Zadatch*, means 'inventive theory of problem-solving,' which is to seek potential access to technological innovation in a systematic way." As Park [7] emphasized, TRIZ is an influential strategy for teaching science and technology, and it can even help develop the problem-solving skills and creativity in virtual environments to have sustainable learning [19]. Also, according to Zhou *et al.* [20], TRIZ helps provide satisfactory solutions for innovation and the creation of new things.

The findings of Al-Haddabi and Al-Jaji [21] demonstrated a statistically significant improvement in students' scientific thinking skills between the pre-test and post-test, with higher performance observed following the intervention. These results indicate that instructional approaches incorporating robotic technologies have a measurable positive impact on the development of learners' scientific thinking abilities. Consequently, the study underscores the effectiveness of robot-based training as a powerful pedagogical tool for enhancing scientific cognition in educational contexts.

The results of Altıok and Üçgül [22] showed a substantial enhancement in students' self-efficacy regarding computational thinking skills following participation in robotics-based coding activities, with this improvement evident across both male and female learners. This consistent pattern suggests that such technology-integrated instructional approaches effectively foster confidence in computational problem-solving irrespective of gender. These findings underscore the potential of robotics coding interventions to strengthen essential 21st-century cognitive competencies. Additionally, Al-Ateeq research [23] indicated significant differences in teachers' assessments of gifted students' academic achievement, suggesting the positive role of robots in fostering their creative skills. The results also showed significant differences in favor of applied scientific subjects, indicating that robots effectively foster creativity among students.

Al-Zahrani study [24] also found that robot programming training positively enhanced students' creative thinking skills. The results showed that the experimental group outperformed the control group in all measured abilities, highlighting the positive role of robot technology education in developing students' skills and improving their academic achievement. Similarly, Korkmaz findings [25] indicated a positive impact of teaching programming languages and robotics on students' academic achievement.

The study by Govender [26] demonstrated that Kolb's experiential learning framework facilitates the progressive acquisition of computer programming concepts by integrating a tangible, physical element such as a robot. The findings further revealed that incorporating microcontrollers with robotic features significantly enhances students' performance by providing a hands-on, physical dimension to the process of learning coding instructions. This synergy between experiential learning and robotic technology fosters deeper conceptual understanding and improved practical application in programming education.

Al-Badou study [27] aimed to investigate the impact of laboratory teaching using robot technology on the mathematical achievement of twelfth-grade female students. The research found that the experimental group, which used robot technology, achieved higher academic performance than the control group that studied using traditional methods. This indicates the positive effect of students' practice with robots on their academic achievement, enhancing both thinking and application skills.

Ammar study [28] aimed to investigate the impact of using educational robots on students' academic achievement in the context of digital transformation. The study sample consisted of 25 ninth-grade female students from Al-Bassaer Private School in Sharjah, UAE. A pre-test was conducted, followed by approximately two months of robot-based instruction of the science curriculum, and then a post-test was conducted. The findings revealed that the use of robot technology in education improved students' academic performance, as measured by the post-application test.

Integrating problem-solving methodologies into teaching practices, rather than relying solely on traditional approaches focused on rote memorization, offers a powerful means to enhance students' academic achievement and cognitive development. Presenting learners with authentic, real-world challenges enables them to develop deeper comprehension, sharpen analytical reasoning, recognize underlying patterns, and apply strategic solutions to potential future problems. This approach necessitates setting well-defined learning objectives, accompanied by purposeful challenges that continuously encourage persistence, sustainability, critical reflection, and iterative problem-solving, rather than allowing immediate resolution. In this context, the findings of Ţălu *et al*. [29] underscore the need to adopt a multidisciplinary framework that aligns artificial intelligence innovations and TRIZ with the sustainable development goals, ensuring inclusivity and long-term societal impact.

This is evident when students assemble and program robots. They encounter various problems that require meticulous thinking and the selection of appropriate solutions from a range of possible options [30]. Studying robotics offers an encouraging environment that promotes self-learning, hands-on experience, and experimental learning. It empowers students to present suitable solutions to the innovation problems they encounter [31].

TRIZ offer a well-thought-out methodology for tackling the interrelated problems in the educational process. Teachers' familiarity with these strategies makes a substantial shift in the teaching environment, as their knowledge directly impacts students. Through constant practice of such strategies, students embrace them, which leads to saving time and effort when solving problems in the future [32]. Since TRIZ techniques are based on traditional educational principles of learning, for example, the principle of accessibility, the principle of awareness, and the principle of individual approach, it is possible to achieve a means of developing the qualities of a creative personality in the students, which is an important result in pedagogical technology [33].

The study by Govender [26] emphasized the importance of conducting an experimental design with a pre-test and post-test. Thus, the importance of this research lies in examining the effectiveness of using TRIZ and emphasizing its application in robot assembly and programming, ultimately enhancing students' academic achievement by addressing the problems they encounter in information technology (IT). Therefore, this study investigates the relationship between Sohar's 7th-grade students' practice of TRIZ and their academic achievement in the IT subject.

Numerous research studies, such as the one by Barak and Zadok [34], have emphasized the effectiveness of TRIZ. According to their research, students who have participated in robot-building projects achieved higher levels of technological problem-solving than non-participants. The study revealed that participating students developed innovative solutions to problems encountered during their robot-building projects by applying technological problem-solving strategies. These students identified certain phenomena in the robot system, studied several factors that influenced robot performance, and investigated suitable solutions. Additionally, the research results indicated that students used informal instruction, drawing on prior science and technology concepts, to solve robot-related issues.

More than that, it enhances male and female students' interest and motivation in learning, and engages them in developing both study skills. According to Hsu and Ou [35], integrating knowledge into inquiry-based teaching to enhance learning motivation results in faster, clearer, and more engaging learning and greater conceptual understanding. That is because students prefer an inquiry-based approach to integrating knowledge over the traditional lecture method.

Al-Oqail study [36] explored the effects of a robot-assembly program on enhancing technological problem-solving abilities and motivation among academically gifted female middle school students in Saudi Arabia. The results indicated that participation in the program significantly improved both problem-solving competencies and motivational levels, suggesting a positive linkage between these two constructs. This evidence underscores the potential of robotics-based learning interventions to simultaneously foster cognitive skill development and intrinsic motivation in gifted female learners.

Likewise, Jarad study [37] aimed to investigate the effectiveness of a program based on the theory of TRIZ in developing mathematics problem-solving skills among eighth-grade students in Gaza, Palestine. The research found significant differences in the mean scores of the experimental group compared to the control group on a TRIZ-based mathematics problem-solving test, favoring the experimental group. This confirms the relationship between TRIZ application and academic achievement in mathematics.

Conversely, evidence from other investigations, such as Afari and Khine [38], indicates that the application of innovative problem-solving methodologies does not yield a statistically significant impact on student performance. Specifically, their analysis found no measurable correlation between learners' academic achievement levels and engagement with the TRIZ framework. These results suggest that, despite TRIZ's structured and creative approach to addressing complex problems, its implementation alone may not directly translate into enhanced academic achievement, underscoring the need for further research into contextual and pedagogical factors that influence its effectiveness. To the best of the researchers' knowledge, few studies investigated how Sohar's 7th-grade students' use of TRIZ affects their academic performance in IT classes. That is the knowledge gap that the current research aims to address. In addition, several studies [25], [27], [28] recommended further research on the impact of applying TRIZ on students' academic achievement.

In response to the Ministry of Education's commitment to evaluating the effectiveness of its educational programs for 7th-grade students, particularly in the robotics unit, this study adopts a pioneering approach to investigate the actual practice of TRIZ-based innovative problem-solving during robot construction and programming. Focusing on the Wilayat of Sohar, the research systematically captures and analyzes the perspectives of IT teachers, moving beyond traditional outcome-based evaluations to assess the real-world implementation of pedagogical practices. Unlike existing studies—which primarily measure the impact of TRIZ on learning outcomes—this work introduces a methodological framework that directly examines the fidelity, depth, and contextual adaptation of TRIZ strategies as applied in classroom-based robotics projects. This approach, to the best of our knowledge, has not been previously employed in either local or international literature, offering a novel lens for understanding how innovation-oriented strategies operate within technology education at the middle school level, also helps to work in conjunction with the requirements and uses of artificial intelligence.

Therefore, in the current study, the concept of robotics centers on the construction and programming of robots and their integration into educational curricula, supported by the provision of EV3 robotics kits in schools to enable students to practice design and programming. Robotics construction and programming is considered a key domain for applying TRIZ. Students explore unit five, "the robot", in the grade seven IT textbook during the second semester, which includes the definition of robots, their types, and various application fields. Students interact with the EV3 kit as an instructional tool accompanying this unit, which contains essential mechanical and electronic components used in assembling the robot.

Consequently, this study investigated the strategy related to the learning and teaching process in the education field. Therefore, it aims to investigate differences between the pre-achievement test and the post-achievement test in the IT subject, and to examine differences in achievement and in robot assembly and programming between male and female 7th-grade students. Thus, the current study intends to answer the following questions:

i) Are there differences between the pre-achievement test and the post-achievement test in the IT subject?
ii) Are there differences in the post-achievement test scores in the IT subject among the 7th-grade students, based on the gender variable?
iii) Are there differences in the level of practice of TRIZ among the 7th-grade students during robot assembly and programming, based on the gender variable?

2. METHOD

2.1. Research methodology

The nature of the current research study necessitates the adoption of the descriptive approach, as it is suitable for describing data as is [39], allowing comparisons between the study variables and determining the extent to which TRIZ is practiced. On the one hand, the robot assembly; on the other hand, and the programming. In short, this study has measured achievement in the IT subject and performance in robot assembly and programming.

This study addresses the emerging intersection of TRIZ and robotics construction/programming—two rapidly advancing domains that have only recently begun to attract scholarly attention. Uniquely, the research develops and validates a tailored set of TRIZ strategies specifically aligned with the robotics unit in the Grade 7 IT curriculum. Unlike prior local and Arab studies, which predominantly measured the outcomes of TRIZ implementation, this work pioneers a methodological approach to diagnosing and analyzing the actual practice of TRIZ strategies during hands-on robot design and programming. By integrating direct observation and curriculum-based adaptation, the study not only fills a critical gap in the literature but also establishes a replicable framework for embedding innovative problem-solving pedagogy into the technology education field and AI.

Students begin by selecting appropriate parts for building the robot and discarding excess components through the application of specific TRIZ strategies; for instance, when connecting motors to the robot's driving base, learners employ the linking strategy, attaching a suitable motor to its designated location. They subsequently progress to programming the robot using EV3 software, choosing appropriate templates and commands while eliminating unsuitable coding elements—another application of TRIZ problem-solving strategies. Through this process, students acquire skills in addressing challenges encountered during robot design, indicating that practicing construction and programming develops their TRIZ, as illustrated in Figure 1. During these steps, their teachers observe them to record their work and orient them.

For this purpose, data on the sample members were collected, organized, and analyzed using appropriate statistical methods to yield the study results. The study sample was selected intentionally and included all schools in Sohar Governorate. The study questionnaire was administered to them to determine the extent to which 7th-grade students use TRIZ during the assembly and programming of the robot, from the perspective of their teachers. Meanwhile, the students were tested on the skills of assembling and programming the robot before starting to practice the TRIZ strategy during assembly and programming, and again after completing the study of the section of the book on assembling and programming the robot.

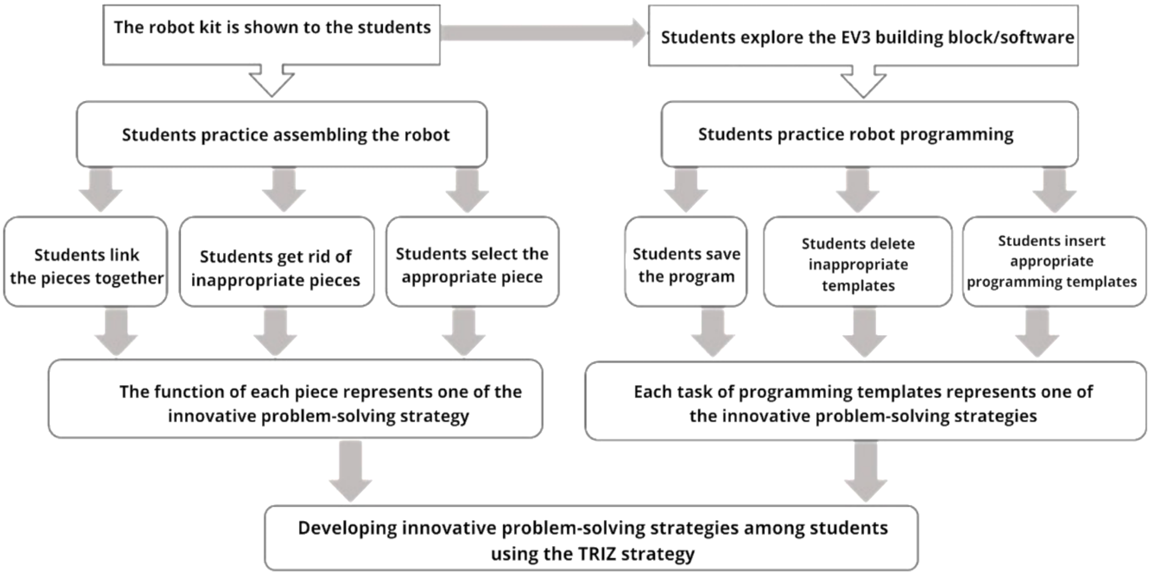

Figure 1. Model of practicing TRIZ during robot construction and programming

2.2. Research population

The research population consisted of all 7th-grade students and IT teachers from 30 public schools under the General Directorate of Education in Sohar, North Al-Batinah Governorate, Oman. The total number of 7th-grade students was 2,320, comprising 1,225 male students and 1,095 female students [40]. Table 1 shows that there were 65 IT teachers, including 28 male and 37 female teachers.

Table 1. Research population

Category	IT teachers	7th Grade students
Male	28	1,225
Female	37	1,095
Total	65	2,320

2.3. Research sample

The research sample was selected randomly using a simple cluster sampling method. The study sample comprised 65 IT teachers from 30 schools in Sohar, representing 100% of the study population. Table 1 shows that 28 male teachers (43%) and 37 female teachers (57%) were present. The 7th-grade basic student sample consisted of 329 students, representing 6.84% of the study population. The male student sample was 158 (48%), while the female student sample was 171 (52%) [40]. A simple random cluster sampling method was used to select the student sample because the study population included categories (males, females, schools, and classes). Table 2 illustrates the distribution of the study sample.

Table 2. The number of the 7th grade students and the IT teachers

Category	IT teachers	Teachers (%)	7th grade students	Students (%)
Male	28	34	158	48
Female	37	57	171	52
Total	65	100	329	100

2.4. Research instruments

After reviewing relevant previous studies, several investigations were identified that addressed the variable of academic achievement and applied instruments to measure it [25], [27], [28]. Additionally, studies focusing on the variable of practicing the TRIZ and on employing instruments to measure its practice were examined [41], [42]. Furthermore, studies that addressed the variable of robot assembly and programming and used tools to investigate the impact of practicing robot assembly and programming were reviewed, including those by Afari and Khine [38], Castledine and Chalmers [43], and Al-Nafea [44].

2.5. Validity of research instruments

The initial versions of the research instruments were presented to a panel of consultants who are experts in measurement and evaluation, as well as supervisors and teachers of IT, and specialists in curriculum design and teaching methods for IT from faculty members in several educational bodies in Oman. Based on the consultants' feedback on the achievement test and the practice scale, some questions and statements were rephrased. Based on that, resulting in the final versions of the two instruments (the achievement test and the practice scale).

2.6. Reliability of research instruments

The reliability of the achievement test was calculated using the SPSS software to determine Cronbach's alpha coefficient for internal consistency. Table 3 shows that the reliability coefficient was 0.90, indicating a high level of reliability for the achievement test. Likewise, the reliability coefficient for the practice scale was 0.88, confirming the stability of both instruments for application to the study sample.

Table 3. The reliability coefficients of the achievement test and the practice scale

Research instrument	Number of items	Cronbach's alpha coefficient
The achievement test	27	0.90
The practice scale	39	0.88

2.7. The difficulty and discrimination coefficients of the achievement test

The achievement test for the robotics unit was conducted on a pilot sample of 30 female students within the study population but outside the 7th-grade student sample at Balqis School (Grades 5-9). This test aimed to ensure the clarity of instructions, item formulation, and appropriate response time, and to calculate internal consistency and reliability. The achievement test results were analyzed by calculating the difficulty and discrimination coefficients for each item using the following difficulty coefficient equation:

$$Difficulty\ coefficient = \frac{The\ number\ of\ students\ who\ provided\ correct\ responses}{The\ total\ number\ of\ students}$$

If the difficulty coefficient value falls between 0.15 and 0.85, the question is considered acceptable. If the value is less than 0.15, the question is deemed difficult; if it is greater than 0.85, the question is considered easy. Most of the difficulty coefficients for the test items were acceptable, except for items 12 and 20, which were retained due to their importance. Table 4 illustrates the difficulty coefficients for each item on the achievement test.

Table 4. The difficulty coefficients of the achievement test items

Item	Difficulty coefficient	Item	Difficulty coefficient	Item	Difficulty coefficient	Item	Difficulty coefficient
1	0.80	6	0.69	11	0.45	16	0.61
2	0.66	7	0.72	12	0.86	17	0.56
3	0.66	8	0.57	13	0.80	18	0.50
4	0.27	9	0.78	14	0.83	19	0.72
5	0.60	10	0.57	15	0.50	20	0.87

Likewise, the discrimination coefficients for each item on the test were calculated as: i) ranking students' scores from highest to lowest; ii) dividing the scores into two groups: 50% upper group, 50% lower group; and iii) determining the number of students who answered correctly in each group for each item. Applying the formula to calculate the discrimination coefficient:

$$Discrimination\ coefficient = \frac{Scores\ of\ the\ upper\ group - scores\ of\ the\ lower\ group}{\frac{2}{1} \times Total\ number\ of\ students}$$

If the discrimination coefficient value is greater than 0.30, the question is considered acceptable, as emphasized by Sharma [45], a list of discriminatory power. Most of the discrimination coefficients for the test items were acceptable, as shown in Table 5, which lists the discrimination coefficients for each item on the achievement test.

Table 5. The discrimination coefficients of the achievement test item

Item	Discrimination coefficient	Item	Discrimination coefficient	Item	Discrimination coefficient	Item	Discrimination coefficient
1	0.60	6	0.55	11	0.67	16	0.43
2	0.30	7	0.36	12	0.40	17	0.87
3	0.55	8	0.70	13	0.30	18	0.56
4	0.44	9	0.55	14	0.32	19	0.48
5	0.61	10	0.30	15	0.80	20	0.44

3. RESULTS AND DISCUSSION

3.1. Descriptive statistics

The normal distribution of data in the research instruments can be verified by the results of central tendency and measures of dispersion, as well as skewness and kurtosis values [46]. Table 6 presents the measures of central tendency for the achievement test, with a mean value of 0.90, a median of 0.91, and a mode of 0.95. The comparison of these values indicates their proximity.

Table 6. The measures of central tendency and dispersion

Instrument	Sample size	Measures of central tendency			Measures of dispersion			Skewness values	Kurtosis values
		Mean	Median	Mode	Standard deviation	Variance	Range		
Achievement test	329	0.90	0.91	0.95	0.07	0.005	0.32	-0.51	-0.28
Practice test	63	4.34	4.35	4.41	0.34	0.04	1.31	-0.85	0.75

Correspondingly, Table 6 shows that the skewness was 0.51 and the kurtosis was 0.28, both of which fall within the range of -1.00 to 1.00. As for the measures of central tendency for the practice scale, the mean value was 4.34, the median was 4.35, and the mode was 4.41. Again, these values are close. The skewness value was -0.85, and kurtosis was 0.75, falling within the acceptable range of -1.00 to 1.00. The results indicate that the data follow a normal distribution, as illustrated in Figures 2 and 3.

Figure 2 shows the distribution of the achievement test responses, which is symmetrically distributed around the mean of 0.90 and follows a curve indicative of a normal distribution. However, Figure 3 shows the response distribution, which forms a bell-shaped curve typical of a normal distribution and is symmetrically distributed around the mean of 4.34. Consequently, this result indicates that most observations are close to the average and can be used for parametric measurements.

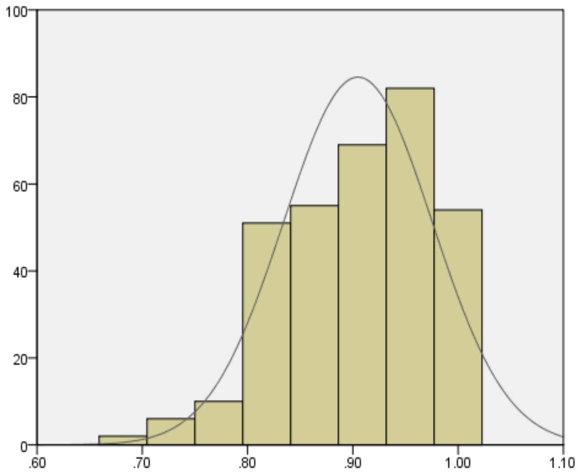

Figure 2. Distribution of sample means for the achievement test

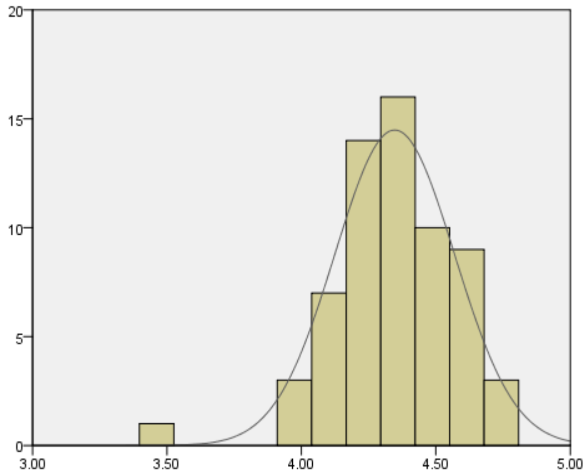

Figure 3. Distribution of sample means for the practice scale

3.2. Results and discussion of the first research question

To answer the first research question, differences among the mean scores and standard deviations of the 7th-grade students' responses on the pre-test and post-test achievement were calculated using a one-sample t-test. Table 7 presents the sample sizes for the pre-test and post-test achievement, totaling 329

7th-grade students from Sohar. The pre-achievement test's mean score was 0.880 with a standard deviation of 0.094; whereas the post-achievement test's mean score was 0.805 with a standard deviation of 0.058. These findings show that 7th-grade students achieved a high level of academic accomplishment in robot assembly and programming in the IT subject.

Table 7. Differences in mean scores and standard deviations of the pre-test and post-test achievement

Test type	Number of students	Mean	Standard deviation
Pre-test	329	0.880	0.094
Post-test	329	0.805	0.058

The results in Table 8 indicate that the significance value is less than the significance level of 0.05, suggesting statistically significant differences in the mean achievement scores of the 7th-grade students between the pre-test and post-test in the IT subject, in favor of the post-test. This implies that learning robot assembly and programming had a positive impact on the academic level of 7th-grade students in the IT subject when they practiced TRIZ. This contributes to achieving educational objectives and acquiring knowledge and skills among this student group. On the other hand, the teaching of IT teachers who are knowledgeable about TRIZ strategies affects their students' achievement in this subject, as Park [7] confirmed that teachers' possession of TRIZ skills increases their beliefs and the effectiveness of their teaching. Additionally, one of the findings of Chen *et al*. [18] is that TRIZ enhances the quality of teaching through targeted improvement procedures; its application helps successfully overcome the failures of the activities used in teaching methods, thereby improving the quality of teaching activities.

Table 8. One-sample t-test for the pre-test and post-test achievement

Test	No.	Mean	Standard deviation	p-value	Degrees of freedom	Significance value	Significance interpretation
Pre- and post-tests	329	-0.077	0.095	-14.710	328	0.00	Significant

These findings align with several studies [23]–[25], which reported that studying robotics led to the application of TRIZ among 7th-grade students in the IT subject. More than that, the study by Koray and Uzuncelebi [47] found that the academic achievement and problem-solving skills of 5th-grade students in the experimental group of a public school in Turkey, who used robotic-assisted activities, were significantly higher on both tests. The researchers attributed this outcome of the current study to the motivational effect of studying robotics, which fosters competition, creates a passion for learning, and enhances higher-order thinking skills, such as creative thinking and problem-solving, through time management. This is also connected to effective information delivery methods, which ultimately improve students' academic performance.

3.3. Results and discussion of the second research question

To answer the second research question, differences in the mean scores and standard deviations of the 7th-grade students' responses on the pre-test and post-test were calculated using an independent-samples t-test. Table 9 indicates a sample of 329 7th-grade students from Sohar on both pre-test and post-test achievement. The table presents the mean scores and standard deviations for the post-achievement test: 0.883 and 0.057 for males, and 0.881 and 0.060 for females. These results suggest a high level of academic achievement for 7th-grade students in the IT subject.

Table 9. Differences in mean scores and standard deviations of the post-achievement test

Gender type	Number of students	Mean	Standard deviation
Male	158	0.883	0.057
Female	171	0.881	0.060

According to the results in Table 10, there are no statistically significant differences in the mean scores of the 7th-grade students between the pre-test and post-test in the IT subject. This is because the significance value exceeds the 0.05 threshold. This suggests that the gender of the 7th-grade students did not significantly affect the influence of the TRIZ strategy on academic progress in the IT subject.

Table 10. Independent samples t-test for the post-achievement test in the IT subject

Gender	Number	p-value	Levene's Sig.	t-value	Degrees of freedom	Significance value	Significance interpretation
Male	158	0.493	0.483	0.337	0.327	0.736	Non-significant
Female	171						

These findings align with the results previous studies [22], [48], [49], which showed equal academic performance improvement in both male and female. The researchers found that students' gender did not significantly affect the influence of TRIZ strategy application on academic performance. That is because the results of Hsu and Ou [35] show that the combination of innovative and sustainability education, along with the effectiveness of students' collaboration, enhances students' learning, regardless of gender.

The reason for this result is that applying TRIZ while studying robotics improved both genders' academic levels in the IT subject. The training on robot assembly and programming skills using TRIZ strategies was evenly distributed between males and females within the same timeframe and educational environment. Therefore, providing equal learning opportunities and experiences for both groups.

3.4. Results and discussion of the third research question

To answer the third research question, mean scores and standard deviations were calculated for males and females, and an independent-samples t-test was used to investigate potential differences in the level of practice of TRIZ between male and female students. Table 11 shows that there is no statistically significant difference in the means of the TRIZ used by male and female 7th-grade students in the applied research instrument. In terms of gender, the mean score for males was 0.90 with a standard deviation of 0.067, while it was 0.90 for females with a standard deviation of 0.073. This suggests that the benefits of practicing robot assembly and programming were gender-neutral and equally influential on male and female.

Table 11. Independent samples t-test for the level of practice of TRIZ between male and female students

Group	Number	Mean	Standard deviation	t-value	Degrees of freedom	Significance
Male	158	0.90	0.067	-1.003	328	0.86
Female	171	0.90	0.073			

These findings align with the results of several studies [22], [48], [34], that the benefits of practicing robot assembly and programming had an equal influence on both male and female. The researchers attributed the need for computational thinking skills to take time to fully develop. However, the students' scores show that students' academic performance improves significantly towards the end of the activity.

This may be attributed to the similar influence of assembly processes and the selection of appropriate programming blocks for each task on both genders. Additionally, the students' programming skills, as well as the presentation of concepts and procedures in the same manner, contributed to similar levels of male and female participation in practicing TRIZ. It is also clear that both males and females exerted equal effort to enhance their TRIZ strategy skills, and because TRIZ strategy is considered a tool that supports creative personality traits regardless of gender [16], [33], this further explains the lack of difference in performance and achievement between them.

4. CONCLUSION

This study demonstrated that integrating robot assembly and programming into IT instruction significantly enhanced 7th-grade students' academic achievement, with post-test results showing marked improvement across both genders. The absence of gender-based differences in either achievement or application of the TRIZ problem-solving strategy underscores its inclusivity and effectiveness in fostering higher-order thinking, innovation, and practical problem-solving skills. The success of TRIZ in this context is attributed to its structured yet flexible approach, provision of diverse problem-solving techniques, and creation of a resource-rich, challenge-oriented learning environment that empowered students to achieve excellence.

These findings highlight the strategic value of embedding innovative pedagogies such as TRIZ into technology education to build sustainable, future-ready competencies. It is recommended that the IT curriculum systematically incorporate TRIZ-based activities and robotics projects to cultivate automation skills and deepen students' understanding of artificial intelligence—critical areas for 21st-century learning. Future research should investigate advanced integrations of AI in robotics within school curricula to expand students' technical mastery, problem-solving capacity, and adaptability in the rapidly evolving digital landscape. Moreover, integrating TRIZ with emerging artificial intelligence tools could further enhance its utility, enabling students to generate, refine, and test creative solutions through AI-assisted modeling, simulation, and predictive analytics. Such integration could open new pathways for cultivating advanced problem-solving skills in both education and professional training contexts.

Although this study offers novel insights into the real-world practice of TRIZ-based innovative problem-solving within the Grade 7 robotics curriculum, its scope was bounded by certain constraints; the findings are limited to unit 5 (robots) of the 7th-grade IT textbook and to a specific sample of IT teachers and students in Sohar Governorate, Oman. While these parameters ensure contextual depth, they may limit generalizability to other regions, grade levels, or subject areas. Despite these boundaries, the methodological framework developed here holds significant potential for adaptation across various STEM disciplines—and even beyond, into fields such as engineering design, environmental problem-solving, and healthcare innovation.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

No conflict of interest.

DATA AVAILABILITY

The data and Instruments available through following link: https://studentssoharuniedu-my.sharepoint.com/:f:/g/personal/aghafri_su_edu_om/Ep_fl-LF1EdCjDqEvlc4u3wBlP0aGu8ktYozgr-csZ2jXA?e=Q5ewPk.

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