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GAMIFIED EDUCATIONAL ROBOTS LEAD AN INCREASE IN MOTIVATION AND CREATIVITY IN STEM EDUCATION

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Abstract. *The combination of education and robots is becoming an increasingly important issue. Although researchers have conducted some studies on educational robotics in STEM education at the undergraduate level, no research examined the effects of gamified educational robotics on participants' motivation and creativity. Therefore, this study examines the effects of gamified educational robots on participants' learning motivation and creativity in STEM. A quasi-experimental research design was used in this study. A total of 108 students from two classes enrolled in the information technology course were involved as participants. Learning motivation and creativity scales were used to collect data. The participants were introduced to a gamified educational robot as the course objective, learning content, and game mechanism to increase motivation and help students solve problems. In contrast, students in the control group received conventional instruction consisting of group discussions and lectures. Activities in both groups were held for eighteen weeks in three phases. The results showed that gamified educational robots could enhance learning motivation and positively influence learners' creativity. The results also indicate that learning motivation has significant effects on creativity, and students with high motivation perform better in terms of creativity. The results strengthen interdisciplinary STEM teaching and promote students' learning outcomes.*
Keywords: *gamification in STEM education, educational robot, STEM curriculum, learning motivation*

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Introduction

With the development of time and the progress of technology, educational reforms are being carried out in various countries to promote competitiveness and demand for STEM education. The alignment of different courses in the field and the curriculum design enables students to continue and integrate learning in various areas and interdisciplinary learning. The current curriculum designs emphasize students' problem-solving ability, deep learning, multidisciplinary knowledge integration, and practical application. STEM, the interdisciplinary teaching model combining science, technology, engineering, and mathematics, provides students with many skills needed in the 21st century, such as complicated communication, problem-solving, and teamwork (Lei et al., 2020). The learning content of the STEM curriculum provides students with specific subject knowledge that connects them to the ability to integrate interdisciplinary knowledge and further promote learning outcomes (Sailer & Sailer, 2021). The STEM curriculum design also emphasizes real-world situations or actual problems as a backdrop for students to solve problems using exploratory and problem-based methods.

The knowledge covered in the STEM curriculum is vast and complicated, and the content could be more abstract and quickly learned. Previous research has shown that learning motivation is essential to students' learning performance (Bai et al., 2020). Unfamiliar or uninteresting content would eventually lead to low student learning motivation. A gamification curriculum could effectively arouse students' learning interest. The term gamification curriculum refers to integrating elements or mechanisms of video games, such as scoreboards, quizzes, and badges, into the classroom. Previous research has found that such a method can improve learning focus, motivation, problem-solving skills, and student willingness to participate (Sanchez et al., 2020). Chevalier et al. (2020) analyzed the results of an educational robot activity for problem-solving. Their results showed that the training helped enhance students' cognitive processes related to problem understanding, idea generation, and solution formulation, helped them develop a well-established strategy for approaching learning robot problems, and could be an effective method for scaffolding.

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In a recent systematic review of studies on educational robotics, Anwar et al. (2019) found 53 studies on educational robotics that addressed creativity and student motivation. The studies in their analyses considered motivational aspects of creativity to improve students' motivation and interest in STEM courses and programming. They found that educational robotics was used in the studies to encourage and increase students' interest in STEM concepts. They also indicated that engaging students in learning robotics could increase student creativity. To parallel this result, Gubenko et al. (2021) have emphasized that gamification can support the implementation of educational robotics interventions. Sailer et al. (2013) have stated that gamification and game elements could stimulate motivational mechanisms and foster motivation. The results from this research indicate that gamified learning robots have the potential to attract and increase students' learning motivation and interest. It was found that they used gamified educational robots in the classroom and introduced them to support students' learning process in programming to improve students' engagement in learning the content of the STEM curriculum (Madariaga et al., 2023). Robotics education could motivate students to study STEM-related subjects (Daher, 2022) and positively support the national demand for capacity in the STEM fields.

A gamified robotics teaching could integrate STEM education to attract students, help students identify and solve problems with multidisciplinary knowledge, and help students overcome the career barrier in STEM. Research has shown that using educational robots in STEM curricula positively influences students' problem-solving and teamwork skills (Chevalier et al., 2020; Madariaga et al., 2023). Some research has found that gamified educational robots can improve students' engagement with the STEM curriculum, attitude, problem-solving, and learning motivation (Reyes et al., 2021). In a newly published study, Leonard et al. (2016) indicated that using robotics and game design encouraged some students to design creative and interesting games.

Gamification involves applying game elements in different situations (Sanchez et al., 2020). Game elements are designed to achieve specific goals and precede certain activities or tasks. When a gamified learning robot with a humanoid appearance presents intelligent features such as voice feedback, communicative dialogs, moving limbs, and mood-simulated displays, it is suitable for integrating the STEM curriculum with gamified instruction because it could encourage students to achieve learning goals with hand gestures and facial expressions in real-time to improve students' learning motivation and learning attitude in the STEM curriculum and indirectly influence learning performance. Gamified educational robots can attract users, elicit learning interests, and make the teaching process in the STEM education process more entertaining. The introduction of gamified educational robots can help teachers develop curriculum and instruction, and students can practice unfamiliar parts with gamified learning robots. In recent years, the widespread integration of educational robots into the classroom to teach specific topics has been to appear in the education field in the literature (Chou, 2018). Similarly to these developments, educational robots have been integrated into many countries' curricula and extracurricular activities. However, the use of gamified educational robots has not been researched by scholars in the current literature. Despite the increased interest in educational robots, there is no current research on using gamified educational robots in the classroom to increase student motivation and creativity. From this perspective, gamification elements are integrated into the curriculum to make learning more exciting and increase student motivation and participation. Hence, this study examined the effects of gamified educational robots on students' learning motivation and creativity in STEM.

Literature Review

The integrated teaching model for science, technology, engineering, and mathematics is called STEM education in the United States. STEM education is stressed because learners can apply the necessary knowledge to solve problems in daily life. Many researchers proposed practical courses for STEM learners to solve problems in daily life (Estes et al., 2014İ; Lent et al., 2021). For example, STEM-centered courses using learning robots can increase students' interest in learning and their cognitive and social skills and help them learn innovative technologies (Sapounidis & Alimisis, 2020). In parallel with this finding, STEM-centered learning that integrates gamified learning robots can have five principles: (1) play and people as the focus of the learning activity, (2) divergent solutions with different learning and outcome pathways, (3) students as creators and publishers, (4) sharing and collaboration, and (5) engaged learning (Mylonas et al., 2021). Previous research has shown that STEM education can successfully integrate robots as learning and teaching tools (Benitti & Spolaôr, 2017; Ching et al., 2019), but the use of gamified learning robots in STEM practice curricula is very rare.

A few similar studies used gamified educational robots in STEM education. For example, Dorotea et al. (2021) examined computer science teachers' knowledge, interest, and confidence in using learning robots. They found that

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teachers' knowledge, interest, and self-efficacy in using learning robots for teaching are very positive. The results also highlight the interest of teachers in using robotics and supporting their students in such learning activities. In another research, Rahman (2021) surveyed to examine the experiences of middle school mathematics and science teachers' experiences with developing and implementing robotics-based instruction. Results indicated that the expected learning outcomes for robotics instruction were related to the learning gains observed in traditional instruction (content knowledge) and improved student behavior and social, scientific, cognitive, and intellectual skills. García-Carrillo et al. (2021) examined teachers' perspectives regarding an integrated STEM approach used in this educational process along with educational coding and robotics in primary education. The results showed that teachers viewed the integrated approach of STEM and pedagogical coding and robotics positively despite their practical difficulties practically. They emphasized that the STEM approach and its methods benefit students and teachers by improving the teaching and learning process.

Theodoropoulou et al. (2021) systematically reviewed published Greek studies on educational robotics. Their analysis revealed that the research promoted the participants' technological literacy, interest, and excitement. In addition, their results show that ER appears to support the development of critical thinking and problem-solving, communication, collaboration, creativity, and innovation. In a recent study, Budiyanto et al. (2022) studied the effects of a hands-on robotics course for pre-service teachers in a STEM workshop. They found correlations between the principles of computational thinking and STEM education and a positive contribution to the learning experiences of preservice teachers.

Meschede et al. (2022) examined the effects of an after-school robotics program on students' interest in STEM and the likelihood that participants would pursue STEM in their academic and professional careers. They collected data in a 7-year follow-up study of intervention and comparison groups participants. Their results showed that college students were significantly more likely to report STEM college-level interests, attitudes, and behaviors than comparison students who had not participated in an educational robotics program. In a different study, Boya-Lara (2022) implemented an educational robotics program to improve the knowledge and skills of engineering students in STEM education. Their results showed that this new teaching tool could promote STEM curriculum among engineering students and motivate them to implement it as new educational robotics. Recently, Fegely and Tang (2022) examined the effects of educational robotics on prospective teachers' programming comprehension and motivation. Their results showed statistically significant values for prospective teachers' comprehension of programming concepts and motivation toward programming. A recent review by Mou and Li (2022) examined the impact of artificial intelligence robots on education. They found 18 articles that met their criteria between 1999 and 2019. They categorized the studies they examined by topic and found that one of the topics related to the studies on robots and education is related to the impact of educational robots with artificial intelligence on students' creativity and motivation.

Although researchers have conducted some studies on educational robotics and STEM education at the college level (for example, Budiyanto et al., 2022), no research examined the effects of gamified educational robotics in STEM education on participants' motivation and creativity. Moreover, scholars have argued the use of gamification and educational robotics in STEM education and reported positive outcomes. For example, Werbach (2014) suggested referring to gamification instruction as the process of making the activity more like a game. Recently, Kalogiannakis et al. (2021) suggested that gamification design should represent essential elements of a game, including game mechanics, dynamics, and framework. In addition, researchers have pointed out that creating a new environment, changing the teaching model, and encouraging student motivation are among the factors that promote and increase creativity. STEM education enhances students' creativity (Aguilera & Ortiz-Revilla, 2021). In examining the studies on STEM education and robots, students with good learning motivation are more persistent and engaged in learning activities in the STEM curriculum, which leads to good learning outcomes. For this reason, when designing the STEM curriculum, students' interest in the subject and its relevance arouse inner drive and promote creativity more successfully. It has been pointed out that the STEM curriculum should pay more attention to enhancing motivation and providing appropriate incentives in time to achieve positive effects on creativity. Because of this reason, the present study hypothesizes that gamified educational robots strengthen interdisciplinary integration and improve student learning outcomes. Based on the above considerations, this study aimed to

1. Promote students' learning motivation and creativity by introducing gamified educational robots into the STEM curriculum.
2. Promote students' creativity through learning motivation in the STEM curriculum.

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Research Methodology

Research Design

This study used a quasi-experimental research design to determine the effects of gamified educational robots on participants' learning motivation and creativity in STEM. A pre-test and post-test design were used in experimental and control groups for this aim. Before the experiment, both groups were tested using data collection instruments. The same instruments were used to determine the effects of instruction after the experiment.

Participants

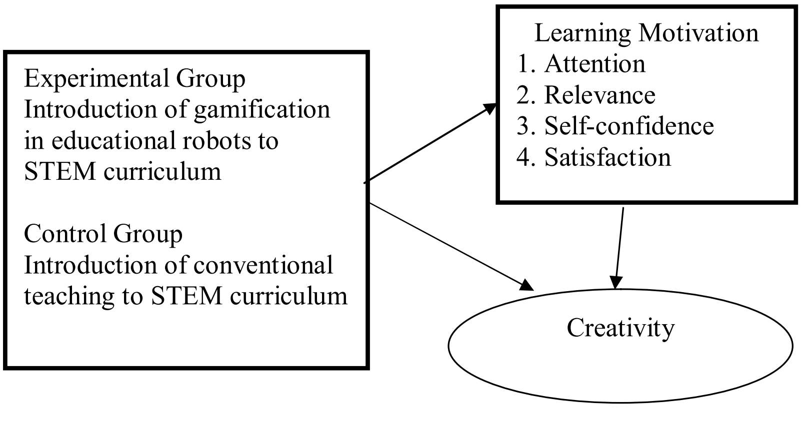
Students from a university in Taiwan were included as participants in the present study. The participants had enrolled in an information technology course. They were from the Department of Computer Science & Information Engineering of the National Kaohsiung University of Science and Technology, Taiwan. The participants were 108 students who registered for the course in the experimental and control groups. The participants attended an information technology course for eighteen weeks in the spring semester between February and July of 2022 teaching year. The experimental and control groups were randomly selected. Each group included 54 students. Participants in the experimental and control groups attended the 18-week experimental class and project practice. In this study, students with knowledge of tool application and programming were selected to provide a more comprehensive basis. The author obtained the necessary permissions from the university where the research was conducted. In addition, the authors promised the participants and lecturers that the data obtained from this study would not be shared with third parties.

Procedures

One experimental and control group included the effects of gamified educational robots on students' learning motivation and creativity. The steps that the researchers followed in the study are as follows. First, 108 students were determined as participants in two classes at a college in Taiwan. One of the classes as the experiment and the other class as the control group was chosen. Both groups consisted of 54 students. Second, a pre-test on course explanation, learning motivation, and creativity was administered during the first week of the semester in which the students were taught. Third, the teaching experiment was conducted over sixteen weeks, including fifty minutes each week. Fourth, a post-test on learning motivation and creativity was administered during the last week of the teaching semester. Fifth, practical ability was assessed based on the students' work. Sixth, the researchers analyzed the data obtained from the survey instruments.

According to the above literature, the following variables are examined in this study.

Figure 1
Structure Diagram



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Two major practices of (1) intelligent streetlight and device placement area and (2) smart trash cans were implemented in the present study. The STEM teaching model integrating science, technology, engineering, and mathematics was used during the activities. STEM education was emphasized because the control group stresses knowledge discourse, causing learners to lack the ability to solve problems in daily life. Many researchers propose hands-on courses in STEM education for learners to solve problems in daily life (Lei et al., 2020). Various activities were designed to provide more development opportunities for students to select their traces and appearance configuration. The work was done after completely connecting such devices and wires. A gamified educational robot was introduced according to the experimental group's course objective, learning content, and game mechanism.

For the curriculum design, a gamified education robot was used in the experimental group that (1) can be controlled by programming or communication technology or precede an appropriate learning activity, (2) whose display has a humanoid appearance, a movable head, hands, and legs, and can simulate a mood, and (3) has voice recognition and communicative dialog functions. "Smart City" is the core of the curriculum design, which uses STEM interdisciplinary knowledge to make students understand the composition of devices and device components in the smart city and the operating principles of these devices and combine them with general knowledge, which is no longer the learning of theories but can be combined with daily life. It enables students to integrate the "smart trash cans" and "intelligent streetlights" planned in their project into the knowledge-learning process through programming and practicing the learned knowledge and ideas. The course content was based on the modular programming and problem-solving practice required for the information technology course. The curriculum design, discussed and drafted with teachers from the relevant areas on and off campus, is consistent with information technology learning content and includes a discussion of social issues related to information technology (smart city) and application and practice of modular programming (smart Arduino intelligent streetlight, smart trash can). The programming language used in the course is taught through a block-oriented language (motoBlockly).

The teacher then guided the students to understand the importance of streetlights and trash cans to develop more functions. Researchers used films and videos to introduce students to intelligent streetlights and smart trash cans designs in various countries. The control group was instructed by the instructors' teacher's narration. The students were taught the principle of connection, parts, and programming. For the experimental group students in the experimental group have game challenges to review course content. On the other hand, the students in the control group discussed with each other and followed the teacher's instructions. This study's implementation of STEM activities was conducted over 18 weeks in three stages. A gamified educational robot was used in each lesson to foster motivation and assist students with the problems. Researchers noted students' challenges during the activities and sought to facilitate the teaching process. The detailed content and explanation for each stage are listed in Table 1.

Table 1
Details of Activities in Procedures

Weeks	Activities per each week	Brief description of the activities
1-2	This stage stresses on the introduction and knowledge of smart city-related concepts.	The two-week course in this stage is divided into 2 parts. (1) The introduction of a smart city, which was carried forward to find out intelligent stuff in city life. (2) The understanding of basic use and the relevant application as well as familiarizing the user interface. The experimental group has a gamified educational robot to induce motivation in order to know the objective of the lesson and the use of the gamified educational robot. The control group applies student discussion and teacher instruction.
3-7	This stage focuses on learning basic applications.	(1) To learn electronic devices used for smart cities and understand the principles as well as learn to program. (2) To learn the operation logic of block-oriented language and the meanings and use of blocks. The experimental group has a gamified educational robot for interactive discussion and problem-solving in practice. The control group applies student discussion and teacher instruction.
8-12	This stage stresses on students' application and practice after the learning in the previous two stages.	The teacher would simply introduce the concept of the practice work and the use of hole sites on the density board. The students would self-construct, decorate, and complete in the remaining time.

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Weeks	Activities per each week	Brief description of the activities
13-17	It is the point in this stage to have students precede intelligent streetlight design and the application and practice of smart trash cans.	A gamified educational robot would introduce the course objective, learning content, and game mechanism to the experimental group. The teacher then guides the students to understand the importance of streetlights and trash cans to develop more functions. Intelligent streetlights and smart trash can designs in various countries in the world are introduced through films and videos. The control group is simply instructed by the teacher's narration. The students are taught to know the principle of part assembly and connection as well as programming. For the experimental group, students in the experimental group have game challenges to review course content. The control group, on the other hand, would discuss with each other and accept the teacher's instruction.
18	Learning outcome check	The works of students in different groups are evaluated, and the learning motivation and creativity post-test is preceded.

Data Collection Instruments

Learning Motivation Scale

The scale we used in this study to measure students' motivation to learn was the Learning Motivation Scale, developed by Lee et al. (2021). They developed this scale according to the ARCS motivation model. The scale contained four dimensions, including attention (twelve items), relevance (nine items), self-confidence (nine items), and satisfaction (six items). It consisted of 36 items in total. Each item was rated on a 5-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). The higher scores gained from the scale show a higher motivation to learn. Cronbach's alpha was 86 in the scale development study.

Creativity Scale

The Creativity Assessment Packet (CAP), developed by Williams (1972), was used to assess student creativity. The CAP aimed to evaluate creativity, merely the "creativity tendency scale" for the participants' works. Many researchers have still used the CAP, even in the newest research in recent years. It has been used as a tool for evaluating creativity. It has 50 questions. It was scored according to three points for complete compliance, two for partial compliance, and one for complete discord. The total score that could be gained was 150 points. There are ten reverse questions among them. If a student gets a higher score from the CAP, it demonstrates a higher level of creativity. The CAP requires students to complete a series of 12 incomplete figures. The CAP consisted of sub-dimensions such as fluency, openness, flexibility, originality, elaboration, and title. Higher scores indicate a stronger ability for a particular aspect. Each dimension of the CAP was scored differently according to guidelines suggested by the developers. The CAP included instructions for scoring. Researchers used these instructions to assess student creativity.

Data Analysis

Analysis of variance was applied to determine the difference between gamified educational robots in the STEM curriculum in terms of learning motivation and creativity. Regression analysis was used to understand the relationship between learning motivation and creativity. An independent samples t-test was used to analyze the differences between the two groups. The results showed that the pre-tests for both groups' prior knowledge, learning motivation, and creativity were insignificant (p = .371; p = .533; p = .482).

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Research Results

Effects of Gamified Educational Robots in STEM Curriculum on Learning Motivation

An independent *t*-test was conducted to determine the effects of the analysis of gamified educational robots in STEM education on learning motivation. For this aim, we run the test for each dimension of the motivation scale. According to independent t-test analysis, we found significant differences between mean scores between control and experimental groups. Table 2 shows higher attention (4.47 > 4.03), relevance (4.52 > 3.81), self-confidence (4.44 > 3.92), and satisfaction (4.43 > 3.89) in favor of the use of gamified educational robots in STEM curriculum than in the control group.

Table 2
Difference Analysis of Gamified Educational Robots in STEM Curriculum on Learning Motivation

Variable		*M*	*t*	*p*
Attention	Experimental group	4.47	2.528	.013
	Control group	4.03		
Relevance	Experimental group	4.52	4.527	.001
	Control group	3.81		
Self-Confidence	Experimental group	4.44	3.197	.002
	Control group	3.92		
Satisfaction	Experimental group	4.43	3.104	.003
	Control group	3.89		

Effects of Gamified Educational Robots in STEM Curriculum on Creativity

We conducted an independent t-test analysis to determine the effects of the analysis of gamified educational robots in STEM education on creativity. According to independent t-test analysis, we found a statistical difference between the control and experimental groups. This difference is in favor of the experimental group. Table 3 reveals higher creativity in the gamified educational robots in the STEM curriculum than in the control group ($p < .001$).

Table 3
Difference Analysis of Gamified Educational Robots in STEM Curriculum on Creativity

Variable		*M*	*t*	*p*
Creativity	Experimental group	4.61	3.417	.001
	Control group	4.06		

Note. $p < 01$

Correlation Analysis of Learning Motivation and Creativity

Table 4 reveals notably positive effects among subdimensions of the motivation scale, such as attention, relevance, self-confidence, and satisfaction ($\beta = 0.311^{***}$; 0.265^{***}; 0.297^{***}; 0.160^{***}) and creativity. These results mean that the subdimension of motivation has a statistically positive effect on creativity.

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Table 4
Analysis of Learning Motivation for Creativity

Dependent variable→ / Independent variable↓	Creativity	
Learning motivation	β	p
Attention	.311***	.001
Relevance	.265***	.001
Self-confidence	.297***	.001
satisfaction	.160***	.001
F	358.541	
Significance	.001	
R2	.933	
adjusted R2	.930	

Note. *** stands for $p < .001$.

Discussion

The research results showed that gamified educational robots could effectively enhance learning motivation because the educational robot could enhance students' attraction to the appearance. The educational robot provided students with lesson points and reminded students to ask questions. This result shows that a gamified educational robot presents higher affinity and interaction with students, as it is not a real person, as well as gesture, speech, and expression. When students inquire, the gamified educational robot enhances their confidence by allowing them to interact with real people and learn in an interesting process. In sum, the gamified educational robot allows students to acquire confidence in the learning process and enhance participation and motivation in class to acquire satisfaction further. This result is partly similar to the results of Madariaga et al. (2023). For example, Madariaga et al. (2023) found that tangible robotics games successfully motivated elementary school students to develop collaborative computational thinking with coding problems as part of the mathematics curriculum. Furthermore, the present study found a statistically significant difference between the control and experimental groups in favor of the experimental class that used gamified educational robotics in the STEM classroom. There is a similarity between the study of Madariaga et al. (2023) and this study regarding increasing the participants' motivation. In addition, this result is consistent with previous research that has shown that educational robotics helps increase preservice science teachers' motivation as they learn to program the robots (Barak & Assal, 2018; Fegely & Tang, 2022; Kim et al., 2015; Kucuk & Sisman, 2018). For example, Fegely and Tang (2022) pointed out that learning robotics can improve pre-service teachers' motivation. Moreover, the results related to motivation support the findings of Anwar et al. (2019), who examined a systematic review of educational robotics. Their analysis found that, in general, researchers have used educational robotics to enhance and promote student creativity, and research was guided by the idea that educational robotics increased student interest and motivation. In their analysis, they found 53 studies on motivation and creativity. Similarly, the results are similar to those of Cuellar et al. (2014), who report that unique and innovative educational robotics motivated students to be interested in science and technology.

The experimental group had significantly higher creativity than the control group. This result shows that including gamified educational robots positively affected learners' creativity tendencies. In the briefing cur-

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riculum design of the gamified educational robot, it is difficult for students to receive solutions from it directly. The gamified educational robot often applies speech functions to ask students or have students precede thinking. During the challenge, students were also encouraged when making mistakes, allowing them to receive inspiration without destroying their emotions and to attempt unknown affairs. In this case, learners, under the assistance of the educational robot, are more enthusiastic, curious, and willing to step into unknown areas for exploration and learning. The findings on creativity in this study are very similar to those of Theodoropoulou et al. (2021), who revealed that educational robotics supported the development of creativity and innovation skills of students at many levels in the majority of the studies they examined. The results related to creativity support the findings of Anwar et al. (2019), who conducted a review on educational robotics. Their analyses revealed that researchers used educational robotics to enhance and promote students' creativity. Their results show that educational robotics has increased students' creativity and that many studies have helped to increase and promote students' creativity.

This study added new insights to the literature by incorporating gamified educational robots into STEM lessons to enhance student motivation and creativity. This research shows that gamified educational robotics can complement STEM lessons to increase student engagement and learning motivation. Hence, this research contributes to the literature by providing robust evidence for using gamified educational robots in the STEM classroom. Moreover, this evidence provides a new viewpoint for using gamified learning robots in the STEM classroom.

This study has some limitations. First, the study was conducted with a limited number of students in Taiwan, and the experimental teaching lasted eighteen weeks. Since the context in which this study was conducted has some unique features, there may be differences in context and contextual factors in further studies. For this reason, future research should be conducted in other contexts. Second, the activities in this study were developed based on the researcher's background and experience with students. Different teaching methods and techniques may be considered to combine and use gamified educational robotics in STEM teaching in different studies.

Conclusion and Implications

This study examined the effects of gamified educational robots on participants' learning motivation and creativity in STEM. The results showed that gamified educational robots could enhance learning motivation and positively influence learners' creativity. The results also showed that learning motivation has significant effects on creativity, and students with high motivation perform better in terms of creativity. The trends in robot technology strengthen interdisciplinary STEM teaching and effectively promote students' learning outcomes. The results show that this research provides important practical implications for using gamified educational robotics in STEM education to engage participants in learning and support their creativity in STEM-related studies. In response to the gradual emphasis on STEM curriculum in education, combining it with practical exercises can help students realize the content required on STEM with the knowledge they have learned. Besides increasing learning fun, they could apply and create what they have learned to build a personal knowledge structure.

For this reason, the learning content in technology was chosen as the basis for the course content, and the smart city was used as the theme for the STEM practice curriculum, which includes science, technology, engineering, mathematics, and the corresponding fields so that students can incorporate electronic elements into the life-related course content. This study's experimental and control groups applied the STEM curriculum to lesson design, including participation, exploration, explanation, implementation, deepening, and evaluation. Organized and hierarchical methods were used to guide students in constructing knowledge. By integrating gamification mechanisms into the STEM curriculum, the learning robot can provide gestures, facial expressions, and speech to make the behavior closer to humans so that students would be more willing to communicate and ask relevant questions. Gamification mechanisms can make the learning content more engaging. The robot provides positive encouragement when students make mistakes in challenges or encounter problems in practice to build confidence and motivation. Implementing a STEM activity requires new strategies and expertise for instructors. Such implementation depends on the creation of new learning environments that allow participants to learn and experience new technologies in STEM education that is new to them.

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Recommendations

Regarding the planning of the teaching content, a smart city was chosen as the theme for the design. Content for the participants can be closer to students' lives and apply to them what they have learned in class. In this way, students can be better motivated and more easily achieve the teaching objectives set by the teacher. The interactive curriculum content with the educational robot in the STEM curriculum is set. The content is designed so students can trigger it by clicking on it. They need to open the corresponding web pages through a computer to make changes. Thus, the learning robot used in this study includes corresponding speech kits and speech assistants for development. The researcher proposes to develop this part in the future to make it more intuitive for students to use and better present intelligence.

In this study, gamified learning robots are used in STEM curricula, and the relevant practice is learning content. Although the content has been designed and the difficulty level has been considered, students still need help understanding the principles of the elements and the logical programming content. In addition, when the teaching time is short, many students are interrupted by the learning process when they are about to engage in the practice. In this case, the implementation complexity should be simplified in the future. Continuous instruction can be necessary, such as two consecutive sessions or club time students can learn wholly and continuously. In addition, lecturers who teach STEM subjects should ensure the implementation of formal STEM education and encourage students and their colleagues to participate in formal STEM activities (Wang et al., 2021). Second, scholars should seek to introduce gamified educational robots, implement them in teaching STEM subjects, and explore how they can be integrated into the teaching process to increase interest and motivation in STEM subjects.

Declaration of Interest

The authors declare no competing interest.

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