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Enhancing computational thinking in elementary students through STEM and Mojobot

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ABSTRACT

The study aims to explore the effects of using Mojobot, an interactive coding robot, within science, technology, engineering, and mathematics (STEM) education to enhance computational thinking (CT) skills among elementary school students. This research explores how educational robotics enhance algorithmic thinking, logical reasoning, and problem decomposition in young learners, addressing future workforce demands for digital literacy and problem-solving. Utilizing a quasi-experimental design with pre-test and post-test measured. The design involved a between-subject experimental group of seventy-four elementary students who were randomly assigned to an experiment (n=37) and a control group (n=37), the latter only receiving traditional STEM instruction without robotics. Students were given a pre-test and post-test to measure their algorithmic thinking, logical reasoning, and problem decomposition skills. Data were investigated using paired-samples t-tests and a 2-way analysis of variance (ANOVA). Outcomes revealed that both groups significantly improved CT skills, but the experimental group (M=28.56) improved significantly more than the control group (M=20.09) with a very large effect size (ES), respectively. The study found that a novel teaching method using Mojobot in STEM education enhances elementary students' CT skills and supports 21st century skill development through robotics.

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1. INTRODUCTION

With technology advancing rapidly in Thailand and the country moving to a knowledge-based economy, education policy has also changed significantly–particularly in regions like the Eastern Economic Corridor (EEC). The EEC, which is the nucleus of advanced industries and technological innovation, is a key economic driver for the country. The Thai government has markedly shifted towards nurturing the skill sets of early learners to meet the demands of a technology-centric workforce [1]. Increasing focus on cultivating computational thinking (CT) skills in the EEC is attributed to workforce scarcity in the region, which prevents them from satisfying skill demand by technology-intensive industries [2]. As per the recent studies, the EEC and other regions need problem-solvers, those with algorithmic thinking skills, to maintain a growing tech workforce in the tech sector [3]. Considering the scenario CT is identified frequently as one of the major competencies to address 21st-century workforce needs and foster innovation in tech-heavy sectors. The demand for these jobs have the high salary and if author can leverage the CT skills in those high-paying jobs, author can create wealth not only for yourself but also help Thailand's technology professionals pursue the expanded EEC era where they need good solutions that address hard problems using new ways.

CT refers to a way of thinking and problem solving that applies across disciplines: the kind of thinking involved in defining problems; decomposing them into manageable subproblems; designing an algorithmic solution; developing this solution by writing computer programs or building robotic systems using one language, tool, or platform [4]. CT as a problem-solving approach has been recognized and emphasized in education. It is important to incorporate CT into early educational settings to help elementary-aged students develop thinking about analysis and deduction. For example, the studies conducted systematic review of programming activities and unplugged exercises to improve teaching CT in primary schools [5], [6]. This review identified serious problems concerning the definition and measurability of CT skills, which must be solved if we want to progress in this field. A journal article emphasized the significance of enlightening CT expertise from an early age [6]. Another study explored the potential for CT to improve learning in K-12 education and concluded that CT has significant benefits for enhancing critical thinking and higher-order problem-solving skills among students [7]. The advent of technology being a great driving force in the future of several plurality sector jobs, CT skills have been identified as crucial to success in the workforce [8].

This process incorporates vital simulated, logical, and systematic skills, which are important for our daily life and the trendy demands of 21st century workforce [5], [6]. The advent of technology being a great driving force in the future of several plurality sector jobs, CT skills have been identified as crucial to success in the workforce [7]. In areas such as the EEC, industries appeal for creative minds with CT skills to help them meet operational challenges through technology in robotics and AI and software development [8], [9]. Studies have demonstrated that high-quality early CT beginning as early as pre-kindergarten can result in substantial learning gains. An 8-week curriculum on robotics provides an example that can demonstrate how CT content at the lower elementary school level could stimulate some necessary skills and perceptions in children; hence, the basis for future learning related to science, technology, engineering, and mathematics (STEM) education [10]. Among these ways for making abstract concepts tangible, robotics and in particular its usage in teaching is remarkable as it provides students with an opportunity to get a practical and tactile feel of how their computational ideas materialize into real world applications [11].

This research was focused on the investigation of Mojobot, a programmable robotic tool to improve the CT skills of primary school students in the EEC region [8]. The study of Mojobot in education was targeted at identifying how Mojobot may support the development of algebraic thinking and problem-solving skills amongst children and to learn from this regarding potential ways that such tools can be embodied within education systems, preparing students for future technology-driven careers [12]. This emphasizes the role of CT skills that are more essential in regions such as the EEC in Thailand in alignment with the National Higher Education Plan for Workforce Production and Development, 2021–2027, there is an emphasis on developing personnel with essential skills for a knowledge-based economy to meet the demands of modern industries [13]. The study explored the long-term impact of early exposure to CT on students' preparedness for future employment in the technology sector. This is especially critical due to the rising demand for CT skills around the EEC, an area essential to Thailand's growth both practically and economically [11].

The study explores the role of Mojobot in early primary education, focusing on CT, STEM education, and robotics. While previous research highlights robotics' potential to enhance CT skills like algorithmic thinking and problem decomposition, most lack attention to regional or economic needs. Targeting Thailand's EEC, a key hub for tech-driven growth, this study takes a localized approach. By integrating Mojobot into STEM education, it addresses the EEC's workforce challenges and strategic goals. This research bridges early education with industry needs, offering a model for similar contexts globally. The study is guided by the following research question: How is the use of Mojobot impacting elementary students' development of CT in the EEC region? The research question of this study is: to what extent will students who use minimally designed robots as part of their programming experience significantly improve their CT ability better than students who do not interact with the robot? This research will inspire the development of the evidence base needed for integrating CT in early childhood education and likely support the growth of the technology workforce long-term in Thailand.

2. METHOD

2.1. Research framework

The flow chart that follows provides a framework for research in which central an issue in STEM education is identified: how does Mojobot influence the development of students' CT skills. The stages of the framework include designing the intervention (with the help of Mojobot), pre-test and post-test data collection, and impact evaluation. The final phase consists of the evaluation which is designed to investigate whether the Mojobot intervention significantly enhanced students CT skills. This framework demonstrates how a strategic game perspective can identify key decisions students in the experimental group undertake whilst partaking in problem-solving tasks that affect their learning outcomes [14], [15]. These students follow rational behaviors like players in a game maximizing their payoff, and Nash equilibrium is the point at which the group cannot better another CT strategy while keeping away from alteration of intervention strategies. This is through the strategic decision-making and interaction outcomes typical of game theory in which students adapt constantly given feedback from peers, the system, and instructors to maximize their learning, as shown Figure 1.

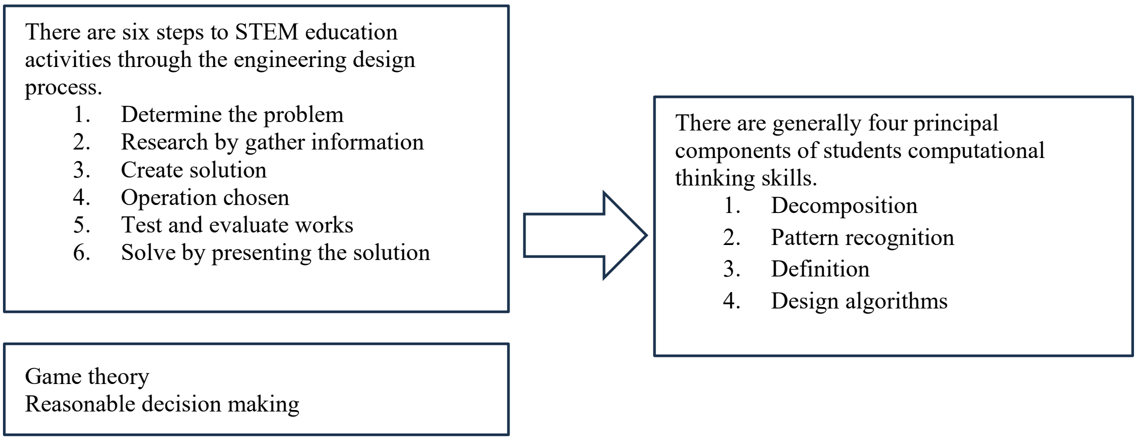

Figure 1. Research framework

2.2. Research design

This study examined the effects of Mojobot and elementary school STEM education on CT skills through a quasi-experimental pretest-posttest control group design. Random assignment of students to classrooms was not feasible, for practical reasons within the school setting, as presented Table 1 [16]. There was no equitable random assignment of individual participants to the experimental condition (STEM intervention with Mojobot) or control condition (standard STEM instruction). CT skills (logical reasoning, algorithmic thinking, problem decomposition, and pattern recognition) were assessable by pre-test and post-test assessments in both groups to monitor the changes over intervention period.

Table 1. Research design

Phase	Experimental group	Control group
Pre-test (O_1)	CT test	CT test
Intervention (X)	STEM activities + Mojobot	Standard STEM instruction
Post-test (O_2)	CT test	CT test

The participants were 74 fourth-grade students (37 girls and 37 boys) from Wat Nong Ketunoi School, Bang Lamung District, Chonburi Province, Thailand. Participants were randomly assigned to the experimental group (n=37) or robotic Mojobot condition intervention, or to an active control group (n=37) receiving standard STEM instruction without robotics. The sample size was determined using G*Power 3.1.9.2 for Windows, ensuring at least 90% statistical power, an alpha level of 0.05, and an effect size (ES) of 0.80, which is considered appropriate for this type of quasi-experimental design. Based on these parameters, the calculation showed that a minimum of 35 participants per group were required (a total of 70 participants) to detect meaningful effects [17]. To account for potential data loss or attrition, an additional 20% was added to the sample size, resulting in 37 participants per group (a total of 74 participants). This approach ensures that the sample size is adequate for detecting significant differences between groups and maintaining statistical power throughout the study. Studies suggest that a sample size of 30 participants per group is typically adequate for detecting medium to large ES in educational research, making this sample size sufficient for our purposes.

However, while G*Power provides a fast and reliable way to determine an appropriate sample size, its use does have limitations. The process involves several critical steps: i) selecting the correct statistical test for the planned analysis; ii) choosing the suitable method of analysis; and iii) accurately inputting parameters such as alpha level, power, and ES, with the latter typically drawn from prior literature. Misestimation of any of these parameters can lead to underpowered or overpowered studies. Moreover, although G*Power helps ensure statistical validity, it cannot compensate for issues such as sampling bias, external validity concerns, or unforeseen attrition during the study. Researchers must be cautious to interpret the calculated sample size within the broader context of study design and research goals [17], [18].

2.3. Research procedure

2.3.1. Pre-test

Both the experimental and control group will complete a CT pre-test. The pre-test for experimental and control groups was administered using a CT skills test, which was conducted individually. The test included open-ended questions based on five simulated real-life scenarios. Each scenario had four questions covering four aspects which were problem decomposition, pattern recognition, abstract thinking, and algorithm development. One by one, the teacher revealed each situation and question pair, and the students had to respond to each question with a short-answer explanation. Each question was assessed based on a rubric and scored individually from 0–3 points. The maximum score a candidate could achieve in the test was 60 points.

2.3.2. Intervention

The experimental group will receive STEM education intervention with Mojobot for a period of four weeks. The intervention duration of four weeks was chosen based on previous studies that demonstrated the effectiveness of short-term robotics interventions in improving CT skills. The participants promised to provide authors with adequate instruction in the appropriate fields but forbade authors from doing any resistance work between 6 AM and 8 AM, as this would then be counted as an overload error for both factors.

2.3.3. Post-test

Both the experimental and control groups completed a CT post-test. The post-test was implemented individually for both experimental and control groups, with a similar construction to the pre-test, namely the same CT skills test. The teacher read the scenarios to individual students, who answered the questions, listing all their own opinions. The teacher put the score for every question on the scoring sheet.

2.3.4. Data analysis

Independent and paired t-tests will be employed to compare the pre-test vs post-test scores of CT skills among groups and within each group. In addition, ES will be computed.

2.4. Measurements

In group trials, a validated pre-test and post-test were used to assess CT skills in both experimental and control groups. The pre-test was given before the intervention, while the post-test followed the STEM program with Mojobot for the experimental group and regular teaching methods for the control group. This approach enabled the evaluation of changes in CT skills over time. The measurement indicators used in the test instrument for evaluating CT included key areas such as algorithmic thinking, logical reasoning, problem decomposition, and pattern recognition. These dimensions were carefully selected to comprehensively assess students' ability to analyze problems, devise solutions, and apply systematic approaches, aligning with the core competencies of CT.

2.4.1. Research tools

The Mojobot was programs to fit into the six-step engineering design process during STEM and computer science education in schools where students are learning professional competences such as problem identification, information gathering, solution knowledge-based creation (project planning), implementation plan formulation (problem solving and reporting creative work planning), testing and evaluation, presenting the solution or artifact. This is in line with the principles of hands-on, inquiry-based learning in both Papert's constructionism and Malaguzzi's Reggio Emilia approach [19]. It enabled group work in a cooperative workspace, where students worked collaboratively on problem solving and coding assignments. Indeed, this is consistent with the shared learning outcomes articulated by previous studies [10], [20], who highlighted how robots can support the development of team-based interaction and communications skills in children. The Mojobot also developed a physical experiential learning environment in which students used joysticks and other interactive tools to move blocks and perform tasks. The grounded in the active learning theory that underpins evolving practices of teaching and learning, the engaging with physical materials during more complex problem-solving, as in CT [21], [22]. Combining haptic feedback with creativity in exploration scenarios (i.e. Mojobot) attracts engagement, especially among younger users [23], capturing the playfulness of more tangible devices for coding.

2.4.2. Statistical analysis

An analysis of variance (ANOVA) was conducted to compare the pre-test and post-test scores on students' CT skills, assessing the impact of the Mojobot intervention between the experimental and control groups. Initially, both groups completed a pre-test to assess their baseline CT skills. Following this, the experimental group participated in STEM activities using Mojobot, while the control group followed standard STEM instruction without robotics. After the intervention, both groups took a post-test to measure changes in CT skills. Data analysis involved averaging pre-test and post-test scores by group, with paired t-tests used to assess within-group improvements. A 2-way ANOVA was then conducted to control any differences in pre-test scores and to compare post-test outcomes between the experimental and control groups. If the post-test scores of the experimental group were significantly higher ($p<0.05$), it indicated that the Mojobot intervention had a positive effect on improving CT skills [24].

2.4.3. Validity and reliability

The design of this study, a high degree of consideration regarding the validity and reliability of the CT test were provided. The pre-test and post-test were based on established instruments, including the CT test by Govind and Bers [25], which has stronger construct validity than most other measures of central aspects of CT (logical reasoning, algorithmic thinking, and problem decomposition). A pilot study was conducted to modify the test and assess the appropriateness of items for clarity in their target age group, as well as ensuring that items were contextually appropriate. The instrument reliability was evaluated by calculating Cronbach's alpha ($\alpha=0.87$), which showed good internal consistency and reliability of the test items. A reliability coefficient of 0.7 and above is considered acceptable in educational research [26]. Moreover, experts in the areas of CT and STEM education validated the test to verify that it measured what it was intended to measure. These steps ensured that the instrument was both reliable and valid for assessing changes in CT skills over the course of the intervention.

3. RESULTS AND DISCUSSION

3.1. Results

The sample consisted of 74 students, with each group comprising an equal number of participants ($n=37$). The experimental group received the Mojobot-integrated STEM program, while the control group experienced traditional STEM instruction without robotics. To evaluate the effectiveness of the intervention, both groups completed a pre-test and a post-test measuring their CT skills. As shown in Figure 2, students exposed to Mojobot-enhanced STEM activities outperformed their peers in the control group in terms of CT skill development. The mean CT score for the experimental group increased from 20.49 (SD=5.12) in the pre-test to 49.05 (SD=5.59) in the post-test, indicating a substantial improvement. In contrast, the control group showed a smaller gain, with scores increasing from 21.32 (SD=5.45) to 41.30 (SD=6.5). Although both groups demonstrated improvement, the greater gain observed in the experimental group highlights the effectiveness of Mojobot-facilitated learning in enhancing CT skills beyond what was achieved through conventional instruction. Moreover, the relatively consistent standard deviations suggest that the performance of the experimental group was stable, further supporting the conclusion that robotics-based learning is an effective approach for promoting CT in elementary students.

The comparison results of CT scores between the experimental and control groups are presented in Table 2. A significant enhancement in CT skills was observed for the experimental group, whose mean pre-test score was 20.49 (SD=5.12) and mean post-test score was 49.05 (SD=5.59), resulting in a mean difference of 28.56. This increase was statistically significant ($t=32.45$, $p<0.001$) with a very large ES (ES=5.33), according to Cohen's guidelines on practical significance [26]. In contrast, the control group also showed improvement, though to a lesser extent. Their mean pre-test score was 21.32 (SD=5.45), increasing to a mean post-test score of 41.41 (SD=6.5), with a mean difference of 20.09. This increase was also statistically significant ($t=20.5$, $p<0.001$), but the ES (ES=3.38) was notably smaller than that of the experimental group. These findings indicate that the integration of Mojobot into STEM instruction significantly enhanced students' CT skills compared to traditional methods. The greater gains in the experimental group suggest that robotics-based learning effectively promoted higher-order thinking. The hands-on, inquiry-driven coding activities supported by Mojobot substantially improved CT performance, with the experimental group showing a marked average gain of 28.56, compared to a more moderate increase of 20.09 in the control group. Both results were statistically significant, underscoring the added value of technology-enhanced STEM education.

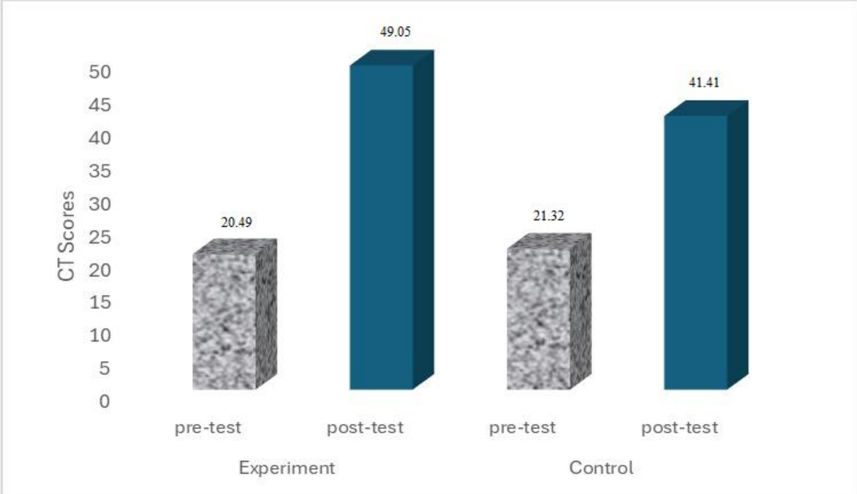

Figure 2. Pre-test and post-test comparison of CT mean and standard deviation experimental group and control group

Table 2. Pre-test and post-test comparison of CT scores between experimental and control groups

Group	Test	Mean (M)	SD	Mean difference	t	p-value	ES
Experiment (n=37)	Pre-test	20.49	5.12		-	-	-
	Post-test	49.05	5.59	28.56**	32.45	<0.001	5.33
Control (n=37)	Pre-test	21.32	5.45		-	-	-
	Post-test	41.41	6.5	20.09**	20.5	<0.001	3.38

**p<0.01

An independent samples t-test was conducted to examine differences in post-test CT scores between the experimental and control groups, as shown in Table 3. The experimental group (n=37), which received the Mojobot-integrated STEM program, achieved a mean post-test score of 49.05 (SD=5.59). In comparison, the control group (n=37), which received traditional STEM instruction, had a mean post-test score of 41.41 (SD=6.5). The statistical analysis revealed a significant difference between the two groups (t(72)=5.426, p<0.001). Additionally, a secondary comparison showed that the mean sub-score of 17.73 (SD=3.65) for the experimental group was significantly higher than the control group's average of 12.15 (SD=4.64). The ES, calculated as Cohen's d equal 1.26, reflects an extremely large effect, highlighting the substantial impact of the Mojobot intervention on enhancing students' CT skills [27]. Therefore, the large ES suggests that the CT skills of students in the Mojobot-infused STEM activities improved significantly better compared to those of control group students.

Table 3. Between-group post-test comparison of CT scores

Group	n	CT scores					
		Mean (M)	SD	t	df	p-value	ES
Experimental	37	49.05	5.59	5.426**	72	<0.001	1.26
Control	37	41.41	6.5				

**p<0.01

3.2. Discussion

The research shows that the integration of robotics in STEM education had a positive impact on elementary students' CT skills. After receiving hands-on, inquiry-based STEM training infused with Mojobot that was based on constructivism [28], the experimental group achieved higher CT post-test scores. They are constructivist pedagogy, learning by making, where the learners actually participate in building their mental models through problem-solving and design explorations. This is consistent with constructivist and social constructionism theory, which asserts meaningful learning if students are stimulated by concrete objects and concise experience. Research has shown that designing interactive learning tools, such as Mojobot, which combines playful interaction with guided education, supports a more engaging and cognitive development experience for children [21], [29].

The findings corroborate with the results of previous studies, suggesting that robotic-enhanced STEM curricula improve student problem solving and algorithmic reasoning [30], [31]. In accordance with the findings of Bers [32], who argued that robotics in PBL significantly augments team-based learning and, in turn, weakens barriers to problem-based learning, our research supports that Mojobot is a practical platform for young learners to build upon CT skills through hands-on practice in collaboration [30]. The students in this study learned through an active learning process with the assistance of concrete objects, enabling interaction through physical activities rather than passive digital content. This aligns with findings by Gerosa *et al*. [33], who observed that tangible interaction with robotics promotes task engagement and supports the development of problem-solving skills in young learners. These interactive activities proved beneficial in transitioning students from passive screen interaction to active, substantive engagement, which is fundamental to the growth of CT [33]–[36]. Additionally, researchers confirm that STEM activities positively impact the development of academic achievement in CT, indicating that participation in STEM activities can truly transform the learning outcomes of primary school students in Thailand [21], [37]. When comparing the educational context related to STEM attitudes and CT skills with other ASEAN countries, it was found that STEM has a positive and significant effect on CT skills, as these skills align closely with broader STEM curriculum goals by fostering problem-solving abilities, critical thinking, and logical reasoning. CT enables students to approach challenges systematically, develop innovative solutions, and apply interdisciplinary knowledge, thereby strengthening their preparedness for STEM-related careers and contributing to the development of 21st-century competencies essential in a technology-driven world [38].

Moreover, the notable increase in post-scores of the experimental group implies that Mojobot is tailored to suit young learners and provides an entry point for novice-level exploratory learning of CT concepts. In addition, the game-like interface and haptic feedback of this study motivate students to master learning competencies, as games can be both fun and effective. In particular, haptic feedback enabled students to physically interact with the tasks that they were solving, providing a tactile learning opportunity that has been shown to improve retention and problem-solving abilities when applied in STEM fields [22], [39]. Those results are consistent with the research supporting an interactive approach in making something abstract more concrete for younger audiences and easing that transition to a more formal learning space. Indeed, according to previous studies [40], hands-on interactive technologies are a way of connecting play-based learning with the more academic content domain because tactile and visual interaction with physical components influence cognitive skills for developing STEM concepts [28], [41].

Although statistically significant, the control group yielded a lower ES, suggesting that standard STEM instruction is not as effective at promoting CT when compared to the Mojobot intervention. This supports previous work proposing that more traditional instructional methods, while beneficial, fail to harness the full potential of interactive learning resources for CT skill enhancement [42]. While the Mojobot intervention had also promoted higher-order thinking skills, it was even more effective in promoting student engagement and motivation-essential prerequisites for effective learning. Hence, this serves as a practical application of the study, whereby it demonstrates how practical STEM programs embedded with technology, such as the one involving Mojobot, can impact CT and problem-solving among young learners who are early on in their stages of learning these concepts [43].

Theoretically, this research adds to the burgeoning science of robot-education literature with a specific emphasis on STEM for elementary students. It expands constructionism and active learning theories by showing how Mojobot fosters CT while enhancing STEM mastery. Through hands-on activities, Mojobot connects abstract STEM concepts to tangible applications, promoting problem-solving, algorithmic thinking, and a deeper understanding of STEM content. The ability for students to engage in all aspects of play, while coupled with more constructivist-style learning structures, creates a unique bridge that both opens up avenues for higher-level thinking and problem-solving. The design of this study was quasi-experimental and adds value to the validity of the findings as it controlled for pre-existing differences in students CT skills and provided a strong experimental comparison between groups [25]. That strong effect in the treatment group combined with the large ES (Cohen's d equal 1.36, which is larger than many educational interventions) provides more demonstrable This article provides evidence for how integrating robotics into early STEM education can create significant new and long-lasting pathways for students through their work roles and skills, either technology-related or not, due to the complex nature of computing skills, problem-solving skills, and numeracy skills, which, for the most part, directly influence students' lifelong learning paths. Such outcomes prepare students to more readily adapt to future workforce needs and strengthen innovation in tech-intensive sectors.

4. CONCLUSION

This study proves that using a new way to teach robotics with Mojobot in STEM subjects improves elementary students' CT skills over time by encouraging them to think about solving problems, using logic, and following instructions through hands-on, question-based learning. The implementation of a STEAM-integrated robotics curriculum not only strengthens fundamental programming concepts but also promotes engagement, collaboration, and creativity-key 21st century skills essential for academic and career success in technology-driven fields. The findings demonstrate that students exposed to structured robotics-based learning significantly outperform their peers in CT, with noticeable improvements in motivation and conceptual understanding. By providing a transformative educational framework, this study highlights the potential of robotics to reshape traditional learning environments and drive innovation in STEM education. The development of CT skills was achieved through the use of Mojobot, an embedded system-based educational tool integrated within STEM learning. This approach led to a statistically significant improvement in CT skills among elementary students, underscoring its value as a novel method for early skill formation.

Future research should investigate the suitability of Mojobot-based interventions for students across various age groups and educational environments. They should also look at how they affect broader STEM skills like scientific reasoning and design engineering, and they should do longitudinal studies to see if teaching CT early on leads to long-term benefits in school and the workplace. Comparative studies with other robotics platforms could help improve the best ways to incorporate robotics into the curriculum. This would make sure that robotics stays a dynamic and ever-changing tool for teaching creativity, digital literacy, and problem-solving to the next generation of students.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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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

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this study. Additionally, there are no conflicts of interest related to funding, affiliations, or institutional involvement that may have biased the research outcomes.

The findings and conclusions presented in this paper are solely the result of independent academic inquiry and do not reflect any external influence or commercial interest.

INFORMED CONSENT

This study was conducted in accordance with ethical research guidelines, ensuring the protection of participants' privacy and rights. Prior to participation, informed consent was obtained from all individuals involved in the study, including written permission from the students' parents or legal guardians. Participants were fully informed about the study's purpose, procedures, potential benefits, and their right to withdraw at any time without any consequences. All collected data were anonymized and used solely for research purposes.

ETHICAL APPROVAL

This study was conducted in compliance with all relevant national regulations and institutional policies, following the tenets of the Helsinki Declaration for research involving human subjects. The research protocol was reviewed and approved by the Institutional Review Board (IRB) of Burapha University, Thailand, ensuring adherence to ethical standards for conducting studies involving human participants. The approval was granted under Ethics Approval Number [HU100/2565]. All participants and their guardians provided informed consent before participation, and strict confidentiality measures were implemented to protect their privacy and rights.

DATA AVAILABILITY

The data supporting the findings of this study are available from the corresponding author [WR], upon reasonable request. Due to privacy and ethical considerations, the dataset containing participant information is not publicly available. However, derived data supporting the key conclusions of this research are included within the article and its supplementary materials.

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