EUROPEAN JOURNAL OF STEM EDUCATION

European Journal of STEM Education,
2025, 10(1), 10
ISSN: 2468-4368

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Fostering a Culture of Innovativeness and Entrepreneurship among Early Secondary School Students through STEM and Coding Education Insights from Massive Open Online Courses (MOOCs) and Start-up Innovation Camp

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Citation: Chamrat, S., Manokarn, M., Suree, N., Damrongpanit, S., Wattanakasiwich, P., Sipitakiat, A., Jaipong, P., Suwannatat, P., Prakobphon, T., Limkumnerd, S. and Yangjeen, S. (2025). Fostering a Culture of Innovativeness and Entrepreneurship among Early Secondary School Students through STEM and Coding Education Insights from Massive Open Online Courses (MOOCs) and Start-up Innovation Camp. *European Journal of STEM Education*, 10(1), 10. https://doi.org/10.20897/ejsteme/17081

Published: September 17, 2025

ABSTRACT

This research aimed to (1) investigate changes in attitudes towards learning STEM and coding, innovativeness, and entrepreneurial attitudes, and (2) synthesize characteristics and evaluate innovations to address problems after participating in an innovation camp for 180 early high school students. Activities included learning platforms to foster competency and coding through open learning for the public, and innovation camps. Students learned via webinars, Massive Open Online Courses (MOOCs), participated in hands-on camps with experts, and developed innovations to solve problems. Data was collected using attitude surveys towards learning, innovativeness, and entrepreneurial attitudes three times. Data was analyzed using repeated measures ANOVA and content analysis. Results showed a significant continuous increase in students' attitudes towards learning STEM and coding, innovativeness, and entrepreneurial attitudes from the first to the third measurement. Innovations that students were interested in solving problems included air pollution (45.45%), medical transport (27.27%), renewable energy (18.18%), and social media and interaction (9.09%). Evaluation results reflected clear problem-solving at a good level, with relatively good evidence seeking and process presentation. Creativity, integration, and impact creation were at an acceptable level.

Keywords: STEM, coding, innovativeness, entrepreneurship, innovation camp

INTRODUCTION

Learning in STEM (Science, Technology, Engineering, and Mathematics) fields is crucial for developing students' learning abilities in the digital world. Not only does it enhance learners' competencies, but it also has significant implications for preparing the workforce for Industry 4.0 and fostering sustainable societal growth

(Hapgood et al., 2019; Grewe, 2025). STEM learning helps establish a solid foundation for students in problem-solving skills, critical thinking, and the development of crucial skills for future emerging professions (Ah-Nam and Osman, 2018). Furthermore, STEM learning provides opportunities for students to understand and address real-world problems using technology and science (Dede, 2010), laying essential groundwork for entry into current and future industries and businesses (Bybee, 2010). It enhances understanding of technology and societal workings in the contemporary era (National Research Council, 2011), opens doors to stable and high-income careers (Deming and Noray, 2019; Winkler et al., 2015), and enables students to contribute to society and the world positively (Honey et al., 2014).

Not only STEM but also Coding education is another significant approach aimed at developing problem-solving skills (Sharma et al., 2018; Sevimli and Ünal, 2022). The advantages of using coding to enhance learning include emphasizing practical coding skills for problem-solving. Students practice real-world tasks and engage in scientific processes more comprehensively. They can formulate hypotheses and systematically plan problem-solving, which is more ideal (Güleryüz and Dilber, 2021; Roopaei and Horst, 2021). Moreover, in terms of the impact on learners, it provides clear pathways for students to enter new technology-related careers and enables them to adapt well to future technological changes (Brookes, 2018; Ekong and Radharamanan, 2014; Rusu et al., 2006). Therefore, under the same objective, although there may be some differing details, they can be integrated to fully enhance student development (Hixson et al., 2012; Winkler et al., 2015).

In Thailand, teaching STEM and Coding is encountering several challenges that affect the quality of education for students. These issues range from the depth of the subjects taught, which may sometimes not meet standards or require additional information for accurate understanding (Blikstein, 2013). Some teachers lack qualifications related to teaching STEM and coding, leading to a lack of depth in teaching as it should be (Du Plessis, 2020). Teachers still perceive STEM and Coding as lecture-based subjects for exam purposes, separating teaching from problem-solving in daily life or challenging students' new abilities (Huang, 2022; Samara, 2023). However, the most severe issue is that STEM teaching fails to instill a positive attitude toward the subject in learners and does not stimulate entrepreneurial thinking in the new era (Huang, 2022; Moomaw, 2024). Therefore, addressing these issues is crucial to improve STEM teaching to align with objectives and provide students with a fulfilling learning experience and understanding (Caine and Caine, 1990). Further studies on methods to develop STEM teaching and motivate students in this subject may provide viable solutions to existing problems (Rahmadani, 2017; Sahito and Wassan, 2024; Ribeirinha et al., 2024). This research aims to experiment with and examine the outcomes of integrating STEM and Coding concepts into learning management approaches to enhance students' attitudes towards learning STEM and Coding, innovativeness, and entrepreneurial attitudes through open online learning platforms combined with innovation camps. The goal is to cultivate awareness of nearby issues, foster a learning attitude to apply knowledge for beneficial purposes, envision new and diverse options, and develop oneself to adapt to the high-tech reliant job market. It seeks to identify challenging opportunities amidst change. To achieve this, it's imperative to thoroughly integrate STEM and Coding learning management strategies, aiming for research outcomes to serve as examples for educators to apply, adapt, or derive inspiration from to transform learning management and clearly observe changes in students beyond just their grades.

Given the importance of STEM and Coding education and the challenges faced in Thailand, this research aims to investigate: (1) changes in Thai early secondary school students' attitudes towards learning STEM and coding, innovativeness, and entrepreneurial attitudes after participating in MOOCs and innovation camps; (2) characteristics of innovations developed by students to address real-world problems; and (3) the effectiveness of these innovations in terms of problem-solving, creativity, and potential impact on local issues. This study seeks to provide insights into effective strategies for implementing STEM and Coding education in Thailand and fostering a culture of innovation and entrepreneurship among students.

LITERATURE REVIEW

STEM and Coding Education

Since the development of science and technology has undergone significant leaps following World War II, STEM education has begun to be recognized and embraced to enhance the quality of student learning. From then until now, it is evident that STEM has become one of the teaching methods capable of improving academic performance, particularly in problem-solving (Aji and Khan, 2018).

The fundamental concept of STEM originates from the interdisciplinary integration of related subject matter, including Science, Technology, Engineering, and Mathematics (Okuşluk et al., 2020; Rahmadani, 2017), aimed at facilitating problem-solving without the constraints of knowledge domains. It integrates all learning aspects to promote the development of efficient problem-solving methods, based on Problem-Based Learning (Iwuanyanwu, 2020; Pepper, 2014), which involves: (1) recognizing and understanding the problem, (2) brainstorming and seeking solutions, (3) making decisions and planning actions, (4) implementing and evaluating actions, and (5) summarizing and exchanging knowledge and understanding. Therefore, when teachers address real-life problems as instructional guides, it results in a flexible and efficient learning process (Javidi and Sheybani, 2017), fostering collaborative learning and working among students through hands-on activities to achieve the best possible solutions, promoting creativity and a clear learning attitude for daily life application (English and Mousoulides, 2015).

Not only has STEM education been utilized to develop students, but the integration of STEM and Coding in teaching and learning has gained significant attention recently. Combining Science, Technology, Engineering, and Mathematics (STEM) with programming (Coding) can foster meaningful and creative learning (Sharma et al., 2018; Zhang et al., 2022). Furthermore, it can promote essential skills for the 21st century (Faber et al., 2013; Iwuanyanwu, 2020) such as analytical thinking, problem-solving, and teamwork (Astuti et al., 2021). Integrated STEM and Coding education not only enhance meaningful and creative learning but also promote learning that can be applied in daily life through systematic problem-solving, learning how to hypothesize, plan, and test problem-solving methods effectively. It benefits the application of knowledge in daily life and various industries, fosters students' creativity, opens opportunities for creating new things according to their interests, develops and improves applications or computer programs, promotes the emergence of new products that address real-world problems, enhances communication skills, goal-setting, task allocation, and efficient teamwork (Ni et al., 2016). Additionally, it prepares students for future careers, allowing them to leverage STEM and Coding knowledge and skills in industries and labor markets that tend to rely on technology and digital innovation, such as data scientist, software developer, digital content creator, app developer, digital marketer, blockchain technology specialist, digital project coordinator, and e-commerce assistant (Javidi and Sheybani, 2017).

The findings from previous research demonstrate the influence of STEM and Coding on the development of attitudes towards learning, innovativeness, and entrepreneurship. Several researchers have employed STEM and Coding in conjunction with innovation camps. For instance, LePendu et al. (2020) discovered that Coding camps can enhance students' self-efficacy and increase their levels of perception and interest in computational thinking. On the other hand, Bevan et al. (2010), Saxon et al. (2003), and Stewart et al. (2020) found that organizing camps for students to apply theoretical knowledge had a positive impact on attitudes towards learning and creativity. Clear behaviors of active participation and experiential learning emerged (Ni et al., 2016; Ward et al., 2014). Utilizing community problems as the basis for problem-solving through STEM and coding education resulted in significant improvements in problem-solving skills and positive attitudes towards learning. The outcomes showed high-impact outputs and commercial development possibilities in the future. Additionally, interesting conclusions regarding the effective organization of camps include increasing interest in STEM learning by promoting diverse and realistic skill usage and fostering self-efficacy in learning and practical engagement (LePendu et al., 2020). Using real-life problems as interesting challenges for developing problem-solving and critical thinking processes (Dochshanov, 2019), designing teamwork-oriented activities (Kilty and Burrows, 2022; Ward et al., 2014), and linking outcomes to personal development for future careers and promoting lifelong learning skills (LePendu et al., 2020).

Attitude Toward STEM and Coding Education

Attitude towards learning is a crucial first component of successful learning. Attitude refers to an individual's opinions or feelings towards what they have learned, as well as serving as a predictor of future behavior. Without a positive attitude towards learning, education may simply become rote memorization and regurgitation, lacking the ability to apply knowledge for personal development or future problem-solving (Samara, 2023). Generating interest in science and technology education can encounter various challenges, such as content misunderstanding, lack of motivation, and failure to apply knowledge in real-life situations, leading students to perceive science as difficult and uninteresting. Addressing these issues should begin with teaching content relevant to real life, using inquiry-based teaching methods, setting hypotheses, and conducting experiments, as well as creating collaborative learning environments and teamwork. Additionally, incorporating technology in teaching to stimulate interest and enhance students' understanding of the content (Aji and Khan, 2018; Astuti et al., 2021). Inquiry-based learning in science can help students develop analytical thinking and problem-solving skills (Javidi and Sheybani, 2017; Okal et al., 2020; Rehmat and Hartley, 2020). Therefore, adapting teaching and learning methods to suit individual students is essential for fostering interest and positive attitudes towards science and technology (Chang and Park, 2014; Faber et al., 2013).

Previous research has revealed the significant role of STEM and coding in developing students' attitudes towards science through meaningful and real-world-connected learning (Miller, 2019; Ni et al., 2016). Students can grasp the importance of science and coding in problem-solving and innovation, leading to behaviors of curiosity and exploration of the surrounding world (English and Mousoulides, 2015; Okal et al., 2020). Moreover, teaching STEM and coding also fosters students' creativity and innovation, which are essential skills for adapting to and meeting the changing demands of the 21st century (Faber et al., 2013). Therefore, teaching STEM and coding plays a crucial role in promoting meaningful learning, developing scientific attitudes, and fostering students' creativity and innovation (Stewart et al., 2020).

Innovativeness

Being an innovator means having the ability to generate new ideas and translate them into the development of products or processes that are beneficial to society or organizations (Liu, 2019). Innovators typically possess distinctive characteristics such as inspiration, imagination, creativity, integrative thinking, hands-on implementation, and teamwork (Moore et al., 2017). Additionally, innovators must have skills in understanding and applying knowledge, as well as the ability to deal with challenges and take calculated risks to create efficient innovations (Bertrand et al., 2023). Therefore, being an innovator is crucial in driving both educational and economic development towards the future.

Teaching STEM and coding plays a significant role in promoting students' creativity and innovation through meaningful and real-world-connected learning (Ni et al., 2016). Students can understand the importance of science and coding in problem-solving and creating new things (Ward et al., 2014). This teaching approach helps foster students' creativity, which is essential for being an innovator (Saxon et al., 2003). Students are encouraged to pose questions in various learning situations, leading to increased curiosity and understanding of the surrounding world (Astuti et al., 2021). Moreover, teaching STEM and coding helps students practice linking situations to discovery, a necessary skill for innovators (Moore et al., 2017). Therefore, teaching STEM and coding is essential in promoting meaningful learning, developing scientific attitudes, and fostering students' creativity and innovation (Stewart et al., 2020).

Entrepreneurship

Entrepreneurship refers to the characteristics of individuals who can create or extract value from various things to develop commercially valuable products or services (Fried and Tauer, 2009; Nebhwani and Syed, 2013; Sithas and Surangi, 2021). The main components of entrepreneurship include (Darmanto and Yuliari, 2018; Hägg and Kurczewska, 2019; Marchand and Sood, 2014; Mars et al., 2008; Sabrina et al., 2023; Mason and Arshed, 2013): Leadership, courage in decision-making and confidence in one's own idea: Initiative, having a strong spirit and not giving up in the face of obstacle; Hunger for knowledge, a desire to learn and challenge one's own thinking; Positive outlook, belief that everything is possible and having the ability to manage all aspects of business; Strategic thinking, always planning ahead to accommodate potential risk. Additionally, entrepreneurs must have the ability to build teams, be creative, and not be afraid to challenge and accept risks to lead the business to success. These characteristics have been proven by research to be developed through STEM and Coding.

Teaching STEM and Coding is crucial for fostering entrepreneurial skills in the digital age, namely: (1) Creative Work Creation: Learners can take knowledge gained from learning and create works in various formats that promote skills and competencies. These creative works can be used to solve everyday life problems (Bevan et al., 2010; Moraiti et al., 2022), (2) Attitude Development: STEM and Coding education promote a positive attitude towards learning, innovation, and entrepreneurship. This learning results in learners having systematic analytical and problem-solving skills (Rembiasz, 2017), and (3) Digital Era Competition: In an era where digital technology is crucial, having skills in STEM and Coding is necessary for students to develop entrepreneurship. Understanding and being able to use digital technology will help learners compete in business and create differentiation (Kolikant et al., 2020; Mason and Aeshed, 2013). Therefore, teaching STEM and Coding is essential for developing entrepreneurship in the digital age.

This research aims to compare the differences in attitudes towards learning STEM and Coding, innovativeness, and entrepreneurial attitudes of students. It will also synthesize characteristics and assess innovations to address problems after participating in a camp for junior high school students.

METHODOLOGY

Participants

This research involves developing students from junior high schools in the northern region, totaling 180 students from 36 schools. Each school selected 5 students (1 team) to represent them in participating in the learning camp. The selected students are between 13–15 years old and come from various affiliations. Each school has supervising teachers responsible for STEM subjects or related subjects. Their roles include observation, listening to student knowledge, monitoring student progress, and providing necessary information to the research team. The researchers aim to ensure that the outcomes of the research project will impact the schools by prompting a review of STEM teaching methodologies, managing necessary learning resources, updating content and curriculum, and promoting the development of teaching staff responsible for managing learning. The goal is to establish a high-quality STEM learning system combined with coding, characterized by the school's identity, for the benefit of the remaining students.

Research Instruments

Measurement of attitudes towards learning STEM and Coding refers to the feelings and opinions of students regarding their learning experiences from activities, understanding the benefits received to use as guidelines for self-development, clearer understanding of science, and the establishment of a network of friends from different schools for learning. It involves the desire to disseminate what they have learned to friends in school, as well as awareness of the benefits and value of the activities received. The measurement is based on 12 questions, such as "I feel excited to attend the innovation camp this time," "I have learned a lot from participating in the activities of the innovation camp," "I just understood clearly how science, math, and coding are interconnected," and "I have a plan to apply the knowledge gained from the camp at school." The analysis found that the questions had item-total correlations coefficients ranging from 0.644 to 0.7779 and a reliability of 0.942.

Measurement of innovativeness refers to the characteristics of students who are bold and adventurous, enjoy seeking new methods and innovatively creating solutions to encountered problems. It consists of 15 questions, such as "I enjoy thinking and proving new ideas frequently," "I am brave to face uncertain situations," "I believe that change always leads to something better," and "I want to help solve others' problems with my new ideas." The questions have item-total correlation coefficients ranging from 0.662 to 0.851 with a reliability of 0.957.

Measurement of entrepreneurial attitude refers to the characteristics of students who are interested in entrepreneurship, perceive professional ability as something close to them, identify opportunities, value addition, analyze situations to explore possibilities, and seek advantages for a successful and outstanding entrepreneurial career. It consists of 10 questions, such as "I think learning about entrepreneurship is beneficial for me," "Learning about entrepreneurship helps me understand professions in society better," "Teaching about entrepreneurship can be applied in practice," and "Based on the knowledge I have gained, I believe I can engage in entrepreneurship." The questions have item-total correlation coefficients ranging from 0.427 to 0.746 with a reliability of 0.890.

The synthesis and evaluation of problem-solving innovation involve assessing innovation based on six dimensions with four levels of scoring. These dimensions include clarity of the issue, supporting evidence of the concept, integration of STEM and Coding, creativity, impact, and presentation. Each dimension evaluates various aspects such as the linkage to problem situations, demonstration of innovation design, integration of knowledge, originality, impact on life, economy, and society, and clarity in communication. Evaluation by three research experts and educational evaluators yielded a perfect expert criteria congruence score of 1.00.

The STEM-focused learning platform offers MOOCs with multimedia materials to enhance STEM, math, and coding skills. With a total duration of 12 hours and 28 minutes, it encompasses six courses: (1) Middle School STEM: The Basic and Beyond, (2) STEM Methodology, (3) Basic Coding for Young Minds, (4) Learn to Code with CodeCombat & GoGo Board: A Middle School Adventure, (5) STEM Coding Project, and (6) Where Entrepreneurs Start: Coding for Life-Business Solutions. These courses cover topics ranging from science, technology, engineering, mathematics, to coding skills. Additionally, there's a two-day camp for startup development, focusing on applying theoretical knowledge practically. The platform emphasizes integrating STEM concepts, interactive and self-driven learning, computational thinking, problem-solving, and creativity. Quality assessment by curriculum and instructional experts resulted in an overall score of 4.75 (equivalent to 95.00%). Notably, the platform excelled in media and equipment quality (score: 5.00) and content richness (score: 4.93), indicating its effectiveness in facilitating learning and interest.

Data Collection and Analyses

The researchers divided the learning process into four phases: Phase 1: Collaborative learning activities through webinars held twice, on June 23, 2023, and July 21, 2023. Phase 2: Collaborative learning activities through MOOC from Lifelong Education, Chiang Mai University. Each school's students enrolled in the online program and completed the first questionnaire (Time 1). Then, they self-studied at their convenience via Power Class and took knowledge assessments. Students had to achieve a minimum score of 70% in all assessments to receive a certificate. Phase 3: Participation in the start-up innovation camp. Participants were selected from Phase 2 and completed the second questionnaire (Time 2) before joining the camp. The camp lasted for three days, and participants completed the final questionnaire (Time 3) afterward. And Phase 4: Innovation development. Students spent time creating innovative solutions to identified problems and presented their work in video clip format. Schools that received outstanding innovation assessments were selected as representatives to participate in the Hackathon Coding Era event in Bangkok, Thailand.

The research team summarized the data collected from each type of research tool, ensuring completeness and sincerity in data provision. They found no issues or anomalies with the data received. Subsequently, they aggregated scores from the data of each tool type. For the analysis to address the first research objective, they utilized data from the STEM and coding opinion survey, the innovativeness measurement, and the attitude toward entrepreneurship measurement. Descriptive statistics were analyzed, and data distribution was checked using skewness (sk) and kurtosis (kur) indices, which should ideally fall between –2 and +2, indicating a normal distribution. Then, they proceeded to analyze the data of all three variables using One-way Repeated Measures Analysis of Variance. In cases where significant variance differences were found between measurement occasions, the researchers interpreted the results using *F*-value based on Greenhouse-Geisser correction to control statistical error and interpret the findings. If significant differences were detected in the *F*-value, post-hoc comparison tests using Scheffe's method were conducted to assess the mean differences between measurement occasions. For the second research objective, the researchers utilized data from student innovation development reports and video presentations of problem-solving innovations. They analyzed the content according to evaluation criteria and relevant observations.

RESULTS

Changes in Attitudes Toward Learning STEM & Coding, Innovativeness, and Attitudes Toward Entrepreneurship

When the repeated measures of student opinions with complete data were analyzed for variance using repeated measures analysis, it was found that the average opinion scores before the project (3.830), before attending the camp (4.230), and after attending the camp (4.630) showed a continuous increasing trend. The preliminary agreement check from Mauchly's W analysis resulted in W = 1.00, *p*-value = 0.981, indicating that the variances of the three measurement occasions did not differ. The skewness values were 0.156, –0.126, –0.806 respectively, and the kurtosis values were –0.381, –1.271, –0.471 respectively (within –2 to 2 range), indicating a normal distribution of the data. Furthermore, the repeated measures variance analysis revealed that the mean of students' scores differed significantly at least once compared to the mean of other measurement occasions with statistical significance at the .01 level (*F*-value = 128, *p*-value = 0.000). Additionally, post-hoc comparisons found that the overall mean opinion scores across the three occasions differed significantly at the .01 level for all three pairs: (1) the mean before attending the camp was higher than before the project, (2) the mean after attending the camp was higher than before the project, and (3) the mean after attending the camp was higher than before attending the camp. This indicates that students' opinions about participating in the project and attending the camp improved and became more consistent, respectively. The data from the three repeated measures explained 27.6% of the variance in student opinions.

For the repeated measures of students' innovativeness with complete data analyzed for variance using repeated measures analysis, it was found that the average innovativeness scores before the project (3.790), before attending the camp (4.080), and after attending the camp (4.570) exhibited a continuous increasing trend. The preliminary agreement check from Mauchly's W analysis resulted in W = 0.636, *p*-value = 0.000, indicating that the variances of the three measurement occasions differed, necessitating consideration of the *F*-value based on Greenhouse-Geisser correction. The skewness values were –0.011, –0.036, –0.483 respectively, and the kurtosis values were –0.229, –0.466, –0.797 respectively, indicating a normal distribution of the data. Furthermore, the repeated measures analysis of variance revealed that the mean of students' innovativeness scores differed significantly at least once compared to the mean of other measurement occasions with statistical significance at the .01 level (*F*-value = 390, *p*-value = 0.000). Additionally, post-hoc comparisons found that the overall mean innovativeness scores across the three occasions differed significantly at the .01 level for all three pairs: (1) the mean before attending the camp was higher than before the project, (2) the mean after attending the camp was higher than before the project, and (3) the mean after attending the camp was higher than before attending the camp. This indicates that students' innovativeness improved and became more consistent through participating in the project and attending the camp, respectively. The data from the three repeated measures explained 44.9% of the variance in student innovativeness.

For the repeated measures of students' attitudes towards entrepreneurship with complete data analyzed for variance using repeated measures analysis, it was found that the average attitude towards entrepreneurship scores before the project (3.720), before attending the camp (3.900), and after attending the camp (4.470) exhibited a continuous increasing trend. The preliminary agreement check from Mauchly's W analysis resulted in W = 0.636, *p*-value = 0.000, indicating that the variances of the three measurement occasions differed, necessitating consideration of the *F*-value based on Greenhouse-Geisser correction. The skewness values were 0.076, –0.156, –0.823 respectively, and the kurtosis values were –0.570, –0.420, –0.047 respectively, indicating a normal

Table 1. Repeated measures analysis of attitudes toward learning, innovativeness, and entrepreneurial attitudes of students

		Mean	Standard error	F-value	η²	Post-hoc (Scheffe')
Attitudes toward STEM	Time 1	3.830	0.047	128**	0.276	1) Time 2 > Time 1 (t = 8.09**)
	Time 2	4.230	0.055			2) Time 3 > Time 1 (t = 15.92**)
	Time 3	4.630	0.036			3) Time 3 > Time 2 (t = 7.95**)
Innovativeness	Time 1	3.79	0.033	390**	0.449	1) Time 2 > Time 1 (t = 13.50**)
	Time 2	4.08	0.028			2) Time 3 > Time 1 (t = 22.00**)
	Time 3	4.57	0.034			3) Time 3 > Time 2 (t = 18.90**)
Attitudes toward entrepreneurship	Time 1	3.720	0.046	230**	0.299	1) Time 2 > Time 1 (t = 13.50**)
	Time 2	3.900	0.040			2) Time 3 > Time 1 (t = 22.00**)
	Time 3	4.470	0.044			3) Time 3 > Time 2 (t = 18.90**)

** p < .01

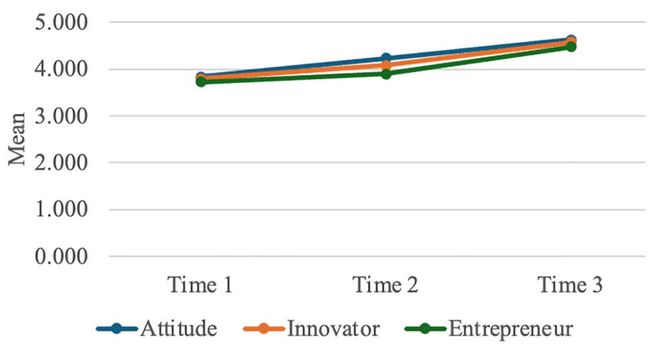

Figure 1. Changes in attitudes toward learning, innovativeness, and entrepreneurial attitudes

distribution of the data. Furthermore, the repeated measures variance analysis revealed that the mean of students' attitudes towards entrepreneurship scores differed significantly at least once compared to the mean of other measurement occasions with statistical significance at the .01 level (*F*-value = 230, *p*-value = 0.000). Additionally, post hoc comparisons found that the overall mean attitude scores across the three occasions differed significantly at the .01 level for all three pairs: (1) the mean before attending the camp was higher than before the project, (2) the mean after attending the camp was higher than before the project, and (3) the mean after attending the camp was higher than before attending the camp. This indicates that students' attitudes towards entrepreneurship improved and became more consistent through participating in the project and attending the camp, respectively. The data from the three repeated measures explained 29.9% of the variance in student attitudes.

Overall, all three variables showed an increasing trend of change, with the attitude toward STEM and coding being the most prominent, followed by innovativeness and attitudes towards entrepreneurship, respectively. Details of the statistical values and trends of change in the mean scores from each measurement occasion are presented in **Table 1** and illustrated in **Figure 1**.

Characteristics of Innovation to Solve Problems After Students Participated in the Junior High School Camp

After developing innovations to solve problems using the knowledge and skills gained from attending the camp, there were a total of 11 submissions of video presentations from students. These submissions could be grouped into four problem-solving dimensions as **Table 2**.

To evaluate the overall performance of the submissions, based on the assessment criteria of 6 aspects, it was found that the average scores ranged from 2.09 to 2.82 (52.27% to 70.45% of the full score of 4). Each submission received evaluations in the following descending order: (1) Clarity (70.45), (2) Presentation Skills (68.18), (3) Supporting Evidence (61.82), (4) Integration (58.64), (5) Impact (56.36), and (6) Creativity (52.27) The details are shown in **Figure 2**.

In summary, students who participated in the project and camp applied their skills to generate problem-solving innovations, demonstrating a good level of clarity, presentation skills, and relatively good supporting evidence. However, their impact and creativity were at an acceptable level. Details of the assessment results for each submission and the overall summary are presented in the table and illustration. In conclusion, the winning submission was the Air Purifier Machine, which scored 20.20 or 84.167% of the full score.

The selected work to represent the Northern region in the national exhibition is the Air Purifier Innovation. This innovation is driven by the alarming levels of air pollution in the region, often ranking at the top globally due to forest fires both domestically and internationally, along with vehicular emissions. These pollutants have adverse

Table 2. Students' innovations

Group of innovations	Students' innovation
Air-related Innovations: This group focused on addressing air-related issues and comprised 5 submissions (45.45%)	• Air purifier machine • Electronic cigarette smoking detection system in schools via Line Notification • Carbon credit calculator set • Smart Dust Tunu air quality monitoring system • Fire smoke and gas detection device
Transportation-related Innovations: This group aimed to solve transportation problems and consisted of 3 submissions (27.27%)	• Intelligent patient delivery vehicle • CPK Office Helper Robot • Traffic Light Coding
Energy-related Innovations: This group targeted energy-related problems and included 2 submissions (18.18%)	• Wind turbine for motorcycle electricity generation • Automatic power appliance control system via mobile phone
Social Interaction-related Innovations: This group focused on addressing social interaction problems and had 1 submission (9.09%)	• Platform for selling second-hand goods and donating items for charity

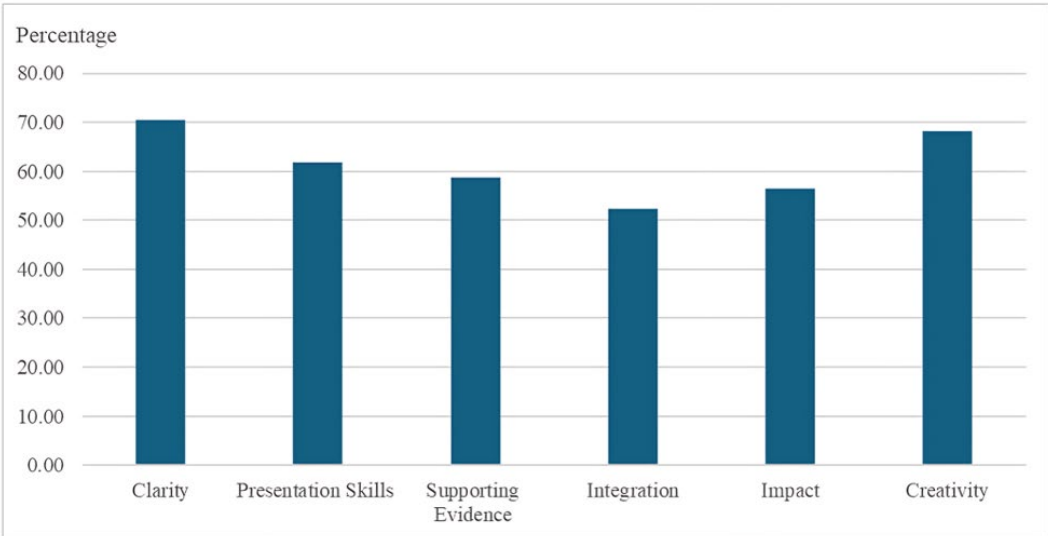

Figure 2. The evaluation results of students' problem-solving innovation across 6 dimensions

effects on public health, livelihoods, and contribute to a higher incidence of lung cancer among the population. Moreover, most of the population is economically disadvantaged, facing limitations in purchasing expensive air purifiers and frequently changing filters, leading to financial burdens. Therefore, the students aimed to develop an affordable and environmentally friendly air purification and refilling system. The air filter developed from quality plant fibers proved effective in reducing particulate matter (PM 2.5) in a 7.5-square-meter enclosed room from 336 micrograms to just 31 micrograms within 10 minutes. Importantly, students estimated the development cost of the air purifier to be approximately 30 USD, significantly reducing the expense compared to commercially available options.

CONCLUSION AND DISCUSSION

The research findings demonstrate the multidimensional development of students participating in the research project, encompassing knowledge, the integration of advanced practical skills, and, importantly, the willingness to embrace technological changes as part of solving daily life problems. From the research outcomes, the researchers have identified four key points of significance.

The first point is that teaching methods emphasizing lesson transmission and mass experiences can change students at the level of knowledge. However, teaching that involves hands-on activities can bring about changes even at the level of practical understanding, fostering good attitudes towards learning and oneself. According to the principles of Learning by Doing and Problem-based Learning, STEM and Coding education, which focus on active student participation, lead to the development of advanced, complex skills. Through well-planned practical activities that solely cultivate scientific processes, students can attain high-quality learning (Nawawi et al., 2021).

Additionally, there is an impact on direct attitude adjustment towards learning because students experience and understand the causes and effects of various hands-on activities themselves. This leads to perception and development of self-efficacy and self-confidence, ultimately resulting in a positive feeling about what they have learned (Aji and Khan, 2018; LePendu et al., 2020; Nawawi et al., 2021; Stewart et al., 2020).

The second point is that learning from nearby things motivates more involvement than learning from distant ones. Students can easily connect emotionally when they think about things they have encountered in daily life, which encourages participation in learning. They perceive the significance and closeness of new knowledge to various things nearby, stimulating serious and profound experimentation. Additionally, using surrounding items as stimuli for learning helps create a friendly atmosphere and promotes conversation. It fosters an environment full of support and encouragement for exchanging experiences and opinions, leading to a sense of safety in learning (Long and Sun, 2018; Rusu et al., 2006; Saxon et al., 2003). This is why students choose to develop innovations related to solving air pollution problems the most, as it is a crisis in the northern region of Thailand that has caused loss of life among the people for years.

The third point is that integrating quality and efficient technology into well-designed learning environments helps students develop high-level thinking skills effectively (Gharib et al., 2021; Javidi and Sheybani, 2017). Using high-quality technology creates opportunities for accessing diverse information and learning resources, which are essential for using as evidence in developing advanced thinking (von Graevenitz et al., 2013). It creates engaging learning environments where students can continuously develop themselves, fostering diverse and interesting learning experiences. Additionally, it promotes learning through efficient communication and collaboration (Aji and Khan, 2018; Kilty and Burrows, 2022).

Finally, STEM and Coding are disciplines that help develop high-level thinking processes. When integrated with technology, they contribute to fostering the Innovators who are the hope of society amidst a world facing new and challenging problems (Long and Sun, 2018; Rusu et al., 2006). Learning STEM and Coding promotes scientific thinking, analysis, systemic thinking, and problem-solving skills (LePendu et al., 2020). It helps students understand the fundamental principles of science and technology better, become aware of the structure and function of technology in solving daily life problems, and respond to societal needs (Nawawi et al., 2021). Importantly, it cultivates strong technological skills, instills a creative use of technology, enables self-protection against technological risks, and creates opportunities in new emerging careers in the future (Brookes, 2018; Dochshanov, 2019; Winkler et al., 2015).

However, over the course of approximately one year of research activities, the research team also found that the innovations developed still have some limitations that prevent a clear assessment of the benefits to students. The researchers observed that in the realm of fostering creative thinking, which is a high-level skill with a complex and profound developmental sequence, students need to undergo numerous experiences of both success and failure (LePendu et al., 2020). Understanding the mechanisms of success and explaining success factors with confidence and courage may require sufficient incubation time for students. For this research project, students were only given a month to apply their knowledge to innovate, which could be a significant factor contributing to the lower levels of assessment in creativity, integration, and impact compared to other assessment dimensions that are more readily developed.

Furthermore, from this research, the research team is interested in the mechanism of expanding the innovation impact of each school's learning process, considering the project's potential to support a limited number of students and open the opportunity for each school to experiment with and disseminate innovations. This opens up opportunities for schools to adapt or apply innovations to fit their context, particularly through content learning via MOOCs, which can recommend lifelong learning courses for students at no cost. However, schools may need to organize additional camps independently through coordination to implement suggestions from the research team if they are still uncertain about the activities.

The research findings indicate that attitudes towards entrepreneurs show the least noticeable change compared to other developmental aspects. It can be analyzed that the content and activities from the research focus on fostering and laying the foundation of STEM and coding to instill a positive attitude towards learning and imbue the principles to be applied in various learning contexts. Additionally, adolescent learners, who are in their formative years, lack real-world business experience, networking opportunities, and experience in analyzing situations to create innovative new opportunities, leading to beneficial outcomes for themselves (Darmanto and Yuliari, 2018; Marchand and Sood, 2014). However, achieving comprehensive development in business conditions within a short two-day camp period is challenging (Bevan et al., 2010). Nevertheless, the research team is satisfied with the outcomes and considers it a good starting point for stimulating a shift in educational management thinking along with fostering readiness for life in a technology-driven new world, opening opportunities for students to confront an unavoidable new era. This limitation will be considered for future development of the research project.

This study, while insightful, has limitations that future research should address. The one-month innovation period may have constrained students' creative potential, suggesting that extended timeframes could yield more comprehensive results. The focus on northern Thailand limits generalizability, calling for broader geographical coverage in future studies. Additionally, long-term impacts and the effectiveness of various pedagogical approaches within STEM and Coding education remain unexplored. Future research should consider longitudinal studies to track students' academic and career trajectories, investigate cultural influences on STEM attitudes in Thailand, and examine how STEM and Coding education can address specific societal challenges. Exploring the impact of teacher training programs on education quality would also be valuable. These directions could enhance our understanding of effectively implementing STEM and Coding education to foster innovation and entrepreneurship among Thai students, contributing to the country's technological and economic advancement.

Implementations

The findings from this research lead to several recommendations for utilizing the research outcomes. Firstly, teachers can adapt and integrate learning activities by using video clips to facilitate STEM and Coding learning through registration in lifelong learning college systems provided free of charge. Subsequently, learners should engage in practical application activities to translate their knowledge into practice, as significant changes in students' attitudes were observed during the camp phase, where students applied their knowledge, experienced trial and error, and discovered their abilities. This phase emphasized teamwork to solve problems, fostering a positive attitude towards using STEM and Coding to cultivate a new culture of learning. Therefore, teachers cannot separate theoretical learning from practical application, and innovation camps or similar activities are crucial. Teachers should adequately allocate time for students to innovate after content learning and camp attendance. The research found that most students achieved self-development during the knowledge application phase, demonstrating problem-solving skills early on, leading to creative thinking. Hence, various aspects mentioned cannot be taught solely through lectures; teachers need promotion and development of vision, methods, essential learning tools, and continuous monitoring of new developments. Lastly, schools should create an environment that addresses everyday problems or those nearby to stimulate students' curiosity and problem-solving skills, integrating STEM and Coding into classrooms and enhancing learning realistically. Providing facilities, equipment, technology, specialized experts, and proactive activities to stimulate continuous innovation will result in clearer student development outcomes.

ACKNOWLEDGMENTS

This work was supported by the NSRF via the Program Management Unit for Human Resources & Institutional Development, Research, and Innovation [grant number B44G660096]. We sincerely express our gratitude to the STEM Center at the Teaching and Learning Innovation Center, Chiang Mai University, and the School of Lifelong Education at Chiang Mai University for their invaluable support and contributions.

ETHICS STATEMENT

All research activity by the authors included in the review have been undertaken with the approval of Chiang Mai University Ethics Committees, COA No.031/66, CMUREC No. 66/144.

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