Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 4, 2439-2458
2025
Publisher: Learning Gate
DOI: 10.55214/25768484.v9i4.6583

Integrating AI and IoT into STEM teacher training: A case study of secondary education in Vietnam

Huy Le Thanh[1], Hung Tran Van[2*], Hai Phung Viet[3], Quynh Tran[4], Hung Nguyen Thanh[5], Binh Doan Duy[6], Manh Tran Duc[7]
[1,2,3,4,5,6,7]The University of Danang, University of Science and Education, Danang, Vietnam; tvhung@ued.udn.vn (H.T.V.)

Abstract: This study aims to evaluate the effectiveness of a blended training program for secondary school teachers in Vietnam that integrates Artificial Intelligence (AI) and Internet of Things (IoT) into STEM education. Using a quantitative research design, data were collected from 854 teachers through pre- and post-training surveys. Findings revealed a high level of satisfaction (Mean = 4.38/5) with the training content, delivery methods, and practical applicability. Teachers reported improved confidence in applying AI and IoT in lesson planning and implementation. This research highlights the feasibility of integrating emerging technologies into STEM teacher training in developing countries and underscores the importance of continuous professional development. The study provides policy implications for scaling such initiatives and recommends future studies on long-term impact assessment and student outcomes.

Keywords: *Artificial intelligence (AI), Internet of things (IoT), Secondary education, STEM Education, Teacher capacity.*

1. Introduction

In the current digital age, STEM (Science, Technology, Engineering, Mathematics) education has become the focus of many educational systems around the world to prepare human resources to meet the requirements of socio-economic development. Integrating the fields of STEM in teaching is considered necessary to help students develop complex and creative problem-solving thinking [1]. Many countries have developed strategies and policies to promote STEM education at all levels. For example, Australia has issued a national strategy on STEM education from the secondary level, emphasizing the importance of an interdisciplinary approach in teaching STEM [2]. In Vietnam, STEM education is also increasingly prioritized in the guidance documents of the education sector. The general education program (issued in 2018) aims to introduce STEM into teaching at all levels of general education to develop students' qualities and capabilities [3, 4]. The Ministry of Education and Training has also issued guidelines on implementing STEM education in secondary schools, typically Official Dispatch 3089/BGDĐT-GDTrH (2020) emphasizing STEM as an educational method that combines knowledge with practice [5]. Along with the development of STEM education, the remarkable advances of AI and IoT technology are changing the way we live and learn. AI and IoT will become the most disruptive technologies in the near future, present in many fields including education. IoT allows the connection and collection of data from devices and real environments, creating a "technological revolution" that provides solutions to solve global challenges such as climate change, food security, and disease control [6]. These technologies offer great opportunities for educational innovation, helping students experience practical applications of science and technology and prepare for future careers. Globally, the integration of AI and IoT into general education curricula is emerging as a growing trend. Some pioneering countries such as China have included AI content in compulsory high

History: Received: 19 February 2025; Revised: 18 April 2025; Accepted: 21 April 2025; Published: 26 April 2025
* Correspondence: tvhung@ued.udn.vn

school cirricula, while many pilot initiatives on teaching with IoT and big data have also been deployed in Europe [7, 8]. However, integrating these new technologies into schools requires careful preparation, especially for the teaching staff, to respond to the strong fundamental and comprehensive educational innovation in Vietnam.

Secondary school teachers are considered one of the core forces that determine the success of STEM education in schools. They are not only responsible for imparting knowledge but also for designing meaningful learning experiences and guiding students in addressing interdisciplinary practical problems. Some studies show that teachers' awareness and capacity directly affect the quality of STEM teaching. Margot and Kettler [9] summarized 25 studies on teachers' views on STEM and concluded that the majority of teachers appreciate the benefits of STEM, but they face many barriers in practical implementation such as lack of interdisciplinary pedagogical skills, limitations in supporting programs and materials, concerns about students' capacity, and especially lack of effective professional development courses. Teachers feel the need for support through collaboration with colleagues, access to a high-quality STEM curriculum, institutional backing, and participation in professional development programs in order to confidently implement STEM education. This shows the important role of teacher training in realizing STEM education goals [10, 11].

In that context, training secondary school teachers on STEM education integrating AI and IoT is an urgent requirement. Integrating AI and IoT into STEM teaching is a new direction, requiring teachers not only to be solid in basic STEM knowledge but also to update new technologies and creative teaching methods [12]. Currently, in Vietnam, STEM education activities integrating contents such as AI and IoT are still spontaneous, mainly carried out by teachers or pilot projects within a narrow scope. The capacity of secondary school teachers in using AI and IoT to design STEM lessons has not been systematically assessed [13]. Therefore, this study was conducted to contribute to that gap by surveying teachers' experiences after participating in a STEM training course integrating AI and IoT. Specifically, the research objectives include: (1) Assessing the level of satisfaction of secondary school teachers with the content, methods and effectiveness of the training course on STEM integrating AI and IoT; (2) Analyze factors affecting teachers' satisfaction and self-assessment capacity after training; (3) Enhance the effectiveness of STEM teacher training programs by integrating advanced technologies and promoting continuous professional development.

2. Theoretical Framework

2.1. STEM Education and the Trend of Integrating AI, IoT

STEM education is an integrated educational approach that aims to equip learners with knowledge and skills in the four fields of science, technology, engineering and mathematics. The term STEM originated from the US National Science Foundation (NSF) in 2001 and has quickly been widely used to refer to efforts to reform science and engineering education in many countries [14]. Unlike traditional teaching method that treat each subject separately, STEM education emphasizes the close interconnection between fields where math and science knowledge is applied in the context of technology and engineering to solve practical problems. The STEM education model is often associated with project-based learning or problem-solving (PBL) [15, 16] where students are encouraged to apply interdisciplinary knowledge to design, manufacture products or come up with creative solutions. According to Kelley and Knowles [17] integrating science, technology, engineering and mathematics in a practical learning context increases the appeal and meaning of lessons, thereby improving students' motivation and learning outcomes. On the contrary, if the approach is divided into separate subjects, students may become disengaged and fail to see the connection between knowledge and real-life applications, which can result in a decreased interest in learning [18]. Therefore, there is a global consensus that STEM education should focus on close interdisciplinary integration rather than teaching each subject in isolation.

In recent years, the trend of integrating advanced technologies such as AI and IoT into STEM education has emerged as a new development. The inclusion of AI and IoT in STEM learning content has the potential to increase the practicality and modernity of lessons, helping students "understand the real-world applications" of scientific and technical knowledge. For example, through STEM projects on smart homes with IoT sensors, students can apply knowledge of physics and computer science to assemble electrical circuits, program device control and analyze data. This provides a learning experience on the intergration of interdisciplinary knowledge with new technology. Similarly, STEM topics on AI-controlled robots can arouse students' interest as they observe the practical application of artificial intelligence principles in action. Huệ and Hoà [19] emphasized that designing STEM topics intergrated with AI and IoT helps students understand the operating principles of automated systems, thereby forming thinking about controlling and monitoring equipment, career orientation and practicing creative skills. Obviously, integrating AI and IoT brings richer experiential learning opportunities for students compared to traditional STEM [20].

In addition to the potential, integrating AI and IoT into STEM education also poses many challenges. Firstly, AI and IoT are emering fields for general education programs, and the teaching content is not yet available in textbooks. Therefore, teachers must learn and design appropriate lessons. This requires a lot of self-study and creativity from teachers, while not everyone has a professional background in information technology or computer science. Secondly, implementing STEM activities with high technology integration depends on facilities such as computers, the internet, IoT kits, robots, sensors, etc. In many schools, especially in rural areas, facility conditions are limited, making it difficult for teachers to organize STEM projects applying AI and IoT. Margot and Kettler [9] also pointed out that teachers often encounter systemic barriers such as rigid curriculum frameworks, and lack of time and resources to experiment with new initiatives. Concerning data security and privacy when allowing students to use networked technology (related to IoT, online AI) there are also psychological barriers that need to be considered. Third, AI and IoT knowledge itself is interdisciplinary and complex, requiring teachers to simplify and design activities that are age-appropriate for students. If not careful, teachers may have difficulty explaining AI algorithm concepts or IoT sensor principles in an easy-to-understand way.

In response to these challenges, the most frequently cited solution in literature is the need for teacher training and support programs to equip educators with the necessary skills and resources. Research by Liu, et al. [21] shows that teachers will overcome barriers to integrating new technologies into STEM teaching if they receive regular training and participate in professional learning communities. Through training, teachers not only enhance their digital competencies but also could exchange experiences and share resources with colleagues, enabling them to more effectively integrate digital tools into the classroom. Thus, to realize the potential of AI and IoT in STEM education, teacher preparation and development are prerequisites [22].

2.2. Teacher Competencies in STEM Education Integrating AI, IoT

Identifying the core competencies that teachers need to have in the context of STEM education integrating new technologies is very important to design appropriate training content. Based on the theoretical overview and orientation of the Ministry of Education and Training of Vietnam, the main competency groups of secondary school teachers in teaching STEM integrated with AI, IoT can be classified as follows:

(a) STEM professional competence: This is the foundation of knowledge in natural sciences, mathematics, technology and engineering that teachers need to master. STEM teachers need to have a deep understanding of each component subject (e.g. physics, biology, computer science, mathematics at secondary educational level) and at the same time grasp how these subjects are interconnecting in interdisciplinary topics. According to Kelley and Knowles [17] a challenge is that many teachers are only trained in a narrow field, so they have difficulty teaching integrated subjects. Therefore, STEM professional competence includes not only academic knowledge but also the ability to connect that knowledge in a meaningful way. Teachers need to possess systematic thinking and the ability to see a big picture to design integrated lessons that remain focused and aligned with established knowledge standards [23]. In Vietnam, some criteria for evaluating secondary school teachers also mention that teachers must have interdisciplinary knowledge and understand the STEM orientation in the new general education program. Strong professional competence will help teachers be more confident when implementing new STEM content such as AI and IoT, because they can put these contents in relation to basic science knowledge to explain to students.

(b) Technological competence, especially in AI and IoT: In the context of integrating Industry 4.0 technology, teachers need to develop digital competence, including the ability to proficiently use digital tools, simulation software, basic programming languages, and data literacy. In addition, secondary school teachers do not necessarily need to program advanced AI but should grasp core concepts such as what artificial intelligence is, how machine learning works, how AI is applied in life, and know how to use some available AI applications in teaching (such as image recognition applications, chatbots that answer simple questions, etc.). Similarly, with IoT, teachers need to understand the principles of sensors and connected devices, know how to collect data from sensors, and to use popular boards at a basic level. In fact, many teachers currently lack confidence in this area of knowledge because they have never been properly trained in AI or IoT. Heintz [13] emphasized through interviews with education experts that to bring AI into schools, it is important to prepare a "well-trained team of teachers" in AI. Otherwise, even if the program includes AI content, the implementation will not be effective if the teachers lack the necessary competence, as in the current situation of "AI is still not widely taught in most high schools". Many countries have begun to act, for example, Norway issued standards on digital competence for teachers, requiring pre-service teachers to be equipped with the ability to teach with digital technology. In Asia, Korea and Singapore have also developed national-scale teacher training programs on AI and IoT [12]. These show that technological competence, especially in new technologies, is an indispensable element in the new-age STEM teacher competency standards.

(c) Pedagogical capacity and organization of experiential activities: In addition to professional and technological knowledge, STEM teachers need to have solid pedagogical capacity, especially in organizing experiential and practical learning activities. The characteristic of STEM education is that students learn through experiments and projects, not just through listening to theoretical lectures [24]. Therefore, teachers must be proficient in active teaching methods such as project methods, discovery methods and station-based learning methods. Teachers need to know how to guide students to conduct a STEM project from problem identification, idea generation, designing, testing to evaluating results. In that process, the role of the teacher is more of a supporter, facilitator than a communicator. To do so, teachers must have the skills to organize and manage the classroom in a flexible learning environment, where students can work in groups, use equipment, and move between learning spaces. In addition, teachers also need the skills to ask open-ended questions, promote critical thinking and creativity of students. Research shows that integrating digital technology can help increase the interactivity and initiative of learners, but only when teachers know how to exploit the right methods. For example, using simulations and virtual labs can allow students to explore and practice problem-solving skills actively [25]. Therefore, pedagogical competence here includes the application of technology to teaching in a pedagogical way, that is, the smooth combination of technological knowledge and pedagogical skills - this is like the concept of TPACK (Technological Pedagogical Content Knowledge) in educational theory, emphasizing that teachers must know how to integrate technological knowledge, pedagogy and professional content.

(d) Ability to innovate and adapt to technology: Finally, an equally important ability of teachers in the era of rapidly evolving technology is the ability to innovate and adapt to new teaching approaches.

Teachers need to be open-minded to new things and willing to learn throughout their lives to stay up to date with scientific and technological advances. As technologies such as AI – IoT are still developing every day, teachers cannot just attend a training course and consider it enough but need to form the habit of self-study and self-improvement through professional communities. For example, after the initial training course, teachers can participate in professional learning communities (PLCs) on STEM, IoT, AI to share experiences, materials, and solve problems encountered in practical applications. Teachers' creativity is demonstrated in their ability to customize program content, design new, attractive, and non-stereotypical learning activities. There is currently no fixed format for the technology-integrated STEM education program in Vietnam, so each teacher needs to experiment with their own initiatives that are suitable for their school conditions. Flexibility also helps teachers handle situations that arise during STEM teaching, for example: when IoT devices have problems, when students go off track in their projects, teachers will improvise and adjust their teaching plans effectively [26].

In summary, the competency set of secondary school teachers in STEM education integrating AI and IoT includes a combination of interdisciplinary professional knowledge, modern technology skills, advanced pedagogical skills and innovative thinking. In Vietnam, these competencies are increasingly emphasized in teacher professional standards and regular training programs. Correctly assessing the components of competencies will help develop appropriate teacher training content and methods, contributing to improving the quality of STEM teaching in schools [27].

2.3. Research Methodology

This study uses a quantitative method with a descriptive survey design to collect data on teachers' satisfaction and perceptions after participating in the training course. The research subjects are junior high school teachers in Vietnam, specifically including 854 teachers from 39 junior high schools in Hau Giang province (39/39 junior high schools participated in the training course). The sample consists of teachers who are teaching STEM-related subjects (such as Math, Physics, Chemistry, Biology, Technology, Informatics) and voluntarily registered for the STEM integrated with AI, IoT training course, organized by the research team in collaboration with the local Department of Education.

Table 1.
Demographic characteristics of participating teachers (The survey data was processed and exported using SPSS software).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Under 5 years	26	3.0	3.0	3.0
	5 to 10 years	26	3.0	3.0	6.1
	11 to 15 years	123	14.4	14.4	20.5
	16 years or more	679	79.5	79.5	100.0
	Total	854	100.0	100.0	

As shown in Table 1, The sample consists of 26 teachers (2.3%) with less than 5 years of working experience, 26 teachers (2.3%) with 5 to 10 years of working experience, 123 teachers (11%) with 11 to 15 years of working experience, 680 teachers (60.8%) with over 16 years of working experience. The group includes 463 female and 391 male teachers with an average age of 42 years (SD = 7) and an average teaching experience of 19 years. The main teaching specialties are as follows: 249 Math teachers, 70 IT teachers, 387 Natural Sciences (Physics, Chemistry, Biology), 6 Math IT teachers, 50 Technology, 67 Fine Arts, 25 teachers of other subjects (Table 2).

Table 2.
Statistics of lecturers participating in the survey (The survey data was processed and exported using SPSS software).

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Maths	249	29.1	29.1	29.1
	IT	70	8.2	8.2	37.3
	Natural Sciences	387	45.3	45.3	82.7
	Maths and IT	6	0.7	0.7	83.4
	Technology	50	5.8	5.8	89.2
	Arts	67	7.8	7.8	97.1
	Others	25	2.9	2.9	100.0
	Total	854	100.0	100.0	

The main data collection tool is an online survey designed on the Google Forms platform. The survey includes 50 5-level Likert scale questions and 01 open-ended question, divided into 2 parts:

- Part A: Personal information (gender, age, teaching subject, experience, etc.).
- Part B: Evaluation of learning experience and outcomes, and course content of STEM integrated with AI, IoT training course using a scale from 1 = Very unsuitable to 5 = Very suitable. The overall satisfaction assessment includes 5 key areas: (1) Level of participation in the training course; (2) Training content; (3) Online learning support system and online management; (4) Organizing online courses before attending direct classes; (5) Effectiveness after the training course. The reliability analysis of these five areas resulted in a Cronbach's alpha of 0.845, indicating high internal consistency.

In addition to the survey, the research team also collected qualitative feedback through end-of-course group discussions between the training instructors and the participants, as well as through short final reports that the teachers submitted on the LMS at https://elc.ued.udn.vn/. However, this paper mainly focuses on analyzing quantitative data from the survey; qualitative data is used in the discussion section to clarify some of the results.

2.4. Research Process

The teacher training course on STEM education integrated with AI, IoT has been conducted over a period of 3 months (from December 2024 to March 2025) in a blended learning format. The course structure includes 4 main modules:

(1) Overview of STEM education and technology 4.0: (2 online sessions before face-to-face training) Providing basic theory of STEM education, introducing basic concepts of AI, IoT and integration trends into educational programs around the world.

(2) Technology knowledge and skills: (3 online sessions) Instructing teachers on basic skills in simple AI programming (using visual AI tools such as Scratch with AI extension, or Google's Teachable Machine to create image recognition models), on how to use Micro: bit board and some basic IoT sensors (temperature, humidity, motion sensors). Participants practice in small groups, with the support of technical instructors.

(3) Integrated STEM lesson design method: (2 online sessions) Focus on pedagogical skills, on how to identify STEM topics related to the secondary school curriculum with AI/IoT content integrated, build objectives, and activity plans. In this session, teachers in teaching subject-based groups work together to outline an integrated STEM activity (for example: "Smart Home" project for Technology and Physics subjects, or "Garbage sorting robot" for Informatics and Biology subjects).

(4) Online practice of STEM products integrated with AI and IoT through instructional videos: (2 online sessions) Teachers themselves implement a small trial activity at their school for 1 week before having 2 days of face-to-face sessions to share and discuss the results with other groups

and with the instructors. In the sharing session, each group briefly reports on the application experience, what was successful and what was not successful.

Following the completion of the online modules, teachers participated in a two-day face-to-face training session designed to reinforce and expand the online content. The in-person training process was organized as follows:

During the two days of direct training, many practical and interactive activities were organized to consolidate and enhance the skills that teachers had acquired through the online learning period. The instructors in charge of training directly simulated and guided the use of technological devices such as STEM kits, AI cameras, and IoT circuit boards to illustrate how to organize practical lessons that teachers had previously built. The simulations were conducted with specific projects such as: "Smart home controlled by AI and IoT," in which the device is connected and controlled via image recognition software, and "Robot remotely controlled by smartphone via IoT network," illustrating how to program robot behavior and respond according to received data; "Simulating 72Max LED board connected to IoT" with the content of the text welcoming teachers to the training course; or "Simulating air temperature sensor in the current classroom" using measuring devices and collecting data directly.

In addition, teachers were divided into groups to present AI/IoT integrated STEM products that they had tested at school, exchange implementation experiences, receive feedback from lecturers and colleagues, and complete lesson plans. Group discussion and feedback sessions helped teachers review the practical application process and created a positive peer learning environment. Thanks to that, the direct learning phase played a good role in consolidating knowledge, practicing practical skills, and increasing confidence in applying new technology to STEM education for middle school teachers.

Immediately after the end of the course (last week of April 2024), the participants were asked to complete the post-course survey (Follow the following link https://forms.gle/WqNNiNFeQLp32dR76). The response rate was 83.97% (854/1017 teachers completed the post-course survey).

Post-course survey data were exported to SPSS 26 software for analysis. Descriptive statistics such as frequency, percentage, mean, and standard deviation (SD) were calculated for each question. In this article, we focus on analyzing 5 post-course contents and related factors. The results show that most of the indicators of confidence and attitude towards STEM, AI, and IoT increased significantly after the training course.

3. Findings

The survey analysis results show that teachers give high ratings to the AI and IoT integrated STEM education training course they participated in. This survey consists of 5 key areas, reflecting teachers' perceptions of the overall quality and effectiveness of the AI and IoT integrated STEM education training course, including the evaluation on content, organization to support system and achieved results. Detailed results of the main findings are given below:

3.1. Overall Satisfaction Level Overview

The survey results show that teachers are generally highly satisfied after participating in the STEM training course integrating AI and IoT (Table 3). On a 5-point scale with each group of 10 questions, the average score of the 5 groups of survey content ranges from about 4.21 to 4.48, demonstrating a significantly high level of satisfaction in all aspects. The percentage of teachers choosing "Satisfied" or "Very satisfied" (level 4 or 5) for most statements is over 85%, or even over 90% for many questions. This shows that many teachers have a positive consensus on the effectiveness and quality of the training course.

Table 3.
General responses of teachers to 5 groups of survey questions (The survey data was processed and exported using SPSS software).

	Mean	Minimum	Maximum	Range	Maximum / Minimum	Variance	N of Items
Item Means	4.379	4.210	4.484	0.274	1.065	0.004	50
Item Variances	.339	0.290	0.400	0.110	1.381	0.001	50

In addition to the impressive quantitative indicators, qualitative feedback from teachers also reinforced the conclusion that the course met expectations. Many teachers expressed their excitement and gratitude for the program. For example, one teacher shared: "The course was really useful and inspired me to apply STEM with AI, IoT technology in my teaching". Overall, the general trend in feedback was positive, indicating that the training provided a good and meaningful experience for the participating teachers. The results are presented in detail by survey areas, including descriptive statistics (Mean, SD, % agreement/satisfaction) and qualitative interpretation of teachers' opinions.

3.2. Level of Participation in Training Courses

Teachers also give a high rating to their level of participation in the training (Table 4). The mean score for the "Level of Participation" categories was 4.44/5 (SD approximately 0.57), with approximately 95% of teachers choosing to be satisfied or very satisfied. Most teachers confirmed that they fully attended the training sessions and were active in the activities. Statements such as "I fully attended the training sessions" (TG1, Mean ~4.47) and "I was always on time for the training sessions" (TG9, Mean ~4.48) had very high mean scores, indicating that attendance and punctuality were well maintained. This shows that many teachers were strongly committed to the course, not only attending fully but also being punctual and proactive.

Table 4.
Teachers' feedback on training course participation level(The survey data was processed and exported using SPSS software).

	TG1	TG2	TG3	TG4	TG5	TG6	TG7	TG8	TG9	TG10
N Valid	854	854	854	854	854	854	854	854	854	854
Missing	0	0	0	0	0	0	0	0	0	0
Mean	4.47	4.48	4.43	4.40	4.48	4.40	4.38	4.40	4.48	4.48
Std. Error of Mean	0.019	0.020	0.019	0.020	0.018	0.019	0.021	0.020	0.019	0.019
Median	5.00	5.00	4.00	4.00	5.00	4.00	4.00	4.00	5.00	5.00
Mode	5	5	4	4	5	4	4	4	5	5
Std. Deviation	0.566	0.580	0.562	0.595	0.538	0.559	0.613	0.584	0.559	0.558
Variance	0.320	0.336	0.316	0.354	0.290	0.312	0.375	0.340	0.313	0.311
Range	2	3	2	3	2	2	3	3	2	2
Minimum	3	2	3	2	3	3	2	2	3	3
Maximum	5	5	5	5	5	5	5	5	5	5

Although the overall level of engagement was high, some aspects had slightly lower mean scores. For example, the level of proactively seeking additional information (TG6, Mean ~4.40) and frequent communication with lecturers and colleagues (TG4, Mean ~4.40) were satisfactory but lower than other aspects. This suggests that not all teachers had the time or opportunity to conduct additional research or regular communication outside the main content of the course. However, with satisfaction rates consistently above 90% for all questions in this categories, it can be affirmed that teacher engagement was positive and comprehensive. As one teacher reflected: "I tried to participate as fully and actively as possible, because the course content was very useful". This response suggests that teachers' intrinsic motivation to participate actively stems from their feeling that the course was of practical value.

3.3. Training Course Content

The training program content was highly rated for its relevance and quality (Table 5). The mean score for the group was ~4.40/5 (SD ~0.58). The percentage of teachers who were satisfied or very satisfied with the learning content was over 90%. This shows that most teachers felt that the course content was relevant to their professional needs and was presented effectively. Statements such as "The course provided comprehensive information on STEM education integrating AI and IoT" (ND3, Mean ~4.42) and "The teaching methods were effectively applied" (ND10, Mean ~4.42) received very high levels of agreement, reflecting that the program well covered the necessary knowledge and modern pedagogical methods. Teachers highly appreciated the logic and ease of understanding of the topics (ND2, Mean ~4.41) as well as the ease of understanding and application of the learning materials (ND4, although Mean ~4.35 was the lowest in the group, still showed significant satisfaction).

Table 5.
Teachers' feedback on training content (The survey data was processed and exported using SPSS software).

	ND1	ND2	ND3	ND4	ND5	ND6	ND7	ND8	ND9	ND10
N Valid	854	854	854	854	854	854	854	854	854	854
Missing	0	0	0	0	0	0	0	0	0	0
Mean	4.34	4.41	4.42	4.35	4.40	4.42	4.41	4.40	4.38	4.42
Std. Error of Mean	.021	.020	.020	.020	.020	.020	.021	.020	.019	.020
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Mode	4	4	4	4	4	4	4^a	4	4	4
Std. Deviation	.603	.582	.573	.598	.592	.571	.600	.573	.562	.591
Variance	.364	.339	.328	.358	.351	.326	.360	.329	.316	.349
Range	3	2	2	3	3	2	3	2	3	2
Minimum	2	3	3	2	2	3	2	3	2	3
Maximum	5	5	5	5	5	5	5	5	5	5

Qualitative analysis shows a positive trend in the perception of the course content. Many teachers said that the program was closely related to their practical needs. A Natural Science teacher commented: "The content is very close to the reality of STEM teaching, I can apply it to my subject immediately". In addition, teachers also particularly appreciated the examples and practice exercises. The items "Practical examples help me understand the content better" (ND7, Mean ~4.41) and "Practice exercises are suitable for the learning content" (ND9, Mean ~4.38) both scored high. This shows that the lively and practical teaching method of the training course helped teachers absorb easily and clearly see how to apply it. Some small comments from teachers suggested that they wanted a longer duration to delve deeper into AI and IoT, but in general they were satisfied with the completeness and reasonable arrangement of the current content.

3.4. Online Learning and Management System

Teachers were satisfied with the online learning support system used in the training course (Table 6). The average score of the questions in this categories was about 4.38/5 (SD ~0.58), with over 88-90% of teachers positively evaluating the online learning experience. Factors such as the friendliness and ease of use of the system (HT1, Mean ~4.34) and stability during operation (HT4, Mean ~4.41) were all well recorded. In particular, teachers highly appreciated the ease of accessing lectures and materials (HT5, Mean ~4.33) as well as supporting platform for doing exercises and submitting assignments (HT10, Mean ~4.39). These responses show that the online platform has effectively met the needs of distance learning, helping teachers to monitor and complete the course smoothly.

Table 6.
Teachers' feedback on online learning and management system (The survey data was processed and exported using SPSS software).

	HT1	HT2	HT3	HT4	HT5	HT6	HT7	HT8	HT9	HT10
N Valid	854	854	854	854	854	854	854	854	854	854
Missing	0	0	0	0	0	0	0	0	0	0
Mean	4.34	4.36	4.38	4.41	4.33	4.39	4.38	4.39	4.39	4.39
Std. Error of Mean	0.020	0.020	0.020	0.020	0.019	0.020	0.019	0.020	0.020	0.019
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Mode	4	4	4	4	4	4	4	4	4	4
Std. Deviation	0.592	0.573	0.583	0.575	0.562	0.585	0.566	0.572	0.576	0.564
Variance	0.350	0.329	0.340	0.330	0.316	0.343	0.320	0.327	0.332	0.318
Range	2	3	2	2	2	3	2	2	2	3
Minimum	3	2	3	3	3	2	3	3	3	2
Maximum	5	5	5	5	5	5	5	5	5	5

Open feedback reinforced the quantitative results. Many teachers praised the system for being "easy to use, with fully updated materials". For example, one teacher shared: "The online learning system is very convenient, I can review the lessons at any time". This emphasizes the role of the system in supporting flexible learning, without time and space limitations. A few teachers who initially had difficulty with the technology also admitted that "after a few sessions, I got used to the system, everything became smooth". In terms of communication, the system was rated as providing good support for interactions with lecturers (HT3, Mean ~4.38) and timely notifications (HT9, Mean ~4.39), helping teachers feel always connected to the course. Although there were a few suggestions for improving the system speed during peak hours, most teachers were satisfied with the online learning experience, considering this a strength of the training course, especially in the current context of digital transformation.

3.5. Organizing Training Courses

The course organization (including scheduling, location, and teaching coordination) was rated as very professional and effective by teachers (Table 7). This categories had an average score of about 4.40/5 (SD ~0.57). The majority of teachers (over 90%) were satisfied with the way the course was organized. In particular, the course was well prepared (TC8, Mean ~4.44) and the highlight was that the classes took place on schedule (TC9) with Mean ~4.45 - the highest in the entire survey. This shows that the teaching schedule was well organized, creating a very good impression on the participants. In addition, other factors such as effective group activities (TC6, Mean ~4.42), clear course information (TC7, Mean ~4.43) and dedicated and enthusiastic lecturers (TC5, Mean ~4.43) all received high and consistent scores. This confirms that the trainers are very dedicated, attentive, and able to create a favorable learning environment, and ensure the training session being organized professionally (TC4, Mean ~4.39).

Table 7.
Teachers' feedback on the organization of the training course (The survey data was processed and exported using SPSS software).

	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10
N Valid	854	854	854	854	854	854	854	854	854	854
Missing	0	0	0	0	0	0	0	0	0	0
Mean	4.27	4.39	4.34	4.39	4.43	4.42	4.43	4.44	4.45	4.43
Std. Error of Mean	0.021	0.020	0.019	0.020	0.019	0.019	0.020	0.019	0.019	0.019
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Mode	4	4	4	4	4	4	4	4	4	4
Std. Deviation	0.610	0.583	0.568	0.590	0.560	0.559	0.572	0.561	0.545	0.566
Variance	0.372	0.340	0.323	0.348	0.313	0.312	0.327	0.315	0.297	0.320
Range	3	3	3	3	2	2	2	2	2	2
Minimum	2	2	2	2	3	3	3	3	3	3
Maximum	5	5	5	5	5	5	5	5	5	5

Although most aspects of organization were rated very positively, one relatively lower score was the time of the course (TC1, Mean ~4.27). Some teachers felt that the course schedule was quite tight or that the time was not convenient for everyone. However, even in this category, over 85% of participants were still satisfied, showing that the time issue did not greatly affect the overall experience. Regarding the learning location (TC2, Mean ~4.39), teachers also highly appreciated the convenience. One teacher commented: "The organizers arranged the class very thoughtfully, the location and equipment were fully equipped, helping us to study comfortably". Overall, the feedback showed that the professionalism of the organization contributed significantly to the success of the training course. The dedication of the organizers and instructors was appreciated by teachers, as shown through the sharing: "The instructors were very enthusiastic, the organizers supported us with everything, from documents to techniques". It can be said that good support during the learning process helps teachers focus on the content without worrying about logistical issues.

3.6. Effectiveness after Training Course

The effectiveness and impact of the training course on teachers' teaching capacity were positively reflected, although the assessment level was slightly lower than that of other categories (Table 8). The average score of the "Effectiveness after the training course" categories was about 4.28/5 (SD ~0.61), with over 85-88% of teachers feeling satisfied with what they achieved after the course. Teachers are more confident in teaching STEM integration: "I am confident in applying the knowledge I have learned in teaching" (HQ1) has a Mean of ~4.24 with about 86% agreeing. Similarly, "The course helped me understand STEM education better" (HQ2) has a Mean of ~4.39 (≈92% agreeing), showing that the program has strengthened teachers' basic understanding of STEM. Many also believe that they can design more effective STEM lessons (HQ3, Mean ~4.22). In particular, teachers highly appreciated the aspect of the course encouraging creativity in teaching (HQ8, Mean ~4.33) and willingness to share knowledge with colleagues (HQ9, Mean ~4.35). The item "I find the course really useful for teaching" (HQ10) achieved Mean ~4.35 with nearly 95% of teachers strongly agreeing, affirming the practical value of the training course for their profession.

Table 8.
Teachers' feedback on effectiveness after training course (The survey data was processed and exported using SPSS software).

	HQ1	HQ2	HQ3	HQ4	HQ5	HQ6	HQ7	HQ8	HQ9	HQ10
N Valid	854	854	854	854	854	854	854	854	854	854
Missing	0	0	0	0	0	0	0	0	0	0
Mean	4.24	4.29	4.22	4.31	4.21	4.28	4.25	4.33	4.35	4.35
Std. Error of Mean	.021	.020	.021	.021	.022	.021	.021	.021	.020	.020
Median	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Mode	4	4	4	4	4	4	4	4	4	4
Std. Deviation	.627	.596	.617	.627	.633	.601	.606	.604	.588	.577
Variance	.393	.355	.381	.393	.400	.361	.367	.365	.346	.333
Range	3	3	3	3	3	2	3	2	2	2
Minimum	2	2	2	2	2	3	2	3	3	3
Maximum	5	5	5	5	5	5	5	5	5	5

However, some aspects of personal effectiveness scored slightly lower than the average. For example, "I am able to integrate AI and IoT into my lessons" (HQ5) only scored Mean ~4.21 – a high level of satisfaction but showing that some teachers are not yet fully confident in their ability to integrate new technology. Similarly, the ability to improve classroom management skills (HQ6, Mean ~4.28) or apply new teaching methods (HQ7, Mean ~4.25) were rated positively but not exceptionally high. These numbers suggest that some teachers need more time and practice after the training course to truly master and apply new knowledge and skills in the classroom. This is completely understandable, because the transition to technology-integrated STEM methods is a continuous process and cannot be completed after just one training course. Although the average score of the effectiveness group was lower than that of the other groups, it was still at a solid level of satisfaction. One teacher shared frankly: "Although I still need to learn more, I am much more confident and ready to experiment with AI and IoT in my lessons." This feedback shows that the course has created an important steppingstone, helping teachers change their mindset and boldly innovate, although they are aware that they need to continue practicing after the course. Overall, the effectiveness of the training course is clearly affirmed through teachers being more confident, knowledgeable and motivated to apply what they have learned into teaching practice.

3.7. Comparison of Results Grouped by Subject Taught and Seniority

Further analysis showed that there were no significant differences in satisfaction levels when compared among various group of the subjects taught or the teachers' seniority. The results of one-way ANOVA and independent t-test showed that high satisfaction was found equally among all groups of teachers, regardless of the subjects they taught or how many years of experience they had. Specifically, the average satisfaction score of teachers of Natural Sciences (such as Mathematics, Physics, Chemistry, Biology) compared to teachers of other subjects (such as Technology, Informatics or even Literature interested in STEM) did not have a statistically significant difference ($p > 0.05$). This implies that the training course has well met the general needs of STEM education for teachers in many different subjects. A Mathematics teacher and a Technology teacher can both feel the benefits of the course, despite different expertise, showing that STEM content integrating AI, IoT is interdisciplinary and can be widely applied.

Similarly, when comparing seniority, both new and experienced teachers rated the course highly. No significant differences were found between teachers with less than 5 years of experience, 5-15 years, or more than 15 years of experience in any of the satisfaction categories ($p > 0.05$). All scored an average satisfaction level of around 4.3–4.5. This suggests that teaching experience did not significantly influence how teachers perceived and evaluated the training. While some older teachers may be more cautious with technology, the data showed that they were equally satisfied with the online learning system and the AI and IoT content delivered as their younger colleagues. In fact, many experienced teachers expressed their excitement about the new knowledge update: "Even though I have been teaching for a long time, I am very happy that the course helped me catch up with modern teaching trends." Overall, the lack of significant differences between groups confirms that the training program is designed to be suitable for all secondary school teachers, regardless of expertise or experience, and everyone can benefit and be satisfied.

3.8. Analysis of Teachers' Open Feedback

In addition to the quantitative questions, the survey also collected additional feedback from teachers after the training. Analysis of the open-ended responses revealed the following prominent themes:

- Praise for the program and instructors: Many teachers expressed their gratitude and appreciation for the quality of the course. They emphasized that the training course was useful, practical, and helped them expand their knowledge (Lin, 2022). One teacher wrote: "It was great! I learned a lot of new things and will apply them to my students right away". Many people especially praised the enthusiasm and high expertise of the teaching staff: "The instructors communicated very easily and were always ready to support us when we had questions". These responses show deep satisfaction and gratitude from the students towards the course organizers.
- Application and expected support after the course: Many teachers shared their plans to apply the knowledge they learned. They were eager to bring STEM, AI, IoT into their classrooms and hoped that students would be more interested in technology-integrated lessons [18]. At the same time, some suggested that after the training course, there should be more support and consulting sessions to help them implement it in practice. For example, one teacher suggested: "After the course, if possible, I hope the organizers will continue to support us when we start implementing real STEM projects at school." This shows that teachers are very willing to apply innovation, and they also appreciate the continuous support from experts to be more confident in implementation.
- Suggestions for improvement: Although satisfied, teachers also have some constructive suggestions to improve the course. First, many people want to increase the practice time: "If only there were more time to practice IoT, it would be great". They believe that on-site practice will help solidify skills. Second, some teachers suggest expanding advanced content on AI and IoT: *"The new course is at a basic level, hopefully there will be an advanced course to delve deeper into AI programming"*. In addition, there are opinions suggesting more flexibility in the schedule, such as spreading out the training time so that teachers can both study and try to apply. These suggestions all come from the desire to further improve the quality of training, and the organizers can consider it for future courses [12].
- Impact on awareness and career: Many personal responses show that the course has created strong motivation and inspiration. Teachers talk about their confidence and innovation in thinking after participating [28]. One teacher shared: "I used to be quite vague about STEM, but now I am confident in designing a STEM lesson for my students". Another wrote: "The course made me realize that I need to constantly update technology to teach more effectively". These confessions show that the profound effectiveness of the training course does not stop at knowledge and skills but also in teachers' attitudes and professional awareness. They are motivated to renew themselves, are willing to share with colleagues and play a core role in promoting innovation at their school.

The open feedback from teachers was largely consistent with the quantitative results, confirming the success of the training course. Teachers were not only satisfied but also enthusiastically proposed ideas to further develop what had been achieved. These contributions were valuable, allowing the organizing team to understand the real needs of teachers and improve the program in the future. The fact that many teachers wanted to maintain the learning community after the course also suggested that the impact of the training course could be replicated and extended with continued support. This is a positive sign that the course has created a close-knit community of STEM teachers who share the goal of educational innovation. The results showed that this pilot training course was successful in raising awareness and motivating secondary school teachers about STEM education integrated with AI and IoT. Most teachers were satisfied with the learning experience, more confident and ready to apply innovation. In addition, the study also revealed factors that influence satisfaction (e.g., practicality of content, interactive training methods) and potential barriers to implementation (lack of equipment, limited time). These findings will be further analyzed in the discussion below.

4. Discussion

The results of study on a group of secondary school teachers in Vietnam after participating in a STEM integrated with AI and IoT training course showed a very high level of satisfaction and positive impacts on teachers' self-assessment capacity. These findings are well-aligned with previous studies on STEM teacher training, while also reflect some specific characteristics of the Vietnamese context when integrating new technology into education.

Firstly, the positive reception of the training and increased confidence after the training are consistent with the findings of much other research indicating that professional training has a significant impact on the attitudes and teaching effectiveness of STEM teachers. Al Salami, et al. [11] noted a clear change in teachers' attitudes after participating in an interdisciplinary professional development program. Specifically, teachers became more open to integrated teaching methods and believed in the benefits of STEM [29]. Our study also showed that after the training, the percentage of teachers willing to apply STEM increased significantly (82% willing, compared to ~50% before the training according to the pre-course survey). This confirms the important role of professional development programs in raising awareness and motivation for innovation among teachers. Our results are also in good agreement with the study of Pozo-Rico, et al. [18] which found that teachers who participated in STEM training in Spain reported increased job satisfaction and teaching effectiveness, while their students also showed improved academic performance. Although the contexts were different, the common takeaway was that a well-designed training program will help teachers "revive" their passion for the profession, gain the confidence to try new things, and ultimately benefit their learners.

An important aspect is that the integration of new technology content (AI, IoT) in the STEM context seems to have a positive effect in attracting teachers' attention and interest. In fact, many teachers responded that they were particularly impressed with the AI, IoT learning section – content which they had little access to before. This suggests that teachers themselves are eager to learn new things, especially when they see its potential applications. According to the theoretical framework of adult learning motivation, when learners (here teachers) see that the learning content is related to practical work needs and is topical, they will participate more actively and be more motivated. The survey results show that teachers highly appreciate the practicality of the course, in line with the orientation that Margot and Kettler [9] stated: teachers need effective and practical PD (Professional Development) programs. Our training courses have tried to meet that (e.g., giving teachers real projects to practice, providing ready-to-use teaching materials), thus achieving high satisfaction.

Compared with some regional studies, such as the STEM training program for primary school teachers in Indonesia by Talib, et al. [28] both recorded a satisfaction level of over 80%. However, the difference is that our program integrates AI and IoT content, which is a new element that has not been implemented in many places. Therefore, this study contributes a reference case to the academic community on how to integrate AI and IoT topics into STEM teacher training. Initial experience shows that this approach is feasible and is positively received by teachers. However, it should be noted that the success of the program may be partly due to the voluntary participation of teachers who were already interested in STEM. If implemented widely across the system, we will encounter teachers who are not ready or lack interest. Therefore, replication requires appropriate promotion and incentive policies, as well as content customization to suit each subject [30].

In relation to STEM education practices in Vietnam, the results of this study have several important implications. Firstly, it reinforces the assumption that one of the key challenges for STEM education in Vietnam is the limited capacity of teachers, as highlighted by Nguyen [3]. As long as teachers are not fully equipped with knowledge and skills, STEM will mainly exist as spontaneous extracurricular activities, lacking sustainability. Our study shows that after being trained, teachers feel much more confident and prepared [21]. This suggests that the barriers from the teacher side can be overcome by investing in professional development. Secondly, the study emphasizes the importance of incorporating Industry 4.0 technologies (such as AI, IoT) into the training program. This not only helps teachers update their knowledge but also creates a stimulus for innovation in their teaching thinking. Many teachers proactively proposed new lesson ideas after the course. This initiative is very valuable and shows the ripple effect of the training course. It is consistent with the observation of Park, et al. [12] when studying the experience of teachers on AI integrating [31]. They believe that when teachers are properly supported, they not only can actively apply new technologies but also become pioneers in promoting innovation in schools. Therefore, investing in teacher training in STEM/AI/IoT can be seen as an investment in the sustainable development of digital capacity of the education system.

In addition to the positive aspects, this study also pointed out some limitations and challenges that need attention. Firstly, it is worth noting that although many teachers are satisfied and enthusiastic, not all are ready to immediately apply them into teaching practice. A proportion of teachers (about 15-20%) are still hesitant due to objective difficulties such as lack of equipment and lack of time in class to implement STEM projects. These are systematically barriers that have been known in many previous studies, and it still takes time and support policies to resolve. For example, if the school does not have a lab or IoT kit, it will be difficult for teachers to maintain long-term interest even if they have good ideas [32]. This implies that along with teacher training, it is necessary to synchronize with investment in facilities and curriculum adjustments (giving teachers the flexibility to integrate lessons) to create real change. Second, in self-reported evaluations, teachers may have a social bias [33]. Although the survey was anonymous, we cannot rule out this bias. Therefore, the high satisfaction level should be interpreted with caution. It would be useful to have independent research assessing the impact of the training on teachers' actual classroom behavior over time (e.g., classroom observations or student outcomes). This is something we aim to do in future research.

Compared with international studies, the new contribution of this study lies in integrating the two fields of AI & IoT into the STEM PD program and evaluating the feedback from teachers. Previously, studies such as Ong, et al. [34] or Liu, et al. [21] have mentioned the importance of technology integration in STEM education, but there is not much empirical data at the level of specific program implementation. Our study provides empirical evidence that general education teachers can absorb new technology topics such as AI, IoT if taught appropriately, and they are willing to bring them into the classroom. This is a positive signal affirming that the direction of bringing AI, IoT into general education is feasible, not only for students but also for improving teachers' capacity.

However, we also found a limitation in the small length and scale of the training course, with a total learning time of about 40 hours, which may not be enough to go very deeply into all aspects. In fact, many teachers suggested that they need to add an advanced course – this shows that their learning needs continue. Therefore, a single training session is not enough; there needs to be a regular, ongoing training plan so that teachers are truly proficient in integrating new technologies.

Another methodological limitation in the study is that the assessment is mainly based on teachers' self-reports immediately after the course. Although we have reliable quantitative data on satisfaction, we do not assess the actual level of knowledge/skill acquisition (for example, if there were a pre-post test on teachers' knowledge of AI, IoT, it would be more objective). In the next study, we plan to add tools to measure knowledge and practical skills to have a more complete view of learning effectiveness [35].

Finally, based on the results and limitations mentioned above, we propose some directions for further research. First, it is necessary to conduct long-term follow-up studies to see whether teachers after training have sustainable implementation of integrated STEM activities, and what factors influence them [36]. Second, compare the effectiveness of different training models: fully online vs. face-to-face, short-term intensive training vs. long-term on-site support, etc. to find the optimal model for the specific context. Third, expand the research to primary or high school teachers, where teachers' STEM and technology competencies may differ, to develop appropriate training programs for each level. Finally, it is possible to study the impact on students, for example, whether trained teachers have improved students' interest and learning outcomes in STEM, compared to untrained teachers. These research directions will help to further strengthen the evidence on the effectiveness of teacher training in the context of educational reform.

5. Conclusion

The study "Training secondary school teachers on STEM education integrating AI and IoT: An experience in Vietnam" has provided initial evidence of the effectiveness of a new professional development model, combining interdisciplinary STEM education with AI and IoT technology in the context of the 4.0 industrial revolution. The survey results of 854 teachers participating in the pilot training course showed some notable findings.

First, many teachers expressed high satisfaction with the training program, with an average score of 4.38/5. Practical, updated content and interactive training methods focusing on practice were factors that were positively evaluated. This shows that if properly designed, training programs on STEM and new technologies can attract teachers' active participation and improve their professional capacity.

Second, the course raised teachers' awareness and confidence in teaching STEM integrating new technologies. Up to 91% of teachers said they felt more confident using technology tools, and 82% were willing to apply what they learned to their teaching practice.

Finally, the study confirms the key role of investing in teacher training in implementing STEM education. However, continuous support in terms of policies and facilities is needed to maintain effectiveness. Difficulties such as lack of equipment and limited teaching time are still barriers that must be addressed synchronously to create favorable conditions for teachers to maximize their equipped capacity.

Funding:
This research was supported by the University of Danang – University of Science and Education ID T2025-ĐH-04

Transparency:
The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

Acknowledgements:
The authors would like to thank the Department of Education and Training of Hau Giang Province and all participating secondary school teachers for their active involvement. We also appreciate the support from the The University of Danang – University of Science and Education in organizing and implementing the training program.

References

[1] T. D. Holmlund, K. Lesseig, and D. Slavit, "Making sense of "STEM education" in K-12 contexts," *International Journal of STEM Education*, vol. 5, pp. 1-18, 2018. https://doi.org/10.1186/s40594-018-0127-2

[2] B. Bentley, R. Sieben, and P. Unsworth, "STEM education in Australia: Impediments and solutions in achieving a STEM-ready workforce," *Education Sciences*, vol. 12, no. 10, p. 730, 2022. https://doi.org/10.3390/educsci12100730

[3] P. L. Nguyen, "Vietnam's STEM education landscape: Evolution, challenges, and policy interventions," *Vietnam Journal of Education*, pp. 177-189, 2024. https://doi.org/10.52296/vje.2024.389

[4] P. N. T. P. Phuong and B. V. H. Hong, "Science, Technology, Engineering, and Mathematics (STEM) Education in the New General Education Curriculum of Vietnam," *AsTEN Journal of Teacher Education*, 2024. https://doi.org/10.56278/asten.vi.2702

[5] P. T. Hiệp, "Developing STEM education capacity for primary school teachers to meet the 2018 general education program in Ho Chi Minh City," *Vinh University Journal of Science*, vol. 53, no. 1C, pp. 48–60, 2024. https://doi.org/10.56824/vujs.2023c093

[6] A. Badshah, A. Ghani, A. Daud, A. Jalal, M. Bilal, and J. Crowcroft, "Towards smart education through internet of things: A survey," *ACM Computing Surveys*, vol. 56, no. 2, pp. 1-33, 2023. https://doi.org/10.1145/3610401

[7] D. A. Quevedo Piratova, M. M. Sánchez Duarte, A. Chiappe, and F. M. Sáez Delgado, "Intelligent classrooms: How AI and IoT can reshape learning spaces," *European Journal of Education*, vol. 60, no. 1, p. e70000, 2025. https://doi.org/10.1111/ejed.70000

[8] J. Su, Y. Zhong, and D. T. K. Ng, "A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region," *Computers and Education: Artificial Intelligence*, vol. 3, p. 100065, 2022. https://doi.org/10.1016/J.CAEAI.2022.100065

[9] K. C. Margot and T. Kettler, "Teachers' perception of STEM integration and education: A systematic Literature review," *International Journal of STEM Education*, vol. 6, no. 1, pp. 1-16, 2019. https://doi.org/10.1186/s40594-018-0151-2

[10] Y.-H. Chien and F.-Y. Chang, "An importance-performance analysis of teachers' perception of STEM engineering design education," *Humanities and Social Sciences Communications*, vol. 10, no. 1, pp. 1-11, 2023. https://doi.org/10.1057/s41599-023-01653-7

[11] M. K. Al Salami, C. J. Makela, and M. A. De Miranda, "Assessing changes in teachers' attitudes toward interdisciplinary STEM teaching," *International Journal of Technology and Design Education*, vol. 27, no. 1, pp. 63-88, 2017. https://doi.org/10.1007/s10798-015-9341-0

[12] J. Park, T. W. Teo, A. Teo, J. Chang, J. S. Huang, and S. Koo, "Integrating artificial intelligence into science lessons: Teachers' experiences and views," *International Journal of STEM Education*, vol. 10, no. 1, p. 61, 2023. https://doi.org/10.1186/s40594-023-00454-3

[13] F. Heintz, "Three interviews about K-12 AI education in America, Europe, and Singapore," *KI-Künstliche Intelligenz*, vol. 35, no. 2, pp. 233-237, 2021. https://doi.org/10.1007/s13218-021-00730-w

[14] S.-C. Fan and K.-C. Yu, "How an integrative STEM curriculum can benefit students in engineering design practices," *International Journal of Technology and Design Education*, vol. 27, pp. 107-129, 2017. https://doi.org/10.1007/s10798-015-9328-x

[15] R. M. Capraro, *Project-based learning: An integrated science, technology, engineering, and mathematics (STEM) approach*. Sense Publishers. https://doi.org/10.1007/978-94-6209-143-6, 2008.

[16] S.-J. Lou, R.-C. Shih, C. Ray Diez, and K.-H. Tseng, "The impact of problem-based learning strategies on STEM knowledge integration and attitudes: An exploratory study among female Taiwanese senior high school students," *International Journal of Technology and Design Education*, vol. 21, pp. 195-215, 2011. https://doi.org/10.1007/s10798-010-9114-8

[17] T. R. Kelley and J. G. Knowles, "A conceptual framework for integrated STEM education," *International Journal of STEM education*, vol. 3, pp. 1-11, 2016. https://doi.org/10.1186/s40594-016-0046-z

[18] T. Pozo-Rico, R. Scott, M. Bąk, J.-L. Castejón, and R. Gilar-Corbí, "Riding the wave towards flourishing in STEM education: Enhancing teaching efficacy through a K-12 training program," *Teaching and Teacher Education*, vol. 143, p. 104564, 2024. https://doi.org/10.1016/j.tate.2024.104564

[19] P. T. K. Huệ and N. T. T. Hoà, "Design some STEM topics integrating AI & IoT technology in teaching informatics and technology grade 10," *Saudi Journal of Engineering and Technology*, vol. 9, no. 3, pp. 135–141, 2024. https://doi.org/10.36348/sjet.2024.v09i03.003

[20] L. Thibaut *et al.*, "Integrated STEM education: A systematic review of instructional practices in secondary education," *European Journal of STEM Education*, vol. 3, no. 1, p. 2, 2018. https://doi.org/10.20897/ejsteme/85525

[21] J. Liu, M. Aziku, F. Qiang, and B. Zhang, "Leveraging professional learning communities in linking digital professional development and instructional integration: Evidence from 16,072 STEM teachers," *International Journal of STEM Education*, vol. 11, no. 1, p. 56, 2024. https://doi.org/10.1186/s40594-024-00513-3

[22] T. J. Kopcha, "Teachers' perceptions of the barriers to technology integration and practices with technology under situated professional development," *Computers & Education*, vol. 59, no. 4, pp. 1109-1121, 2012. https://doi.org/10.1016/j.compedu.2012.05.014

[23] J. H. L. Koh, C. S. Chai, B. Wong, and H.-Y. Hong, *Design thinking for education.* Singapore: Springer. https://doi.org/10.1007/978-981-287-444-3, 2015.

[24] M. Hurley, D. Butler, and E. McLoughlin, "STEM teacher professional learning through immersive STEM learning placements in industry: A systematic literature review," *Journal for STEM Education Research*, vol. 7, no. 1, pp. 122-152, 2024. https://doi.org/10.1007/s41979-023-00089-7

[25] S. Lyu, S. Niu, J. Yuan, and Z. Zhan, "Developing professional capital through technology-enabled university-school-enterprise collaboration: An innovative model for C-STEAM preservice teacher education in the Greater Bay area," *Asia Pacific Journal of Innovation and Entrepreneurship*, vol. 18, no. 3, pp. 270-299, 2024. https://doi.org/10.1108/APJIE-01-2024-0014

[26] L. T. B. Le, T. T. Tran, and N. H. Tran, "Challenges to STEM education in Vietnamese high school contexts," *Heliyon*, vol. 7, no. 12, 2021. https://doi.org/10.1016/j.heliyon.2021.e08649

[27] F.-H. Tsai, H.-S. Hsiao, K.-C. Yu, and K.-Y. Lin, "Development and effectiveness evaluation of a STEM-based game-design project for preservice primary teacher education," *International Journal of Technology and Design Education*, pp. 1-22, 2021. https://doi.org/10.1007/s10798-021-09702-5

[28] S. Talib, B. S. Alias, and M. E. E. M. Matore, "Exploring teacher preparedness for STEM education: A systematic literature review," *Universal Journal of Educational Research*, vol. 12, no. 6, pp. 136–146, 2024. https://doi.org/10.13189/ujer.2024.120602

[29] M. Ammar, N. J. Al-Thani, and Z. Ahmad, "Role of pedagogical approaches in fostering innovation among K-12 students in STEM education," *Social Sciences & Humanities Open*, vol. 9, p. 100839, 2024. https://doi.org/10.1016/j.ssaho.2024.100839

[30] C. Stone, E. Freeman, J. E. Dyment, T. Muir, and N. Milthorpe, "Equal or equitable?: The role of flexibility within online education," *Australian and International Journal of Rural Education*, vol. 29, no. 2, pp. 26-40, 2019. https://doi.org/10.47381/aijre.v29i2.221

[31] K. Kavitha and V. Joshith, "Pedagogical incorporation of artificial intelligence in K-12 science education: A decadal bibliometric mapping and systematic literature review (2013-2023)," *Journal of Pedagogical Research*, vol. 8, no. 4, pp. 437-465, 2024. https://doi.org/10.33902/JPR.202429218

[32] O. B. Joseph and N. C. Uzondu, "Professional development for STEM educators: Enhancing teaching effectiveness through continuous learning," *International Journal of Applied Research in Social Sciences*, vol. 6, no. 8, pp. 1557–1574, 2024. https://doi.org/10.51594/ijarss.v6i8.1370

[33] D. Thi Thuy Linh, P. Thi Ngoc Tu, H. Thi Quynh Thi, N. Thi Hieu, N. Thi Luan, and T. Viet Nhi, "Bibliometric analysis of publications on STEM and STEAM education in early childhood from Southeast Asian countries," *Vinh University Journal of Science*, vol. 53, no. Special Issue 1, pp. 17–30, 2024. https://doi.org/10.56824/vujs.2024.htkhgd01

[34] E. Ong, M. U. Wong, A. Huffman, and Y. He, "COVID-19 coronavirus vaccine design using reverse vaccinology and machine learning," *Frontiers in Immunology*, vol. 11, p. 1581, 2020. https://doi.org/10.3389/fimmu.2020.01581

[35] D. Smith-Mutegi, Y. Mamo, J. Kim, H. Crompton, and M. McConnell, "Perceptions of STEM education and artificial intelligence: a Twitter (X) sentiment analysis," *International Journal of STEM Education*, vol. 12, no. 1, pp. 1-18, 2025. https://doi.org/10.1186/s40594-025-00527-5

[36] D. J. Shernoff, S. Sinha, D. M. Bressler, and L. Ginsburg, "Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education," *International Journal of STEM Education*, vol. 4, pp. 1-16, 2017. https://doi.org/10.1186/s40594-017-0068-1

Appendix

SURVEY ON SATISFACTION LEVEL AFTER TRAINING ON STEM EDUCATION IN DIGITAL TRANSFORMATION

Purpose: To survey the satisfaction level of teachers after participating in the training course on STEM education integrated with digital technology, AI and IoT.

Personal information:

- Full name: ....
- School: ....
- Teaching department: ....
- Teaching experience: ....

Instructions for answering:

Please tick (✔) the level that best fits your opinion according to the following Likert scale:

1 - Completely dissatisfied | 2 - Dissatisfied | 3 - Neutral | 4 - Satisfied | 5 - Very satisfied1.

1. LEVEL OF TRAINING PARTICIPATION

Encryption	**Survey Content**	**1**	**2**	**3**	**4**	**5**
TG1	I attended all training sessions.					
TG2	I actively participated in discussion activities during the training.					
TG3	I completed all assigned exercises and tasks.					
TG4	I regularly discussed with the instructor and colleagues during the course.					
TG5	I attended all practical sessions.					
TG6	I actively sought out additional materials related to the training content.					
TG7	I contributed ideas in group activities.					
TG8	I felt that the training time was reasonable.					
TG9	I was always punctual for training sessions.					
TG10	I was willing to support colleagues when attending the training.					

2. TRAINING COURSE AND TRAINING COURSE CONTENT

Encryption	Survey Content	**1**	**2**	**3**	**4**	**5**
ND1	The training course content is suitable for my teaching needs.					
ND2	The topics are logically arranged and easy to understand.					
ND3	The course provides complete information about STEM education integrating AI and IoT.					
ND4	The learning materials are easy to understand and apply.					
ND5	The lectures are presented vividly and engagingly.					
ND6	The training content helps me develop my STEM teaching skills.					
ND7	The practical examples help me better understand the course content.					
ND8	The training course provides practical solutions for implementing STEM.					
ND9	The practical exercises are suitable for the learning content.					
ND10	The teaching methods are applied effectively.					

3. ONLINE LEARNING SUPPORT SYSTEM AND ONLINE MANAGEMENT

Encryption	Survey Content	1	2	3	4	5

HT1	The online learning system is easy to use.					
HT2	The documents on the system are fully updated.					
HT3	The system supports good communication with lecturers.					
HT4	The online learning system operates stably.					
HT5	I can easily access lectures and learning materials.					
HT6	The online tests are clear and easy to understand.					
HT7	The course management system helps me track my learning progress.					
HT8	The online learning resources are diverse and rich.					
HT9	The system's notifications are sent promptly.					
HT10	The system supports good homework and assignment submission.					

4. ORGANIZING TRAINING COURSES

Encryption	**Survey content**	**1**	**2**	**3**	**4**	**5**
TC1	The course duration is reasonable.					
TC2	The location is convenient for participation.					
TC3	The facilities are well-suited for the learning process.					
TC4	The course is professionally organized.					
TC5	The lecturers are dedicated and enthusiastic.					
TC6	The group activities are effectively organized.					
TC7	The information about the course is clearly communicated.					
TC8	The course is well-prepared.					
TC9	The classes are on schedule.					
TC10	The organizers provide good support during the learning process.					

5. RESULTS AFTER TRAINING COURSE

Encryption	**Survey Content**	**1**	**2**	**3**	**4**	**5**
HQ1	I am confident in applying the knowledge I have learned to my teaching.					
HQ2	The course helped me understand STEM education better.					
HQ3	I can design more effective STEM lessons.					
HQ4	The course helped me develop my digital skills.					
HQ5	I am able to integrate AI and IoT into my lessons.					
HQ6	The course helped me improve my classroom management skills.					
HQ7	I can apply new teaching methods.					
HQ8	The course encouraged me to be creative in my teaching.					
HQ9	I am willing to share knowledge with my colleagues.					
HQ10	I find the course really useful for my teaching job.					

Additional comments:

……
……
………………………………………………………………………………………

Thank you for completing the survey.

Edelweiss Applied Science and Technology
ISSN: 2576-8484
Vol. 9, No. 4: 2439-2458, 2025
DOI: 10.55214/25768484.v9i4.6583