Lin, C.-H., Yu, C.-C., Shih, P.-K. & Wu, L.-Y. (2021). STEM-based Artificial Intelligence Learning in General Education for Non-Engineering Undergraduate Students. *Educational Technology & Society*, *24* (3), 224–237.

STEM-based Artificial Intelligence Learning in General Education for Non-Engineering Undergraduate Students

Chun-Hung Lin[1], Chih-Chang Yu[2], Po-Kang Shih[3] and Leon Yufeng Wu[4*]
[1]Center for Teacher Education, Chung Yuan Christian University, Taiwan // [2]Department of Information and Computer Engineering, Chung Yuan Christian University, Taiwan // [3]Center for General Education, Chung Yuan Christian University, Taiwan // [4]Graduate School of Education, Chung Yuan Christian University, Taiwan // chlin@cycu.edu.tw // ccyu@cycu.edu.tw // sportgun@cycu.edu.tw // leonwu@cycu.edu.tw
[*]Corresponding author

ABSTRACT: This article describes STEM education with artificial intelligence (AI) learning, particularly for non-engineering undergraduate students. In the designed three-week learning activities, students were encouraged to put their ideas about AI into practice through two hands-on activities, utilizing a provided deep learning-based web service. This study designed pre-test and post-test surveys to investigate the performance of students in different aspects of AI. With 328 students involved in these learning activities, we discovered from the surveys that the proposed learning method can effectively improve AI literacy among non-engineering students. This study also found that students' AI literacy correlated significantly with their awareness of AI ethical issues and that the STEM-based AI curriculum increased the awareness of AI ethical issues among low-AI-literate learners. This article discusses the association between learning activities and different aspects of AI learning. The proposed method can be used by teachers who want to introduce AI knowledge into general education courses.

Keywords: Artificial intelligence, STEM education, General education, Non-engineering students, Artificial intelligence literacy

1. Introduction

Artificial intelligence (AI) has become part of the educational curriculum and educational services in modern society (Goel, 2017). For non-engineering students, it is important to learn the basic concepts of AI and to develop their understanding of AI and its application directions so that they can picture a future AI-enriched world. The learning process of AI education requires students to combine knowledge from different fields. Hence, incorporating AI learning into STEM education is worthwhile at this moment because STEM education focuses on interdisciplinary learning experiences. Previous studies have identified the trend of incorporating STEM integration into education to foster future citizenship in science (Li et al., 2020). Although a previous study indicated that pre-college math and science test scores and levels of confidence in other related quantitative skills (i.e., ACT math and science test scores and placement test scores) may be used to distinguish non-engineering students from others (Veenstra et al., 2008), educators have increasingly stressed an STEM-integration orientated learning infrastructure for non-engineering students (Nathan et al., 2013) because the interdisciplinary learning experiences reflecting science, technology, engineering, and mathematics are connecting the authentic world more than ever (Katehi et al., 2009). However, numerous studies have depicted negative pre-mindsets among non-engineering students toward learning in a pro-STEM environment (Hu et al., 2020). Non-engineering students often reveal that they are disconnected from the real world in a conventional learning environment. Owing to the nature of non-engineering students' training processes, the value and trends of STEM-based interdisciplinary learning are not always understood among non-engineering students (Lau et al., 2016; Lo et al., 2017).

For most non-engineering students, STEM-related courses are not their primary interests or requirements. Thus, in their learning paths in higher education, science, technology, engineering, and math are not the focus in their learning portfolios. In most cases, it is easier to reach these non-engineering students through STEM-related introductory courses in the general education curriculum. To gain a deeper understanding of what factors affect non-engineering students, this study aimed to understand how different students' backgrounds and characteristics affect their understanding of AI and awareness of AI ethical issues in the course.

1.1. Scientific introductory courses in general education

The core value of the university was holistic education, which included general education and intellectual education. However, with modernization, the goal of university education was repositioned to cultivate professional and technical skills. General education can make up for the shortcomings of current education and improve students' creativity, comprehensive ability, judgment, critical ability, and cognitive skills, so that students can have cross-discipline cooperation ability and develop more mature personalities (Pan & Pan, 2005). General education allows students to realize the world from multiple perspectives and find the meaning and purpose of life through a culture-type course.

In addition to the humanities, science is an important part of general education (Kirk-Kuwaye & Sano-Franchini, 2015). Scientific introductory courses emphasize the "spirit of science" and "scientific literacy" for non-engineering students, as courses that focus solely on "knowledge" would be boring and would therefore reduce students' learning motivation (Pintrich, 1990). Discussing philosophy is sometimes too abstract and unreal; it is crucial in science learning that the design of instructional materials is relevant to authentic daily life (Abd-El-Khalick et al., 1998). Therefore, linking life experiences is essential when appropriating learning materials to achieve better scientific literacy (DeBoer, 2000). Allowing students to learn and understand the science applied in life can help them think about the meaning of science and stimulate their interest in learning (Glynn et al., 2005). For example, using augmented reality (AR) and virtual reality (VR) technologies to teach an astronomy course, students were motivated and encouraged with the assistance of technologies (Liou et al., 2017).

1.2. Instructional strategies for STEM education

Previous studies have confirmed that STEM education has a significant impact on student learning outcomes, especially among Asian students (Wahono et al., 2020; Dong et al., 2020). STEM education can be implemented in various ways. Experiencing a successful STEM education depends not only on the teachers' beliefs, knowledge, and understandings but also on the adequate instruction of STEM concepts (McMullin & Reeve, 2014; Dong et al., 2020). Many past studies have attempted to incorporate problem-based learning strategies into STEM education and have found that they have a positive impact on students' learning outcomes (Sayary, Forawi, & Mansour, 2015; Wang, 2020). With a proper design, STEM education can be extended to ubiquitous learning (Wu et al., 2013). Following the above suggestions, this study adopts a problem-based learning strategy to design the learning activities. The challenge here is to apply STEM enactment to students who are unfamiliar with AI technology. Section 3 describes the details.

Hands-on scientific courses in general education can improve students' motivation and self-confidence in learning science and technology (Krupczak et al., 2005). STEM courses can be part of the university's general education courses that are designed to let students understand not only humanities, writing and literature, and history but also the sciences (including mathematics and technology). For college and university students not majoring in science or engineering, STEM courses can help them look for ways to solve problems and strengthen their educational experiences for future job opportunities (Enderson & Ritz, 2016).

1.3. Important scientific issues: AI education and literacy

The content of teaching and the way of learning about scientific issues need to keep pace with the times (Huang, 2005). For example, technology education has become a basic learning content, and the rise of AI in recent years has been one of the most important scientific and technological issues (Cantú-Ortiz et al., 2020). AI had been developed rapidly and was widely used in different fields, such as manufacturing, economy, communications, transportation, medical care, and education (Pan, 2018).

Thinking about how to teach AI has become important because people's demand for AI applications has increased; however, it is not easy to design a proper AI course which matches students' expertise in the educational field. Allowing the application of AI technology to integrate closely with educational theory can help students obtain a more basic and comprehensive understanding of this topic (Chen et al., 2020). In addition to teaching knowledge, adding practical content to AI courses can increase students' learning motivation (Kostaris et al., 2017). Lin and colleagues (2021) discovered that intrinsic motivation has a significant influence on career motivation. Therefore, educators should foster students' intrinsic motivation and design appropriate instructional strategies so that students wish to strengthen their career motivation by pursuing AI-related knowledge.

In future education, students will learn not only knowledge but also literacy, which is a combination of knowledge, attitude, and skills. For example, scientific literacy is manifested in people's lifestyles and is the internalization of scientific knowledge and understanding of life (Maienschein, 1998). AI education can improve students' AI literacy. Moreover, AI education does not specifically refer to improving students' technical knowledge of, for example, programming, but rather their understanding of AI concepts and applications. The application of AI is quite extensive, and improving students' AI literacy helps to strengthen their ability to cooperate and communicate with others so that students can recognize and solve problems (Konishi, 2016; Long & Magerko, 2020).

1.4. Ethics as a Social Scientific Issue (SSI) element for an AI course

As an important technology widely utilized in daily life, AI has greatly impacted people's lives in many ways. Hwang et al. (2020) documented the connotation of AI education from several angles, such as the development of learning models, implementation frameworks, and learning systems. As such, researchers ought to revisit existing educational theories, learning strategies, and methods to reflect this emerging knowledge in education.

In addition to the increasing stress of learning about basic knowledge of AI, ethical issues regarding the practice of AI technology are equally stressed in current education connotations. Due to various prejudices and algorithms that lack humanity, the abuse of AI violates human rights and inequalities. This violation is an ethical issue that will generally attract people's attention. Therefore, it is necessary to emphasize human-centered AI, enhance learners' awareness of ethical issues through education, and implement the moral teaching of AI for the practitioners (Goldsmith & Burton, 2017; Yang et al., 2021). The course design should not only help students understand the knowledge of AI but also emphasize the impact of AI technology on morality. In recent years, increasing research in the AI field has raised ethical issues. From 2016 to 2018, discussions of interchange, fairness, responsibility, and sustainability increased in AI academic papers (Jobin et al., 2019; Hagendorff, 2020). Research on AI literacy should discuss these issues.

1.5. Purpose of the current study

Since AI is an important scientific issue in this era, it has been regarded as a priority in higher education. For engineering students, AI is a kind of technology. However, for non-engineering students, AI is more likely to be a tool. Hence, the designed learning unit was placed in a general education course with participants who were all non-engineering students. This study investigates the AI literacy of non-engineering university students and identifies the differences in students' AI literacy before and after receiving related courses; the findings will serve as a reference for future curriculum development and revision. The study also determines the impact of the STEM-based course on learners' awareness of AI issues among learners with different AI literacy levels.

This study attempts to answer the following two questions:

(1) Does the STEM-based AI course have an impact on the understanding of AI and AI literacy among students from different majors?
(2) Do different levels of AI literacy have an impact on students' awareness of AI ethical issues?

2. Methodology

2.1. Participants

This study involved 328 non-engineering freshmen from various majors at a university in Taiwan. There were 40–65 students per course and 13 classes. In terms of gender distribution, 108 students were male (32.9%), and 220 students were female (67.1%). Of the students, 79 were from the Department of Accounting (24.1%), 71 were from the Department of Business Management (21.6%), 65 were from the Department of Information Management (19.8%), 41 were from the Department of Landscape Architecture (12.5%), 23 were from the Department of Applied Linguistics and Language Studies (7%), 22 were from the Department of Finance (6.7%), 16 were from the Department of International Trade (4.9%), 4 were from the Department of Teaching Chinese as a Second Language (1.6%), 2 were from the Department of Special Education (0.6%), 2 were from the Undergraduate Program in Social Design (0.6%), 2 were from Department of Financial And Economic Law (0.6%), and one was from the Department of Commercial Design (0.3%). The study was approved by the campus ethics committee, and all participants agreed to participate in the experiments.

2.2. Procedure

This study designed a three-week AI course as part of a regular 18-week general education course, Introduction to Science and Technology, at a university in northern Taiwan. The designed course consisted of lectures for the first week and hands-on exercises for the following two weeks (see Table 1). All participants had a two-hour activity each week.

To evaluate the potential contribution of the proposed AI literacy cultivation, a pre-test was administered before the course to survey learners' AI literacy, AI understanding, and awareness of AI ethics. After the pre-test survey, a lecture was given to establish a baseline of the learners' knowledge in week one. We then provided a series of instructions for hands-on activities in week two. The third week involved a small summative exercise requiring students to utilize the knowledge they had learned in week two to train an AI model that could recognize the "moving directions" and apply the model to a "motor-controlled car kit built on Raspberry Pi" (see Figures 1 and 2). After the activities were completed in week three, a post-test was applied to evaluate whether there was a learning effect on students' AI literacy, understanding, and awareness of AI ethics.

*Table 1***.** The STEM-based AI course unit design

Weeks	Activities
Week 1	Pre-test (10 mins) Lecture (110 mins)
Week 2	Train an AI model (60 mins) Create an object recognition application (60 mins)
Week 3	Train an AI model that can recognize road signs (30 mins) Apply the model to the car kit (90 mins) Post-test (10 mins)

Table 2. Connections between AI learning activities and knowledge points

Item	Corresponding Learning Activities	Knowledge Point (AI Understanding Question Items)
1	Lecture in week 1	I think AI can generate new knowledge.
2	Activity in week 2	I think we must collect enough data to create a good AI model.
3	Activity in weeks 2 & 3	Programming language is required for designing AI applications.
4	Lecture in week 1	I think AI improves its accuracy by reducing certain errors.
5	Lecture in week 1	Deep learning is an AI technique.
6	Activity in weeks 2 & 3	I think the abilities of current AI models are limited.
7	Activity in weeks 2 & 3	I think the algorithm of designing an AI model is important.
8	Lecture in week 1 Activity in weeks 2 & 3	I think most existing AI models are task-specific.

Several training activities were conducted in each of the three weeks. Each proposed activity correlated highly with knowledge points in the survey items (See Table 2). In the first week, students were taught about several important topics in the AI field, including the history of AI and what the scientists are trying to achieve, the definition of supervised learning and unsupervised learning, applications in AI, and ethical issues within the development of AI. The three professional lecturers were from the Departments of Information and Computer Engineering, Information Management, and Electrical Engineering. The purpose of the first week of lectures was to provide students with a basic understanding of AI technology, including its purpose, achievable goals, and current bottlenecks.

Because engineering students lack knowledge of the programming language required to design an AI model, this study utilized a web service called Custom Vision, provided by Microsoft Azure. Custom Vision utilizes a deep learning technique called convolutional neural network (CNN) and provides a web-based interface for users to train their models by adopting transfer learning (Zhang et al., 2018). The provided interface hides the implementation details of creating an AI model, but allows flexibility in designing the problem. Users need only to upload an image dataset to complete an object recognition task. This tool is highly suitable for this study, which aims to teach students how to solve problems using AI techniques. In the training activity in week two, we used a public dataset containing 25,000 images of two types of objects. Each student was given a training dataset and a test dataset. The training dataset contained two classes (e.g., images of cats and dogs), and each class contained 500 images. The test dataset had 20 images. We asked the students to perform the following three experiments:

(1) Use five images from each class to train the model and then test the accuracy using all test datasets.
(2) Use 20 images from each class to train the model and then test the classification accuracy.
(3) Increase the number of images to train the model until all images in the test dataset are correctly classified.

In this training activity, the students discovered that the trained model was highly inaccurate when using only 10 training images. However, the accuracy improved to almost 100% after using more than 100 images for training. This exercise gave them the knowledge that sufficient training data are needed to create a good AI model. In addition, students were asked to choose a picture containing neither of the two classes, feed this picture to the network, and observe the recognition result. The purpose of this exercise was to let students know that the AI model can output only what it knows. For the model to be able to distinguish between "true objects" and "none of the above," it is necessary to provide additional images that do not contain any desired objects (called negative samples), set them into a category, and allow the model to learn them.

In the training activity in week three, students were separated into groups, and each group was provided with a motor-controlled car kit, as shown in Figure 1. The car kit was built using a Raspberry Pi with Raspbian OS so that it could execute programs. The car kits used in this study were equipped with USB cameras to capture images. We also provided two types of road signs (i.e., moving directions for the cars: a left-turn sign and a right-turn sign). In this training activity, the students were asked to design a model that could drive the wheels under different circumstances. More specifically, when the car kit "saw" a right-turn sign, it should turn right. Similarly, it should turn left when the car kit "saw" the left-turn sign. To accomplish this task, students had to first collect several road sign images, upload the images to the Custom Vision website, and then train a model. In addition, students had to consider how to react when the car did not "see" any road signs. For example, if the car stopped at a crossroad, it had to keep waiting until it saw a road sign. At that moment, it would try to detect whether there was a road sign in front of it or not. That is, they had to collect images that represented negative samples, and this practice was related to the activity they did in week two. After finishing the design, the teaching assistants in the class helped the students deploy the model on the car kit. This step was slightly technical, so we intentionally avoided having students do it on their own. Students could determine if there was a problem with the model they had designed by how it behaved on the car kit. If the model did not perform well enough—for example, the car was unable to recognize the road sign correctly—they were encouraged to collect the data again and train a better model.

In this training activity, students realized that they had to design a proper algorithm so that the car kit could respond correctly. We asked the students to engage in this exercise in groups. Because the algorithm they designed may have contained flaws, the teachers needed to guide them in revising their algorithm through discussions. Even if the algorithm were designed well, the car kit might sometimes not have reacted correctly due to the wrong recognition results on road signs. In addition, they could not directly take the model they trained in week two and tackle the problems they encountered in week three. While these activities contain knowledge related to understanding items 6–8 in Table 2, it is worth pointing out that the current AI model was a purpose-specific model, not a generic one. Figure 3 summarizes the relationships between the knowledge points and training activities.

Figure 1. Car kit "motor-controlled car kit built on Raspberry Pi" used in this study

Figure 2. Actual teaching scenario in this study. A student was holding one road sign of moving direction and training the motor-controlled car kit built on Raspberry Pi

In summary, the three-week course began by introducing the basic concepts of AI, presenting several applications that would allow students to think about the development of AI, and introducing ways to solve problems with current AI models. In the first week of interaction, the students had some questions about current AI technologies. To validate their questions, the students had to train their AI models to solve certain problems over the next two weeks. From these experiments, they understood several basic concepts of AI. First, the training of AI models is a data-learning mechanism, which means that we must provide enough data to make the model accurate. Second, the current AI model is task-specific; in other words, it does not know how to solve the given problem. Therefore, it is necessary for humans to design an appropriate algorithm to solve problems with the help of the AI model. Finally, even if properly designed, AI models still have their limitations. It is still possible for an AI model to give wrong decisions. How to deal with these anomalies is an important task for humans.

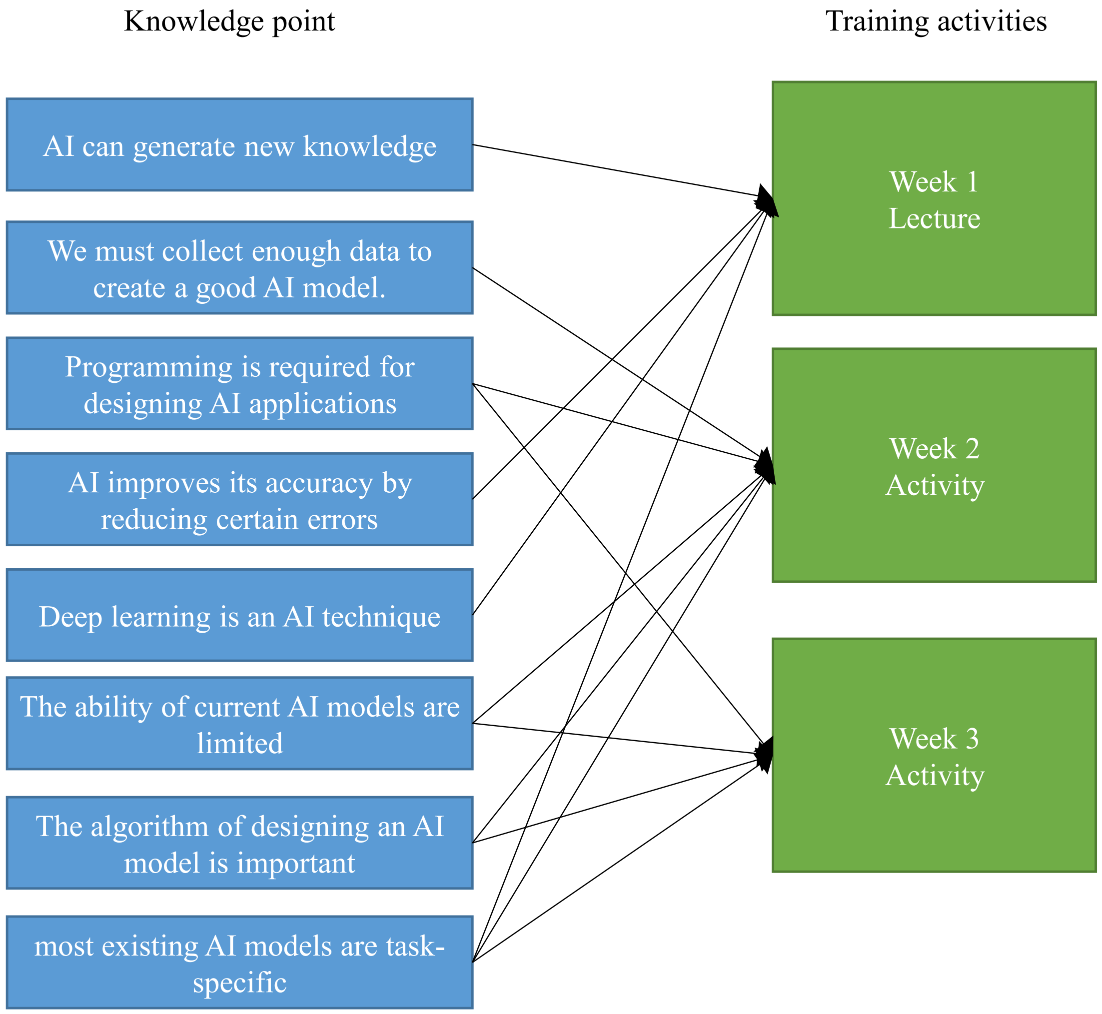

Figure 3. Connections between all knowledge points and the designed three-week lecture and activities

2.3. Instrument

2.3.1. AI literacy scale (AI literacy)

This study adapted an AI literacy scale developed by Lin et al. (2020) to evaluate learners' AI literacy. This scale is designed in the form of a Likert-style five-point scale with 1 corresponding to "strongly disagree" and 5 corresponding to "strongly agree." To understand the important factors of AI, this study applied factor analysis to construct validity. The result of the KMO value was .945, and the significant value of Bartlett's spherical test was .000, suggesting that the dataset was suitable for factor analysis and could explain up to 65.29% of variance. Finally, two important aspects were extracted: (1) teamwork (four items) and (2) attitude toward AI (eight items). The overall internal consistency reliability (Cronbach's alpha) was 0.943, suggesting that the scale maintained good reliability. As illustrated in Section 3.2, the pre-test survey was administered before the first learning activity, and the post-test was administered at the end of the third week.

2.3.2. AI understanding scale (AI understanding)

Eight question items were designed with the revision comments of three experts in relevant fields to estimate the learners' levels of AI understanding after the course. During the course, these question items also served as knowledge points to better align with the design of the lessons and the learning activities. The AI understanding survey was also designed in the form of a Likert-style five-point scale with 1 corresponding to "strongly disagree" and 5 corresponding to "strongly agree." To justify, AI is an ongoing area of science, just like other areas of science still in the process of continuing development. Often, some scientific statements merely describe the current state of development and might not always be true in the future. Therefore, we placed this set of questions to estimate students' levels of AI understanding in our experimental design. Further, the instructors of these courses also employed these questions as discussion topics during the courses.

2.3.3. AI ethics awareness scale (AI ethics)

To understand learners' awareness of the ethical issues of AI, this study developed an AI awareness scale with references to the findings of Jobin et al. (2019) and Hagendorff (2020). The scale was developed using a five-point Likert-type scale, with 1 corresponding to "strongly disagree" and 5 corresponding to "strongly agree." The scale contained 15 questions on four dimensions: Transparency (1,2,3,4), Responsibility (12,13,14), Justice (7,8,9,10), and Benefit (16,17,18,19). The reliability of the overall scale was higher than 0.7, indicating that the scale had good reliability.

3. Results and discussion

In this section, several analyses were conducted to respond to the research questions raised in this study.

3.1. Research question 1: Does the STEM-based AI course have an impact on the understanding of AI among students from different majors?

To estimate learners' levels of AI understanding after the STEM-based AI courses, a repeated *t*-test analysis was applied in this study. The comparisons between the pre- and post-tests (see Table 3) showed that the score of students' AI understanding (mean value) increased from 4.02 to 4.13, and the standard deviation was .60 and .62 respectively. The t-value was 2.99 ($p = .003 < .01$), indicating a significant difference between the pre-test and the post-test scores. The results showed that non-engineering students' levels of AI understanding improved significantly after the course. Hence, we can infer that the present AI course can help enhance students' understanding of AI. Furthermore, it was pointed out that hands-on activities in STEM courses are an important element that can effectively enhance students' active learning and increase their learning effectiveness (Yannier et al., 2020; Mater et al., 2020). The experimental results in this study also matched this viewpoint, showing that students' understanding of AI improved through hands-on activities.

Table 3. Results of the repeated *t*-test analysis on students' understanding of AI

	N	Pre-test		Post-test		*t*
		M	*SD*	*M*	*SD*	
Understand of AI	328	4.02	.60	4.13	.62	2.99^{**}

Note. $^{**}p < .01$.

To determine whether there were differences in students' understanding of AI among students from different majors, we used students' pre-test scores of AI understanding as a covariate and students' post-test scores of AI understanding as the dependent variable, and we applied ANCOVA. No significant difference was found in students' understanding of AI from different majors (see Table 4). After examining the performance of students' pre-test and post-test scores, we observed that students' post-test scores were higher than their pre-test scores but not at a significant level (see Table 5).

Table 4. Results of the analysis of covariance on students' understanding of AI across different majors

Majors	*N*	Mean	*SD*	Adjusted mean	*F*
Accounting	79	4.06	.58	4.10	.67
Business Management	71	4.16	.62	4.15	
Information Management	65	4.27	.60	4.22	
Landscape Architecture	41	4.07	.73	4.07	
Applied Linguistics and Language Studies	23	4.13	.43	4.10	
Finance	22	4.15	.61	4.16	
International Trade	16	4.03	.74	4.06	
Teaching Chinese as a Second Language	4	3.81	.75	3.93	
Special Education	2	4.38	.18	3.93	
Social Design	2	3.75	1.06	3.92	
Financial and Economic Law	2	4.00	.00	3.85	
Commercial Design	1	3.00	-	3.34	

Table 5. results of the repeated t-test analysis on students' understanding of AI across different majors

Majors	*N*	Pre-test		Post-test		*t*
		M	*SD*	M	*SD*	
Accounting	79	3.94	.59	4.06	.58	1.67
Business Management	71	4.05	.51	4.16	.62	1.47
Information Management	65	4.14	.55	4.27	.60	1.74
Landscape Architecture	41	4.02	.81	4.07	.73	.39
Applied Linguistics and Language Studies	23	4.09	.54	4.13	.43	.50
Finance	22	3.99	.61	4.15	.61	1.20
International Trade	16	3.64	.68	4.03	.74	.40
Teaching Chinese as a Second Language	4	3.75	.65	3.81	.75	.24
Special Education	2	3.62	.53	4.38	.18	1.50
Social Design	2	3.65	.88	3.75	1.06	1.00
Financial And Economic Law	2	4.38	.53	4.00	.00	1.00

3.2. Research question 2: Does the STEM-based AI course have an impact on the AI literacy of students from different majors?

Table 6 depicts the effect of STEM-based AI courses on overall students' AI literacy. The analysis results show that after the STEM-based AI course, students' performance in the two dimensions of AI literacy—attitude toward AI and teamwork—improved significantly, indicating that non-engineering students' AI literacy can be positively enhanced through the proposed STEM-based AI course.

Table 6. Results of the repeated *t*-tests on students' AI literacy

AI literacy	*N*	Pre-test		Post-test		*t*
		M	*SD*	*M*	*SD*	
Attitude toward AI	328	4.07	.65	4.14	.69	2.02^{*}
Teamwork	328	3.42	.71	3.83	.73	10.10^{***}

Note. $^{*}p < .05$; $^{***}p < .001$.

As mentioned above, this study found that the hands-on activities in the present AI courses improved students' understanding of AI. Furthermore, this study found that combining hands-on activities with group work helped enhance non-engineering students' perceptions of AI issues and strengthen their awareness of interdisciplinary teamwork. In the process of completing tasks related to AI through teamwork, learners can have the opportunity to realize that cooperation is an important channel for completing tasks related to AI, and this awareness is an important part of AI literacy. This finding echoes those of a previous study (Hurson et al., 2011).

To determine whether there was a difference in students' learning performance in AI literacy among students from different majors, we used students' pre-test scores of AI literacy as a covariate and students' post-test scores of AI literacy as the dependent variable, and we applied ANCOVA. The results showed that there was no significant difference in students' AI literacy from different majors (Table 7). After comparing the performance of students' pre-test and post-test scores, we observed that students' post-test scores were higher than their pre-test scores. Moreover, the results of the repeated t-test analysis showed that students from the Department of Accounting, Business Management, Information Management, Landscape Architecture, Applied Linguistics and Language Studies, and Finance showed significant changes in AI literacy. By contrast, students from the Department of International Trade (IT), Teaching Chinese as a Second Language (TCSL), Special Education (SE), Social Design (SD), and Financial and Economic Law (FEL) did not reach significant differences in AI literacy (Table 8). It is thought that a desired outcome was not observed among some majors due to unbalanced participant data, as the results revealed that those majors with relatively more participants benefited from the course. Therefore, we conjecture that, overall, the STEM-based course may have an impact on participants from different majors.

AI ethics are important for everyone due to the maturity of AI technology. Kocanjer and Kadoić (2016) recommended a method to raise students' ethical awareness by organizing workshops or debates on topics of ethics. Takahara and Kajiwara (2013) adopted debates in engineering ethics classes to improve students' communication skills. From their research, we can conclude that debate is a good activity for raising students' ethical awareness. This study also designed some question items to estimate the ethical awareness of students. Table 9 tabulates the correlation between students' AI literacy and their awareness of AI ethical issues. From an analysis of the results, we can see that the scores for awareness of AI ethical issues positively correlated with AI literacy, which shows that a correlation exists between different AI literacies and students' perceptions of AI ethics.

Table 7. Results of the analysis of covariance on students' AI literacy across different majors

Majors	*N*	Mean	*SD*	Adjusted mean	*F*
Accounting	79	3.90	.63	3.93	.55
Business Management	71	3.97	.61	3.96	
Information Management	65	4.21	.61	4.10	
Landscape Architecture	41	4.02	.72	4.01	
Applied Linguistics and Language Studies	23	3.83	.67	3.90	
Finance	22	4.03	.70	4.04	
International Trade	16	3.95	.68	4.01	
Teaching Chinese as a Second Language	4	3.84	1.12	4.16	
Special Education	2	3.69	.09	3.93	
Social Design	2	3.81	1.15	4.02	
Financial and Economic Law	2	2.94	.09	3.54	
Commercial Design	1	3.00	-	3.85	

Table 8. Results of the repeated *t*-test analysis on students' AI literacy across different majors

Majors	*N*	Pre-test		Post-test		*t*
		M	*SD*	*M*	*SD*	
Accounting	79	3.70	.57	3.90	.63	2.70^{**}
Business Management	71	3.76	.56	3.97	.61	2.57^{*}
Information Management	65	3.93	.56	4.21	.61	3.39^{**}
Landscape Architecture	41	3.76	.56	4.02	.72	2.97^{**}
Applied Linguistics and Language Studies	23	3.63	.56	3.83	.67	2.39^{*}
Finance	22	3.73	.50	4.03	.70	3.04^{**}
International Trade	16	3.63	.63	3.95	.68	1.40
Teaching Chinese as a Second Language	4	3.19	.65	3.84	1.12	1.50
Special Education	2	3.31	.27	3.69	.09	1.66
Social Design	2	3.38	.71	3.81	1.15	1.37
Financial and Economic Law	2	2.68	.27	2.94	.09	2.00

Note. $^{*}p < .05$; $^{***}p < .001$.

Table 9. Correlation between students' AI literacy and awareness of AI ethical issues

	Transparency	Benefit	Justice	Responsibility	Cognition	Awareness	Teamwork
Transparency	-						
Benefit	$.80^{***}$	-					
Justice	$.85^{***}$	$.86^{***}$	-				
Responsibility	$.45^{***}$	$.88^{***}$	$.86^{***}$	-			
Cognition	$.38^{**}$	$.41^{***}$	$.37^{***}$	$.37^{***}$	-		
Awareness	$.46^{***}$	$.44^{***}$	$.43^{***}$	$.45^{***}$	$.60^{***}$	-	
Teamwork	$.30^{***}$	$.31^{***}$	$.31^{***}$	$.25^{***}$	$.47^{***}$	$.49^{***}$	-

Note. $^{**}p < .01$; $^{***}p < .001$.

To further confirm the relationship between AI literacy and perceptions of AI ethical issues, this study analyzed students' perceptions of AI ethical issues. By utilizing ANOVA, the data were categorized into different levels of AI literacy. The overall result between the pre-test and post-test was not significant. As mentioned above, fostering ethical awareness in students requires in-depth interactions and discussions over a long period. Because the proposed course design comprised only six hours over three weeks, there was not enough time to organize enough interactions that might inspire students' ethical awareness via the learning activities. However, this study adopted the teacher-directed strategy to bring some ethical cases into the discussions in-depth. For example, teachers asked students about the ethical issues of autonomous vehicles: "How will the machine react if it has to make choices, like the classical trolley problem? Or say, how should it react?" Students elaborated on or debated their thoughts in class with their peers. To verify the performance of this design, we divided the responses from the students on AI literacy into two levels: high and low. Then, we examined each dimension by their levels of AI literacy. Tables 10 and 11 present the results of the analysis.

Table 10. Effects of AI literacy on students' awareness of AI ethical issues

Dimensions	*N*	*df*	*MS*	*F*	Group	*M*(*SD*)
Transparency	328	1	15.39	41.76^{***}	High	4.53(.54)
					Low	4.10(.68)
Benefit	328	1	15.24	39.05^{***}	High	4.53(.57)
					Low	4.09(.68)
Justice	328	1	15.41	39.69^{***}	High	4.53(.57)
					Low	4.09(.68)
Responsibility	328	1	14.16	35.90^{***}	High	4.56(.58)
					Low	4.14(.68)

Note. $^{***}p < .001$.

Table 11. Changes in Awareness of AI Ethical Issues among Students with Different AI Literacies

Dimensions	Group	*N*	Pre-test		Post-test		*t*
			M	*SD*	*M*	*SD*	
Transparency	High	179	4.60	.47	4.53	.54	1.49
	Low	149	3.99	.62	4.10	.68	2.10^{*}
Benefit	High	179	4.57	.47	4.53	.57	1.16
	Low	149	3.96	.66	4.09	.68	2.70^{**}
Justice	High	179	4.57	.48	4.53	.58	0.56
	Low	149	3.98	.65	4.09	.76	2.43^{*}
Responsibility	High	179	4.65	.47	4.56	.58	2.03^{*}
	Low	149	4.04	.69	4.14	.68	1.93

Note. $^{*}p < .05$; $^{**}p < .01$.

The results suggest that the higher the level of AI literacy students possess, the higher the level of their awareness of AI ethics. This characteristic is reflected in the four dimensions of ethics: transparency, benefit, justice, and responsibility. A further comparison of the averages of AI ethics shows that students with high AI literacy have significantly higher levels of transparency, benefit, justice, and responsibility than students with low AI literacy (see Table 10). In addition, students with lower levels of AI literacy benefited more significantly from the course on all four dimensions than those with higher levels of AI literacy (see Table 11).

The ethical issues of AI have received increasing attention in recent years, and this study found that the performance of students' AI literacy in the context of STEM-based courses was significantly and positively correlated with students' awareness of AI ethical issues. The results in Table 11 revealed that bringing case discussions of ethical issues into STEM-based curricula helped to increase low AI-literate learners' awareness of AI ethical issues. However, the proposed type of discussion was not effective in increasing the awareness of AI ethical issues among high AI literate students. This finding is likely because teacher-directed case-based instruction is effective in increasing students' basic concepts of ethical issues but not in enhancing learners' higher levels of ethical issues (Takahara & Kajiwara, 2013). Learners with higher ethical literacy require more sophisticated teaching methods and activities, such as group debates and case studies.

4. Conclusions and future work

This study proposes a set of STEM-based course modules in the form of lectures, case discussions, and hands-on activities for students with non-engineering backgrounds. These course lessons were developed with a supporting previous framework of AI literacy. Several findings during the analysis showed that the course effectively improved students' AI literacy (i.e., perceptions toward teamwork in an AI-enriched environment and AI adoption) among non-engineering students. The students' AI literacy was correlated with their awareness of AI ethics, and increments occurred in the levels of awareness of AI ethics among learners with low AI literacy. On the contrary, we found that students with high literacy could experience less or limited awareness of ethical issues. For the high-literate students, what might have occurred during the course at various points was not discovered in the current study. A possible future direction could be to customize some more challenging hands-on activities for higher AI-literate learners to see if their levels of awareness of ethical issues could be developed during their teamwork. Designing instructions for different levels of certain perceptions toward core course objectives is reasonable. Furthermore, the experience or ability to define and discuss the problems encountered with their AI car kit was an important learning objective in relation to STEM learning.

In this study, we discussed the effects of a STEM-based AI course on students' understanding of AI and examined its effects on students' awareness of ethical issues in AI. A positive correlation was found between students' AI literacy and their awareness of AI ethical issues. We found that learners with high AI literacy showed a higher awareness of AI ethical issues. In AI education, instructors usually place great emphasis on students' engagement in AI tasks, motivation to learn AI-related content, and learning performance in AI-related topics. Whether AI literacy has the same impact on these dimensions is a valuable direction for future research. Through this kind of study, we can deepen our understanding of the relationship between AI literacy and students' AI learning.

General education is an appropriate way to cultivate students' literacy. For non-engineering students, general education is a medium through which to expose them to important scientific issues, such as AI. We designed a three-week AI course, merged AI literacy into the course, and obtained positive results. In other words, the designed lessons expand the scope and purpose of scientific introductory courses in general education by including the field of AI. This study provides suggestions based on empirical evidence for future STEM-based AI instructional designs.

Acknowledgement

This study was partially funded by the Ministry of Science and Technology and the Ministry of Education, Taiwan (R.O.C.). under grant no. MOST 109-2221-E-033-033-, MOST 108-2511-H-033-003-MY2 and PGE1090426.

References

Abd-El-Khalick, F., Bell R. L., & Lederman N. G. (1998). The Nature of science and instructional practice: Making the unnatural natural. *Science Education*, *82*, 417-436.

Burton, E., Goldsmith, J., Koenig, S., Kuipers, B., Mattei, N., & Walsh, T. (2017). Ethical considerations in Artificial Intelligence courses, *AI Magazine*, *38*(2), 22-34.

Cantú-Ortiz, F. J., Sánchez, N. G., Garrido, L., Terashima-Marin, H., & Brena, R. F. (2020). An Artificial intelligence educational strategy for the digital transformation. *International Journal on Interactive Design and Manufacturing*, *14*, 1195–1209.

Chen, X. L., Xie, H. R., Zou, D., & Hwang, G. J. (2020). Application and theory gaps during the rise of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 100002. doi: 10.1016/j.caeai.2020.100002

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, *37*(6), 582-601.

Dong, Y., Wang, J., & Yang, Y. (2020). Understanding intrinsic challenges to STEM instructional practices for Chinese teachers based on their beliefs and knowledge base. *IJ STEM Ed*, *7*, 47. doi:10.1186/s40594-020-00245-0

Enderson, M. C., & Ritz J. (2016). STEM in general education: Does mathematics competence influence course selection. *The Journal of Technology Studies*, *42*(1), 30-40.

Glynn, S. M., Aultman L. P., & Owens A. M. (2005). Motivation to learn in general education programs. *The Journal of General Education*, *54*(2), 150-170.

Goel, A. K. (2017). AI education for the world. *AI Magazine*, *38*(2), 3-4.

Goldsmith, J., & Burton, E. (2017). Why teaching ethics to AI practitioners is important. *Proceedings of the AAAI Conference on Artificial Intelligence, 31*(1), 4836-4840.

Hagendorff, T. (2020). The Ethics of AI ethics: An Evaluation of guidelines. *Minds and Machines*, *30*, 99–120.

Hu, C. C., Yeh, H. C., & Chen, N. S. (2020). Enhancing STEM competence by making electronic musical pencil for non-engineering students. *Computers & Education*, *150*, 103840. doi:10.1016/j.compedu.2020.103840

Huang, C. J. (2005). A Study of using science news as general education program teaching materials. *Nanhua General Education Research*, *2*(2), 59-83.

Hwang, G. J., Xie, H. R., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, 1, 100001. doi:10.1016/j.caeai.2020.100001

Hurson, A. R., Sedigh, S., Miller, L., & Shirazi, B. (2011). Enriching STEM education through personalization and teaching collaboration. In *Proceedings of the 7th IEEE International Conference on Pervasive Computing and Communications Workshops*. doi:10.1109/PERCOMW.2011.5766949

Jobin A., Ienca, M., & Vayena, E. (2019). The Global landscape of AI ethics guidelines. *Nature Machine Intelligence*, *1*, 389–399.

Katehi, L., Pearson, G., & Feder, M. (2009). *Engineering in K-12 education: Understanding the status and improving the prospects.* Washington, WA: National Research Council.

Kirk-Kuwaye, M., & Sano-Franchini D. (2015). Why do I have to take this course? How academic advisers can help students find personal meaning and purpose in general education. *The Journal of General Education*, *64*(2), 99-105.

Kocanjer, D., & Kadoić, N. (2016). Raising students' awareness about ethical behavior. In *Proceedings of the 4th Global Virtual Conference* (pp. 88-93). doi:10.18638/gv.2016.4.1.764

Konishi, Y. (2016). What is needed for AI literacy? *RIETI Special Series: Priorities for the Japanese Economy in 2016*. Retrieved from https://www.rieti.go.jp/en/columns/s16_0014.html

Kostaris, C., Sergis, S., Sampson, D. G., Giannakos, M. N., & Pelliccione, L. (2017). investigating the potential of the flipped classroom model in K-12 ICT teaching and learning: An Action research study. *Educational Technology & Society*, *20*(1), 261-273.

Krupczak, J. J., Vanderstoep, S., Wessman, L., Makowski, N., Otto, C. A. & Dyk, K. (2005). Work in progress - Case study of a technological literacy and non-majors engineering course. In *Proceedings Frontiers in Education 35th Annual Conference* (S1J-36). doi:10.1109/FIE.2005.1612208

Lau, C., Lo, K., Chan, S., & Ngai, G. (2016). From zero to one: Integrating engineering and non-engineering students in a service-learning engineering project. In *Proceedings of the Second International Conference on Service-Learning (ICSL 2016)* (pp. 186-191).

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A Systematic review of journal publications. *International Journal of STEM Education*, *7*(1), 11. doi:10.1186/s40594-020-00207-6

Liou, H. H., Yang, S. J., Chen, S. Y., & Tarng, W. (2017). The Influences of the 2D image-based augmented reality and virtual reality on student learning. *Educational Technology & Society*, *20*(3), 110-121.

Lin, C. H., Wu, L. Y., Wang, W. C., Wu, P. L., & Cheng, S. Y. (2020, February). *Development and validation of an instrument for AI-Literacy*. Paper presente at the 3rd Eurasian Conference on Educational Innovation (ECEI 2020), Hanoi, Vietnam.

Lin, P. Y., Chai, C. S., Jong, M. S. Y., Dai, Y., Guo, Y. M. & Qin, J. J. (2021). Modeling the structural relationship among primary students' motivation to learn artificial intelligence. *Computers and Education: Artificial Intelligence*, 2, 100006. doi:10.1016/j.caeai.2020.100006

Lo, K. W. K., Lau, C. K., Chan, S. C. F., & Ngai, G. (2017). When non-engineering students work on an international service-learning engineering project - A Case study. In *Proceedings of the 2017 IEEE Global Humanitarian Technology Conference (GHTC)*. doi:10.1109/GHTC.2017.8239292

Long, D., & Magerko, B. (2020). What is AI literacy? Competencies and design considerations. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems* (pp. 1–16). doi:10.1145/3313831.3376727

Maienschein, J. (1998). Scientific Literacy. *Science*, *281*(5379), 917-917.

Mater, N. R., Hussein, M. J. H., Salha, S. H., Draidi, F. R., Shaqour, A. Z., Qatanani, N., & Affouneh, S. (2020). The Effect of the integration of STEM on critical thinking and technology acceptance model. *Educational Studies*. doi:10.1080/03055698.2020.1793736

McMullin, K., & Reeve, E. (2014). Identifying perceptions that contribute to the development of successful project lead the way pre-engineering programs in Utah. *Journal of Technology Education*, *26*(1), 22–46.

Nathan, M. J., Srisurichan, R., Walkington, C., Wolfgram, M., Williams, C., & Alibali, M. W. (2013). Building cohesion across representations: A Mechanism for STEM integration. *Journal of Engineering Education*, *102*(1), 77-116.

Ng, O. L., Shi, L., & Ting, F. (2020). Exploring differences in primary students' geometry learning outcomes in two technology-enhanced environments: Dynamic geometry and 3D printing. *International Journal of STEM Education*, *7*, 50. doi:10.1186/s40594-020-00244-1

Pan, J. D., & Pan, H. M. (2005). Accomplishments of the holistic education idea: An Example from Chung Yuan Christian University. *Chung Yuan Journal*, *33*(2), 237-251.

Pan, Y. H. (2018). 2018 special issue on artificial intelligence 2.0: theories and applications. *Frontiers of Information Technology & Electronic*, *19*(1), 1-2.

Pintrich, P. R., & de Groot, E. V. (1990). Motivational and self-regulated learning components of classroom academic performance. *Journal of Educational Psychology*, *82*(1), 33–40.

Sayary, A. M. A., Forawi, S. A., & Mansour, N. (2015). STEM education and problem-based learning. In *The Routledge International Handbook of Research on Teaching Thinking* (pp. 357-368). New York, NY: Routledge.

Takahara, K., & Kajiwara, T. (2013). Engineering ethics education on the basis of continuous education to improve communication ability. *Electrical Engineering in Japan*, *183*(3), 1–8.

Veenstra, C. P., Dey, E. L., & Herrin, G. D. (2008). Is Modeling of freshman engineering success different from modeling of non-engineering success? *Journal of Engineering Education*, *97*(4), 467-479.

Wahono, B., Lin, P. L., & Chang, C. Y. (2020). Evidence of STEM enactment effectiveness in Asian student learning outcomes. *International Journal of STEM Education*, 7, 36. doi:10.1186/s40594-020-00236-1

Wang, Y. (2020). Integrating games, e-books and AR techniques to support project-based science learning. *Educational Technology & Society*, *23*(3), 53-67.

Wu, P. H., Hwang, G. J., & Tsai, W. H. (2013). An Expert system-based context-aware ubiquitous learning approach for conducting science learning activities. *Educational Technology and Society*, *16,* 217-230.

Yang, S. J. H., Ogata, H., Matsui, T. & Chen, N. S. (2021). Human-centered artificial intelligence in education: Seeing the invisible through the visible. *Computers and Education: Artificial Intelligence*, *2*, 100008. doi: 10.1016/j.caeai.2021.100008

Yannier, N., Hudson, S.E., & Koedinger, K.R. (2020). Active learning is about more than hands-on: A Mixed-reality AI system to support STEM education. *International Journal of Artificial Intelligence in Education*, *30*, 74–96.

Zhang K., Cheng H. D., & Zhang B. (2018). Unified approach to pavement crack and sealed crack detection using preclassification based on transfer learning. *Journal of Computing in Civil Engineering*, *32*(2), 04018001. doi:10.1061/(ASCE)CP.1943-5487.0000736