Hsu and Chen *RPTEL (2022)17:27*
https://doi.org/10.1186/s41039-022-00202-1

Research and Practice in
Technology Enhanced Learning

RESEARCH

Open Access

The engagement of students when learning to use a personal audio classifier to control robot cars in a computational thinking board game

Ting-Chia Hsu[*] and Mu-Sheng Chen

*Correspondence:
ckhsu@ntnu.edu.tw

Department of Technology Application and Human Resource Development, National Taiwan Normal University, 162 Section 1, Heping East Road, Daan District, Taipei 10610, Taiwan

Abstract

This research explored the creative thinking, learning achievement, and engagement of students when they integrated the application of the personal audio classifier (PAC) into the competition of a computational thinking (CT) board game (i.e., the experimental group), or did not integrate it into the competition but only collaborated with peers to test the function of the program which they had developed (i.e., the control group). The students had experienced popular speech recognition usage in their daily life, such as Siri and Google Assistant; therefore, this study developed instructional material for university freshmen to learn to develop their own artificial intelligence (AI) application (app) on a smart phone with PAC in MIT App Inventor. The PAC platform and the learning material cultivated students to train their own voice classification model, which is a form of supervised machine learning in the AI domain. The results showed that both groups, who had successfully trained computers to distinguish received voice commands with PAC receiving the human voice spectrogram via the cloud platform developed by MIT, made significant progress in their learning effectiveness in AI education. When the students employed the AI app on smartphones in the CT board game, the students' voice commands could be classified, and then the corresponding command could be executed through the program to control the action of the robot car on the map, regardless of whether they were competing or not. This study not only successfully provided the students with simple AI learning material, but also cultivated their creative thinking, as identified in the survey of the computational thinking self-efficacy scale. During the process of completing a mobile phone application with AI, students should know and use the function of voice classification to achieve goals and expand their cognition of AI applications. This study concluded that the AI learning material for general students rather than students in the department of computer science facilitated the students' engagement.

Keywords: Board games, Audio classifier, Computational thinking, Creative thinking, Artificial intelligence education, Engagement

Introduction

The rapid development of artificial intelligence (AI) has greatly influenced various fields and changed the world's requirements for the new generation. Computational thinking, programming ability, and AI have become important content of contemporary students' scientific and technological cognition. Computational thinking has become a necessary basic skill for everyone (Yadav et al., 2014). In recent years, the world has put forward corresponding science and technology education policies to cultivate important digital talents such as CT and AI education. The Ministry of Education in some regions such as Taiwan has also promoted AI education in schools (Hsu et al., 2021). With the advancement of AI, machine learning plays a key role in AI technology. Therefore, machine learning is gradually being valued. In recent years, machine learning has been applied in educational activities using image recognition, but education models of voice recognition have rarely been applied.

As time goes by, innovative educational activities are continually appearing. Game competitions have always been an indispensable part of education, and the game concept has been integrated into different subjects (Hinebaugh, 2009). Students' learning motivation and engagement can be enhanced and maintained via game-based learning (Clark et al., 2016), which also stimulates their deeper thinking (Drake & Sung, 2011). In recent years, many researchers have integrated board games into teaching. Gee (2005) stated that by establishing learning goals, board games can become one of the effective tools to promote self-directed learning, problem-solving, and deep learning. Students can socialize and interact with peers and learn from each other when experiencing educational board games (Wu et al., 2014), which shows that such games have unique advantages for supporting interactive learning (Mayer & Harris, 2010).

This research allowed students to train their AI model, cultivate their knowledge of the machine learning process, and apply this model to the operation of board games. The purpose of board games is to cultivate students' computational thinking ability. Our previous study analyzed the learning process when students learned by playing the educational board game named "AI 2 Robot City" (Hsu et al., 2021). It found that encouraging students to plan and predict before taking action is an effective process for students to enhance their learning. Accordingly, students can use AI technology to play board games and carry out the process of computational thinking. A previous study pointed out that creative thinking is one of the important dimensions affecting CT because a person needs to have imagination of the possibilities of the results during problem-solving (Yağcı, 2019). In the same way, when students learn with board games, it is helpful for them to develop strategies during problem-solving by creatively imagining what would happen in the next steps before taking action (Hsu et al., 2021). Therefore, the current study employed creative thinking as a critical assessment scale when cultivating the computational thinking abilities with the board game. Another empirical study also showed that a CT educational board game was beneficial for collaborative creation (Kuo & Hsu, 2019).

Literature review

AI education

There are many divisions of AI education, such as expert systems, machine learning, and so on (Hwang, 2020). However, due to the significant improvement in the calculation speed of the hardware, machine learning has begun to attract a great deal of attention. It used to take decades for humans to learn a profession, and even when they have completed the learning, humans cannot make decisions quickly and immediately. However, machine learning only needs to complete one correct training session, and then the machine can quickly make decisions. Also, machines can be replicated in large numbers (Carbonell et al., 1983), and because of recent technological advances, the computing speed and method have been greatly improved, allowing machine learning techniques to be carried out (Mnih et al., 2015). As a branch of AI, machine learning is still far from true AI, but people can learn how machine learning is different from human learning. By understanding the process of machine learning, people can know more about AI. The scope from broad (e.g., AI) to narrow (e.g., deep learning) AI in Education (AIED) has been illustrated by previous scholars (Chen et al., 2020). Therefore, we developed learning material for general students to learn the application of supervised machine learning.

As AI swept in and had a great impact on many fields (Schmidhuber, 2015), voice recognition was the first technical field to achieve breakthroughs. It was also the first to be introduced into daily life after the laboratory experiments succeeded and can now be seen in the smartphones that everyone carries, or in the upcoming smart speakers which are equipped with voice assistants to provide voice interaction. In modern society, young students have a high degree of acceptance of various electronic products, so we can take advantage of this feature to have students start learning from an early age (Hwang et al., 2010). They are aware that there will be many electronic products equipped with voice recognition. Also, they can bring the concept of voice recognition into their daily lives and make use of it to improve their cognition of AI. Therefore, this study developed the learning material which integrated AI education and computational thinking for general students to learn in universities.

Computational thinking

Computational thinking is a thinking mode that uses the concepts of computer science to solve problems, design systems, and understand human behavior (Wing, 2006). People can learn computational thinking from program design, software, simulations, and operations performed by machines so as to have the appropriate thinking habits (Tedre & Denning, 2016). Thus, when a person has the literacy of computational thinking, he or she has the same thinking mode as a computer scientist does when facing problems (Grover & Pea, 2013). Korkmaz et al. (2017) proposed that computational thinking can be defined as the knowledge, skills, and attitudes which are required to solve problems in life via computers. Therefore, Wing (2006) stated that once students master computational thinking literacy, they can apply it to fields other than computer science.

Creative thinking is closely related to CT and plays a vital role in developing students' motivation and interest in CT education (Korkmaz & Bai, 2019; Korkmaz et al., 2017; Yağcı, 2019). Papert (1980) stated that students' creative thinking can be developed through computers. Until recent years, creative thinking has not been considered to be related to CT education, so some researchers have explored the correlations of CT and creative thinking (Hershkovitz et al., 2019). There was also research showing that the improvement in creative thinking can enhance CT learning, so they emphasized the cultivation of CT and creative thinking at the same time (Israel-Fishelson et al., 2021).

In recent years, computational thinking education, such as programming and algorithms, has received increasing attention (Bocconi et al., 2016). Previous scholars have conducted programming workshops for over 10 years and have indicated that those workshops involving programming on computers have been held to promote creative thinking (Tsutsui & Takada, 2018). In modern society, most elementary and middle school students can easily operate a variety of electronic products. Teachers should use this feature to teach students from an early stage in order to improve their computational thinking at an earlier age, because computational thinking is a competence which students of the new generation must be equipped with (Hsu et al., 2018; Wing, 2008). No matter what kind of field or domain, people would be best to cultivate their computational thinking competence well in a digital world full of software-driven objects (Román-González et al., 2017).

Computational thinking requires training and guidance, because it does not occur naturally (Sanford & Naidu, 2016). In modern society, computational thinking is considered a universal ability, so it should be added to each child's analytical ability, becoming a core part of their learning in school (Voogt et al., 2015). Therefore, instructors have thought about how to teach computational thinking. A previous study confirmed that the computational thinking abilities could be significantly improved regardless of using unplugged (i.e., non-digital or without a computer) game-based learning or plugged (i.e., digital or with a computer) game-based learning (Hsu et al., 2021). Chang (2014) adopted two block-based programming tools, Scratch and Alice, for undergraduates to write game programs, and selected 19 questions from Venkatesh's (2000) questionnaire to find that learning engagement, including the students' learning anxiety, playfulness, and enjoyment, improved. It was found that the factors of learning anxiety, playfulness, and enjoyment are emphasized in CT-related studies. For example, another study also found the importance of those feature factors in LEGO block-based programming involving competition games (Hsu et al., 2021). Scholars have noted that computer anxiety has an indirect effect on intention to adopt gamified learning (Adukaite et al., 2017), and self-efficacy has an indirect effect on behavioral intention through perceived playfulness (Wang & Wang, 2008). When the students first come into contact with CT education, low CT self-efficacy would lead to a decrease in their learning engagement (Bandura, 1977; Pellas, 2014). If there is further development of game-based learning in CT-related instructional material or tools, it would be valuable to confirm whether the new tools are effective in terms of learning engagement.

Game-based learning

Scholars have noted that game-based learning is one of the popular learning approaches for learning computational thinking (Hsu et al., 2018). Many people have devoted themselves to research in this field, trying to develop new teaching models (Bressler & Bodzin, 2013). Game-based learning has been adopted by a growing number of researchers who have found that it is possible to trigger flow through game-based learning (Kuo & Hsu, 2019; Chen & Hsu, 2020), thus connecting flow theory with game-based learning (Hoffman & Nadelson, 2010). Scholars have stated that game-based learning is accompanied by high participation, and have inferred that high engagement or flow can enhance learning and academic achievement (Hoffman & Nadelson, 2010). Su (2016) elucidated the relationship model between gamification learning, learning motivation, cognitive load, learning anxiety, and academic performance, and the research model verified that learning gamification can assist in enhancing learning motivation, presenting teaching content, and encouraging the willingness of students to explore more content, due to entertainment value and game challenge.

Some game-based learning can also simulate and provide meaningful questions, situations, and knowledge in the real-world or in virtual scenarios, enabling students to analyze, think, and organize knowledge content during the learning process (Jonassen et al., 2003). Game-based learning systems have been found to foster students' engagement and to provide the creation and integration of appropriate content with gamification (Licorish et al., 2018). Digital game-based learning is for students to enhance the acquisition of knowledge and skills by experiencing game content and gameplay. The game content includes problem-solving and achievement challenges (Kirriemuir & McFarlane, 2004). Students can actively explore, evaluate, integrate, and construct organized and diverse knowledge (Hwang et al., 2015). Also, students are free to try various methods to achieve the clearance conditions set by the game. Through the design of the game, scholars use its rules or competition or rewards to guide students to think, analyze, and then make meaningful decisions (Coller & Scott, 2009).

Games can make students learn more actively. Digital games can arouse students' intrinsic motivation, increase their learning interest and memory retention, provide exercises and feedback, and enable them to think at a higher level (Hogle, 1996). In the past traditional education, teachers always played the guiding role. In such a system, students' engagement and learning enjoyment were relatively low, indirectly leading to poor learning effectiveness. Therefore, in the modern era, this guiding role should be turned into a game system, which can guide students to a higher learning level, and game-based learning can be used to stimulate students' zone of proximal development (Vygotsky, 1978). Through digital game-based learning, a virtual situational space is simulated to shorten the gap between students' mental and actual situations and to stimulate their learning motivation (Hwang et al., 2015). Rosar and Weidlich (2022) examined the interaction effects between the learning environment and students' creativity and found that creative students presented more motivation after working on creative tasks in a visually rich environment.

Research method

Participants

The experimental subjects of this research were 59 students enrolled in a fundamental Introduction to Computer Science course in a university. There were totally 30 males and 29 females who were all programming novices. The instructional experiment was conducted by the same instructor. In the learning activities, all the students had to write a mobile phone program with MIT App Inventor and the PAC platform so that the program the students learned to develop had the AI function of voice recognition. This research mainly used the personal audio classifier (PAC) for students to carry out the process of voice recognition and experience the process of supervised machine learning. Then, the students had to examine the AI application they had developed for the real task on the map of the board game.

Research tools

This research used the personal audio classifier (PAC) online platform developed by MIT. This platform supported the students to easily conduct the process of supervised machine learning and to train a voice recognition model from steps 1 to 4, as shown in Fig. 1, without the necessity of learning complicated mathematics. Students do not need to write the supervised algorithm on their own, but only need to follow the steps on the PAC platform. This process can help them understand the process of supervised machine learning, and they can train the voice recognition model by themselves. After training the voice recognition model, they can apply this model to the MIT App Inventor for more applications with block-based programming which makes it easy for novices to write an App to run on Android smart phones.

The instructional experiment of the study attempted to help the students develop the supervised machine learning concepts from the process of using PAC, so that they could gain an understanding of AI applications. Their learning effectiveness and learning engagement regarding the subject of AI learning and application were thereby evaluated in the study. In addition, their creative thinking was assessed using the CT self-efficacy scales.

The CT self-efficacy scales were proposed by Yağcı (2019) and include problem-solving, cooperative learning, critical thinking, creative thinking, and algorithmic thinking. The Cronbach's alpha value which presented the reliability of the CT self-efficacy scales is 0.969. For this research, we adopted the four items in the scale of creative thinking because creative thinking has been regarded as an important factor in board games (Kuo & Hsu, 2020). The items included "1. I enjoy coming up with new ideas that nobody has thought of before," "2. I get bored of doing the same thing," "3. I enjoy designing systems to perform a task automatically," and "4. I am curious about how the structure of systems that perform a task and how they work." The creative thinking of the CT self-efficacy scale used a 5-point Likert scale, with 1 point for "*strongly disagree*" to 5 points for "*strongly agree*."

The learning engagement questionnaire used in this study is a science and technology acceptance scale compiled by Venkatesh (2000), which is used for assessing students' learning engagement. There are 44 questions and a total of eight dimensions in

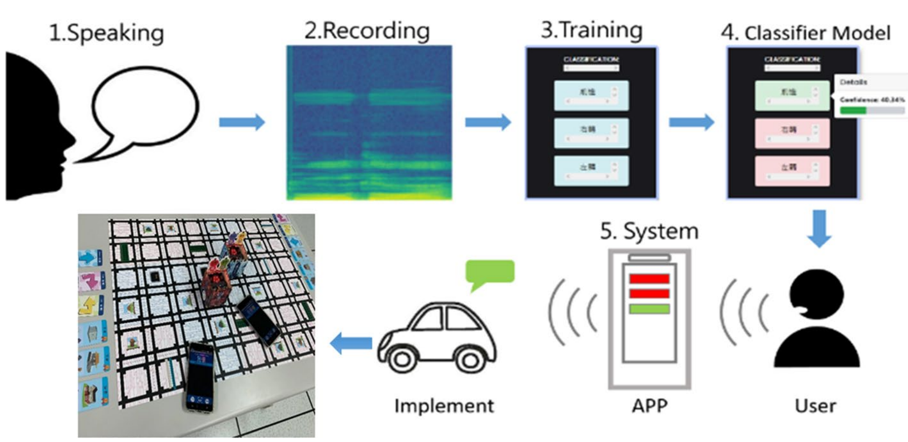

Fig. 1 The students experienced the learning process from steps 1 to 4 on the MIT App Inventor Platform

the original questionnaire. The eight scales were behavioral intention to use, perceived usefulness, perceived ease of use, perceptions of internal control (i.e., computer self-efficacy), perceptions of external control (i.e., facilitating conditions), computer anxiety, computer playfulness, and perceived enjoyment. A previous study adapted the dimensions of anxiety, playfulness, and enjoyment for assessing the learning engagement of students learning block-based programming (Chang, 2014). Taking an item of the anxiety scale for example, "PAC course does not scare me at all." As for the instance of the playfulness scale, the item is like "Do you agree questions in the PAC course require you to characterize themselves in the programming course as follows? spontaneous." In terms of the enjoyment scale, here is an example of items "I find the programming course to be enjoyable." The Cronbach's alpha values of learning anxiety, playfulness, and enjoyment were 0.91, 0.88, and 0.90, respectively, with a total of 19 questions and a 5-point Likert scale.

In order to assess the students' learning effectiveness, the pretest and posttest items were developed by two experienced teachers together. The pretest had a total of 10 multiple-choice questions and four matching questions, with a perfect score of 100. The posttest had a total of 12 multiple-choice questions and four matching questions, with a perfect score of 100.

Experimental procedure

There were 32 students in the experimental group and 28 in the control group. However, there was one student in the experimental group who did not fill out all of the questionnaire, so finally only 59 students' data were analyzed for the statistical results.

The students in the experimental group used the AI app they had developed by themselves with MIT App Inventor. The app was installed on the smartphone to control the robot cars on the computational thinking board game, and to compete with another group, as shown at the end of Fig. 1. The students enhanced their computational thinking while playing the board game because it involved route plans, resource allocations, and calculation, and the students had to put the phases of CT (e.g., problem decomposition, pattern recognition, abstraction, algorithm steps) into practice so as to solve their construction tasks in the board game (Hsu et al., 2021).

The students in the control group did not compete with other groups. Two students as a group collaborated to evaluate and optimize the AI app on the smartphone together, as shown in Fig. 2. They did not need to compete with other groups.

This research had students carry out the process of voice recognition through the personal audio classifier (PAC) platform. After completing the voice recognition model, the students further applied the model they had trained and built on their own to the MIT App Inventor for writing the mobile phone program which was used for controlling the robot cars on the CT board game. The purpose of the curriculum practicing PAC is to have students learn and complete voice recognition with interactive operations step-by-step without the need for complicated mathematics capability. It is expected that the instructional tool packages of AI education are useful for enhancing the learning achievement, creative thinking, and learning engagement of students learning AI.

The current study used audio instruction to control the robot car, while the previous study used instruction images shown in the cards to control the robot car in the

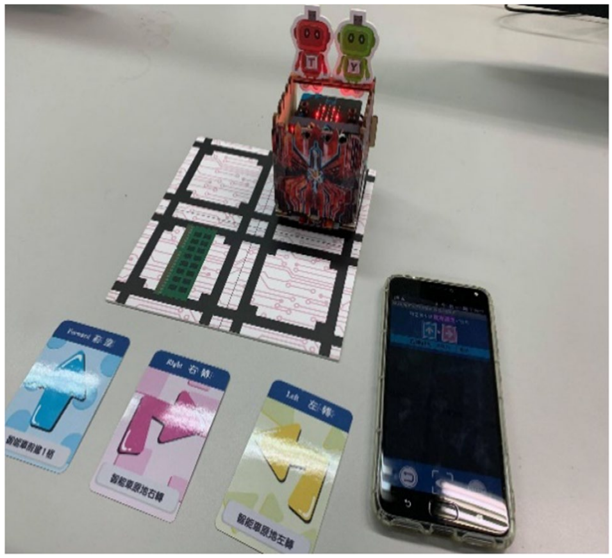

Fig. 2 Two students collaborated to assess their AI app on the smart phone together in the control group

board game named “AI 2 Robot City” (Hsu et al., 2021). The robot car could recognize the instructions of the players after the students employed the personal audio classification model into the application of the smart phone in both experimental and control groups. For example, when the student said “turn right,” he or she would see the robot car turn right on the map of the board game.

As shown in Fig. 3, before the experiment, this study used the computational thinking and AI concept test paper, creative thinking of the CT self-efficacy scale, and the questionnaire of learning engagement to perform pretests on students to assess their prerequisite knowledge and attitudes. Then, the students experienced the learning activities, as shown in Fig. 3. After the teacher introduced PAC and instructed the students to implement it, they followed the steps on the PAC platform to complete their own voice recognition model. After the students built and trained the model of voice recognition with the PAC platform on their own, they uploaded this voice recognition model onto their project in the MIT App Inventor platform. The students wrote the mobile phone program with the block-based programming interface on MIT App Inventor. The students were required to complete the program which would be used to control the robot car movement and load the program to the mobile phone for actual tasks in the CT board game. On the one hand, the control group used the mobile phone application program to control the robot car with voice recognition, which is one application of AI literacy, so as to examine the performance of the AI application they wrote with PAC and MIT App Inventor. On the other hand, the experimental group conducted a board game competition with the PAC model installed into the smart phone app which they developed for controlling the robot car with voice recognition. After the learning activities, the students had to fill in the same computational thinking and AI concept test papers, the creative thinking section of the CT self-efficacy scale, and the questionnaire of learning engagement as a posttest, to understand whether the results improved, regardless of whether they

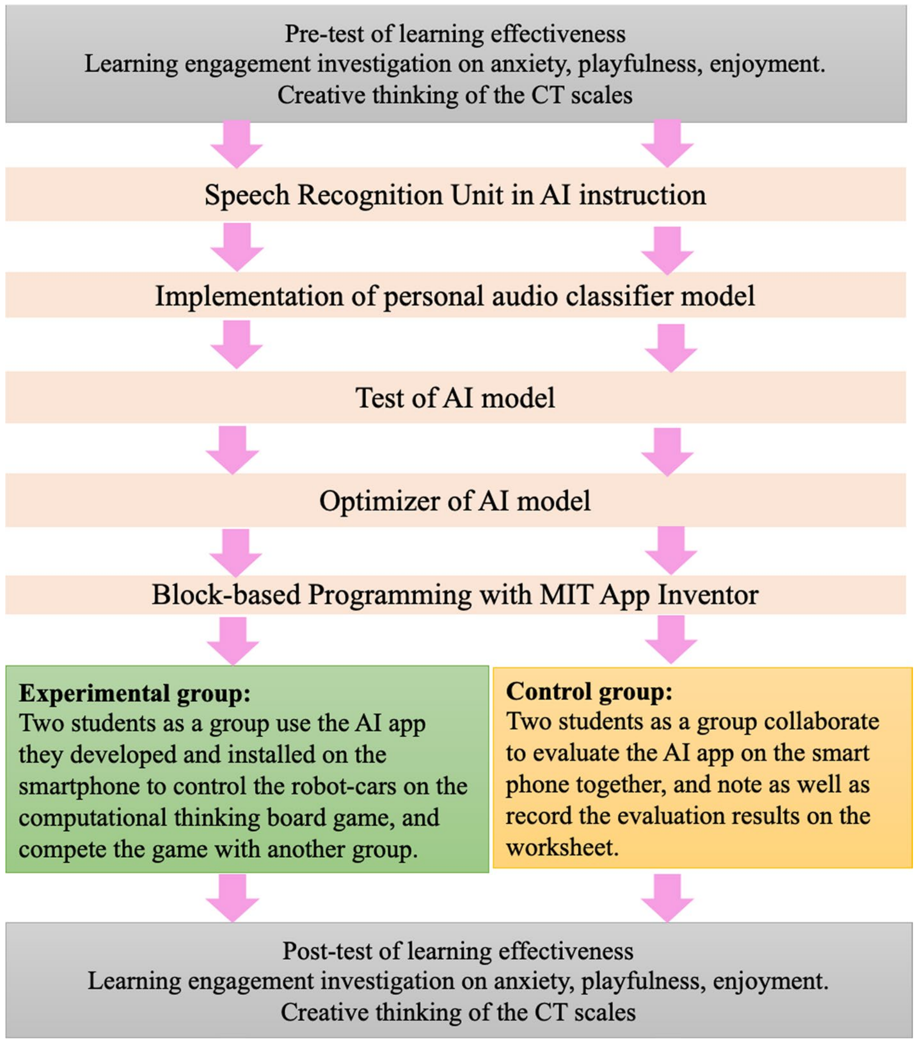

Fig. 3 Experimental process

used a competitive way (i.e., the experimental group) or an uncompetitive way (i.e., the control group). The experimental process took a total of six class periods to complete. Each class period was 50 min with a 10-min break.

This study employed the paired-sample *t* test to determine whether students in both groups made significant progress in learning achievement, creative thinking, and learning engagement. In addition, analysis of covariance (ANCOVA) was adopted to compare the learning effectiveness of the two groups, where the covariance was the pretest, the dependent variable was the posttest, and the factor was groups. As for the scales, learning anxiety, playfulness, and enjoyment, this study used multivariate analysis of covariance (MANCOVA) to check the differences between the two groups. The results are shown in the following section.

Table 1 Paired-sample *t* test between the pre- and posttests of learning effectiveness for the experimental and control groups

Group	Learning achievement	N	Mean	SD	t
Experimental group	Pretest	31	47.61	13.65	− 6.90***
	Posttest	31	67.87	11.74	
Control group	Pretest	28	46.75	15.82	− 3.63***
	Posttest	28	59.11	14.88	

***$p < 0.001$

Table 2 The ANCOVA result of learning achievement

Group	N	Mean	SD	Adjusted mean	SE	F	p	η^2
Experimental group	31	67.87	11.74	67.81	2.35	6.315*	.015	.103
Control group	28	59.11	14.88	59.24	2.47			

*$p < 0.05$

Research results

This research aimed to explore whether the integration of the personal audio classifiers into a computational thinking board game would be helpful for students' learning achievement and engagement.

The results of learning achievement

This study used computational thinking and AI concept test papers to conduct pre- and posttests, and the paired-sample *t* test was used to analyze the results of the pre- and posttests so as to identify the students' progress. As can be seen in Table 1, the posttest scores of the control group students were significantly greater than their pretest scores, $t(27) = -3.63^{**}$, $p < 0.01$, and the posttest scores of the experimental group students were also significantly greater than their pretest scores, $t(30) = -6.90^{***}$, $p < 0.001$. Thus, introducing the audio classifier into the computational thinking board game could significantly increase the students' learning achievement, regardless of whether they used the competitive way (i.e., the experimental group) or the uncompetitive way (i.e., the control group).

Analysis of covariance (ANCOVA) was further conducted to compare the learning achievements of the two groups. There was no interaction between the pretest and the independent variable (i.e., groups) because tests of between-subjects effects showed no significance ($F = -0.357$; $p = 0.553 > 0.05$), inferring that the homogeneity of the regression coefficient was confirmed before performing ANCOVA. The Levene's homogeneity test showed that ANCOVA ($F = 1.491$, $p = 0.227 > 0.05$) was able to be used to analyze the posttest scores of the experimental and control group students. As shown in Table 2, the adjusted mean value and standard error of the posttest scores were 59.24 and 2.47 for the control group and 67.81 and 2.35 for the experimental group. According to the results ($F = 6.315$, $p = 0.015 < 0.05$), there was a significant difference between the two groups; that is, the students in the experimental group showed significantly better learning achievement than those in the control group.

The results of creative thinking

This research also attempted to explore the variation in creative thinking which is the performance of the students' CT self-efficacy scale. The analysis of the paired-sample *t* test of creative thinking in the two learning activities found that the students in the control group had no significant improvement in the creative thinking section of the CT scale, while the students in the experimental group had significant improvement in the aspect of creative thinking, as shown in Table 3.

From Table 3, it can be seen that the increasing variation in the creative thinking of the experimental group students was significant with $t(30) = -3.18^{**}$, $p < 0.01$. The posttest score ($M = 3.69$, $SD = 0.58$) was significantly greater than the pretest score ($M = 3.34$, $SD = 0.51$) for the experimental group. On the other hand, the students in the control group had no significant differences in their creative thinking. Thus, based on the results of the experimental group, introducing the audio classifier into the computational thinking board game with appropriate competition made a significant contribution to increasing the creative thinking presented by the students.

The results of learning engagement

This study intended to explore the students' learning engagement. The learning engagement scale was divided into three aspects: "learning anxiety," "playfulness," and "enjoyment." After conducting the paired-sample *t* test for analyzing the pre- and posttests in both groups, we found that the experimental groups were significantly different in every aspect, while the control group was only significantly different in the dimension of enjoyment.

From Table 4, the learning anxiety of the students in the experimental group achieved remarkable difference before and after the treatment ($t(30) = -3.87^{***}$, $p < 0.001$). The posttest score ($M = 3.71$, $SD = 0.62$) was significantly greater than the pretest score ($M = 3.24$, $SD = 0.44$). As for the playfulness of the students in the experimental group, there was also a significant increase ($t(30) = -2.82^{**}$, $p < 0.01$). The posttest score ($M = 3.48$, $SD = 0.59$) was significantly greater than the pretest score ($M = 3.13$, $SD = 0.31$). For the enjoyment of the students in the experimental group, the significant improvement was also confirmed ($t(30) = -2.73^{*}$, $p < 0.05$). The posttest score ($M = 3.54$, $SD = 0.96$) was significantly greater than the pretest score ($M = 2.88$, $SD = 0.89$), so the enjoyment of learning to develop an AI application was enhanced.

Table 3 Paired-sample *t* test between the pre- and posttests of creative thinking for the experimental and control groups

Group	Creative thinking	*N*	Mean	SD	*t*
Experimental group	Pretest	31	3.34	0.60	−3.18**
	Posttest	31	3.69	0.70	
Control group	Pretest	28	3.37	0.41	0.56
	Posttest	28	3.32	0.46	

$^{**}p < 0.01$

Table 4 Paired-sample *t* test between the pre- and posttests of learning engagement with learning anxiety, playfulness, and enjoyment for the experimental and control groups

Scale	Group		*N*	Mean	SD	*t*
Learning anxiety	Experimental group	Pretest	31	3.24	0.44	− 3.87**
		Posttest	31	3.71	0.62	
	Control group	Pretest	28	3.15	0.64	− 1.07
		Posttest	28	3.25	0.68	
Learning playfulness	Experimental group	Pretest	31	3.05	0.30	− 2.88**
		Posttest	31	3.69	0.59	
	Control group	Pretest	28	3.14	0.36	− 1.27
		Posttest	28	3.28	0.47	
Learning enjoyment	Experimental group	Pretest	31	3.12	0.89	− 2.73*
		Posttest	31	3.48	0.96	
	Control group	Pretest	28	2.90	0.69	− 2.98**
		Posttest	28	3.37	0.62	

*$p < 0.05$; **$p < 0.01$

Table 5 MANCOVA of learning engagement

Scales	Groups	*N*	Adjusted Mean	SE	Comparison	Wilk's Lambda	*F*	*p*	Partial η^2
Anxiety	Experimental (a)	31	3.54	0.13	a > b	0.822	3.756*	0.026	0.178
	Control (b)	28	3.28	0.11					
Playfulness	Experimental (a)	31	3.44	0.13					
	Control (b)	28	3.27	0.11					
Enjoyment	Experimental (a)	31	3.19	0.19					
	Control (b)	28	3.37	0.16					

*$p < 0.05$

On the other hand, the students in the control group only had significantly different perceptions in the enjoyment aspect ($t(27) = -2.98^{**}$, $p < 0.01$). The posttest score ($M = 3.37$, SD = 0.62) of learning enjoyment was significantly greater than the pretest score ($M = 2.90$, SD = 0.69). Therefore, employing PAC in learning how to collaboratively develop a voice recognition app on the smart phone could enhance the students' learning enjoyment.

Accordingly, introducing PAC into learning how to collaboratively develop a voice recognition app on the smart phone and then competing with other teams on the CT board game could enhance students' learning engagement. The students in the experimental group perceived higher learning anxiety, playfulness, and enjoyment at the same time. However, the students in the control group only perceived higher enjoyment when they employed PAC for learning how to collaboratively develop a voice recognition app on the smart phone without the task of competition with other teams on the CT board game.

This study further conducted multivariate analysis of covariance (MANCOVA) to compare the difference between the two groups, as shown in Table 5. The homogeneity of variances and covariances was accepted in the MANCOVA, while there was no significant difference in Box's M test of equality of covariance matrices (Box M = 12.047; $F = 1.892$, $p = 0.078 > 0.05$). The results of MANCOVA revealed that there was a statistically significant difference between the two groups on the combined dependent variables, $F(3,52) = 3.756^{*}$, $p = 0.016$, Wilk's $\Lambda = 0.822$, partial $\eta^2 = 0.178$. The learning anxiety of the experimental group was significantly higher than that of the control group.

Discussion and conclusion

In recent years, the application of AI in education has attracted increasing attention from researchers in the field of computer science and education (Hwang et al., 2020). This research developed the AI educational curriculum with the integration of PAC for the general population to learn the voice application of AI, and finally the students had to run the application they had developed on the map of the CT board game. In the game-based learning, the students could discuss with their partner first during the game tasks and made their thinking visible with the arrangement of the oral comments. After they confirmed each other's intentions, they finally made decision on their best arrangement of the oral comments. The divisible steps and concrete actions during the game tasks were helpful for the novices learning CT.

Via the PAC platform in MIT App Inventor, the students could train a voice recognition model to understand the process of machine learning. The results showed that after the learners had gone through the course and completed the experiment, regardless of whether they used a competitive way (i.e., the experimental group) or not (i.e., the control group), the learning achievement and learning enjoyment of both groups improved significantly. However, the improvement in the experimental group's scores was greater than that of the control group's scores, and a significantly different degree between the two groups was achieved in the current study. This result showed that introducing PAC to the CT board game, either in a competitive or uncompetitive environment, increased the learning achievement of AI concepts and application. Competitive game-based learning is undoubtedly useful as the creative thinking and learning engagement of the students in the experimental group were significantly enhanced. Williams and Clippinger (2002) stated that when a game opponent is a real person, it helps to increase the participants' retention and enjoyment, revealing that the learners' creative thinking and learning engagement significantly increased in the current educational CT board game with AI application. The cloud-based environment and mobile application has been confirmed to have a significant effect on the creative performance of students (Chang, 2019), as was the PAC which is also a cloud-based environment in the current study.

Following is a discussion of the results indicating that the students in the experimental group had significant improvement in their learning engagement. During the learning process, all stages of learning were closely connected, and the learning tasks became increasingly difficult in different stages. The students in the experimental group tended to perceive higher anxiety when completing more complex tasks in the game-based learning, which was consistent with the results of Martyastiadi (2018) and Chen and Sun (2016). It is inferred that the supervised machine model which the students trained in the learning stage of PAC would result in imperfect accuracy of the AI application on the smartphone which they used to compete with others in the game in the experimental group, causing students' anxiety during the operation (Beilock & Carr, 2005). On the other hand, the board game in the experimental group adopted a competitive game mode, in which the fierce situation may have caused students to experience extra anxiety (Hong et al., 2012). However, the learning anxiety in the experimental group of the current study was confirmed to be helpful for increasing the students' learning engagement rather than hindering their learning because their playfulness and enjoyment as well as the learning effectiveness all achieved significant improvement. These results are similar to our previous study, showing that appropriate anxiety or pressure was beneficial for their learning outcomes (Kuo & Hsu, 2019).

In this study, we designed a game-based learning AI curriculum to enhance students' learning engagement, and to allow them to learn how to write a voice recognition app from the AI curriculum at the same time. It is suggested that future studies explore larger samples and students' behavioral patterns so as to find out the reason why not only the learning engagement increased in the game-based learning of the experimental group, but also why their learning anxiety significantly increased. The current study could only infer that the competition factor may have been the main different factor between the control and experimental group. A previous study found that the collaborative and competitive game-based learning environment would lead students to a better interaction between different levels of students (Hung et al., 2015). While the students in the control group of this study only needed to collaborate with their partners in the same team to examine their AI application with voice recognition to control the robot car on the map, the students in the experimental group had to compete with the other team in addition to collaborating with their peers in the same team. It is recommended that students' learning motivation and cognitive loads be analyzed when the AI education game is developed with more game factors, and that voice recognition or conversational AI be employed in general classes for other students to learn the application of AI in the near future.

The participants stated that the speed of the Internet service was of vital importance in this activity. In the experimental group, the students' perceived anxiety sometimes came from the delay in the responses and replies from the app during the competition. This is outside interference which had never been deeply considered before the instructional experiment because the current university environment provides adequate Internet service. This interference was a research limitation of this study. Because the calculation of the audio classification was conducted via the Internet, it is suggested that it is essential to provide a high-speed Internet environment for when students use the PAC platform to design their AI applications. As for the research limitations, while there are many methods of measuring the learning performance of CT, the current study only adopted pretest and posttest of CT concepts related to the learning activities and did not employ delayed test to assess the long-term effects of the treatment due to the time limitation in this study. In addition, this study suggests future research devote their efforts into evaluating different parts of cognitive and affective effects because this study only introduced creative thinking, and engagement. It is valuable for future studies to compare whether the findings will turn out to be different if different aspects of CT assessment are chosen.

Abbreviations

AI	Artificial intelligence
App	Application

CT Computational thinking
PAC Personal audio classifier
MIT Massachusetts Institute of Technology

Acknowledgements
The authors would like to thank the MIT APP Inventor team to freely provide the PAC service online so that we can develop the instructional tool named "AI 2 Robot City" integrating the audio classifier practice for young students.

Authors' information
Dr. Ting-Chia Hsu is currently a professor with distinguished award at the Department of Technology Application and Human Resource Development in National Taiwan Normal University. Her research interests included computer education and technology enhanced learning. Mu-Sheng Chen is currently a doctoral student in the Department of Technology Application and Human Resource Development in National Taiwan Normal University. His research interests included technology education and e-learning.

Author contributions
T-CH was responsible for conceptualization, funding acquisition, project administration, supervision, methodology, interpretation of data, project administration, interpretation of data and writing—original draft, and review of the manuscript, and contributed to editing of the manuscript. M-SC was responsible for instruction, data curation, formal analysis and investigation, interpretation of data and writing—original draft, and contributed to editing of the manuscript. All authors had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis and validation. Both authors read and approved the final manuscript.

Funding
The research is supported in part by the Ministry of Science and Technology under Contract Numbers MOST 108-2511-H-003-056-MY3.

Availability of data and materials
Please email to the corresponding author to get the statistical data.

Declarations

Competing interests
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Received: 10 February 2021 Accepted: 6 July 2022
Published online: 16 July 2022

References

Adukaite, A., Van Zyl, I., Er, Ş., & Cantoni, L. (2017). Teacher perceptions on the use of digital gamified learning in tourism education: The case of South African secondary schools. *Computers & Education, 111*, 172–190. https://doi.org/10.1016/j.compedu.2017.04.008

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavioral change. *Psychological Review, 84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

Beilock, S. L., & Carr, T. H. (2005). When high-powered people fail: Working memory and "choking under pressure" in math. *Psychological Science, 16*(2), 101–105. https://doi.org/10.1111/j.0956-7976.2005.00789.x

Bocconi, S., Chioccariello, A., Dettori, G., Ferrari, A., & Engelhardt, K. (2016). Developing computational thinking in compulsory education—Implications for policy and practice. *European Commission, JRC Science for Policy Report*. https://doi.org/10.2791/792158

Bressler, D. M., & Bodzin, A. M. (2013). A mixed methods assessment of students' flow experiences during a mobile augmented reality science game. *Journal of Computer Assisted Learning, 29*(6), 505–517. https://doi.org/10.1111/jcal.12008

Carbonell, J. G., Michalski, R. S., & Mitchell, T. M. (1983). An overview of machine learning. In *Machine learning* (pp. 3–23). Elsevier. https://doi.org/10.1016/B978-0-08-051054-5.50005-4

Chang, C. K. (2014). Effects of using Alice and Scratch in an introductory programming course for corrective instruction. *Journal of Educational Computing Research, 51*(2), 185–204. https://doi.org/10.2190/EC.51.2.c

Chang, Y. S. (2019). The mediating role of motivation for creative performance of cloud-based m-learning. *Australasian Journal of Educational Technology, 35*(4), 34–45. https://doi.org/10.14742/ajet.4418

Chen, L.-X., & Sun, C.-T. (2016). Self-regulation influence on game play flow state. *Computers in Human Behavior, 54*, 341–350. https://doi.org/10.1016/j.chb.2015.08.020

Chen, M.-S., & Hsu, T.-C. (2020). Incorporating the audio instruction classifier into the computational thinking board game. *The International Conference on Education and Artificial Intelligence 2020* (ICEAI 2020), HongKong.

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

Clark, D. B., Tanner-Smith, E. E., & Killingsworth, S. S. (2016). Digital games, design, and learning: A systematic review and meta-analysis. *Review of Educational Research, 86*(1), 79–122. https://doi.org/10.3102/0034654315582065

Coller, B. D., & Scott, M. J. (2009). Effectiveness of using a video game to teach a course in mechanical engineering. *Computers & Education, 53*(3), 900–912. https://doi.org/10.1016/j.compedu.2009.05.012

Drake, P., & Sung, K. (2011). *Teaching introductory programming with popular board games*. In *Proceedings of the 42nd ACM technical symposium on computer science education*. https://doi.org/10.1145/1953163.1953338
Gee, J. P. (2005). Learning by design: Good video games as learning machines. *E-Learning and Digital Media, 2*(1), 5–16. https://doi.org/10.2304/elea.2005.2.1.5
Grover, S., & Pea, R. (2013). Computational thinking in K–12: A review of the state of the field. *Educational Researcher, 42*(1), 38–43. https://doi.org/10.3102/0013189X12463051
Hershkovitz, A., Sitman, R., Israel-Fishelson, R., Eguíluz, A., Garaizar, P., & Guenaga, M. (2019). Creativity in the acquisition of computational thinking. *Interactive Learning Environments, 27*(5–6), 628–644. https://doi.org/10.1080/10494820.2019.1610451
Hinebaugh, J. P. (2009). *A board game education*. R&L Education.
Hoffman, B., & Nadelson, L. (2010). Motivational engagement and video gaming: A mixed methods study. *Educational Technology Research and Development, 58*(3), 245–270. https://doi.org/10.1007/s11423-009-9134-9
Hogle, J. G. (1996). *Considering games as cognitive tools: In search of effective" edutainment."*. Citeseer.
Hong, J.-C., Pei-Yu, C., Shih, H.-F., Lin, P.-S., & Hong, J.-C. (2012). Computer self-efficacy, competitive anxiety and flow state: Escaping from firing online game. *Turkish Online Journal of Educational Technology-TOJET, 11*(3), 70–76.
Hsu, T.-C., Chang, S.-C., & Hung, Y.-T. (2018). How to learn and how to teach computational thinking: Suggestions based on a review of the literature. *Computers & Education, 126,* 296–310. https://doi.org/10.1016/j.compedu.2018.07.004.
Hsu, T. C., Abelson, H., Lao, N., Tseng, Y. H., & Lin, Y. T. (2021). Behavioral-pattern exploration and development of an instructional tool for young children to learn AI. *Computers and Education: Artificial Intelligence, 2,* 100012. https://doi.org/10.1016/j.caeai.2021.100012.
Hung, H. C., Young, S. S. C., & Lin, C. P. (2015). No student left behind: A collaborative and competitive game-based learning environment to reduce the achievement gap of EFL students in Taiwan. *Technology, Pedagogy and Education, 24*(1), 35–49. https://doi.org/10.1080/1475939X.2013.822412
Hwang, G.-J., Chiu, L.-Y., & Chen, C.-H. (2015). A contextual game-based learning approach to improving students' inquiry-based learning performance in social studies courses. *Computers & Education, 81*, 13–25. https://doi.org/10.1016/j.compedu.2014.09.006
Hwang, G.-J., Chu, H.-C., Shih, J.-L., Huang, S.-H., & Tsai, C.-C. (2010). A decision-tree-oriented guidance mechanism for conducting nature science observation activities in a context-aware ubiquitous learning environment. *Journal of Educational Technology & Society, 13*(2), 53–64.
Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*. https://doi.org/10.1016/j.caeai.2020.100001
Israel-Fishelson, R., Hershkovitz, A., Eguíluz, A., Garaizar, P., & Guenaga, M. (2021). The associations between computational thinking and creativity: The role of personal characteristics. *Journal of Educational Computing Research, 58*(8), 1415–1447. https://doi.org/10.1177/0735633120940954
Jonassen, D. H., Howland, J., Moore, J., & Marra, R. M. (2003). *Learning to solve problems with technology: A constructivist perspective*. https://www.semanticscholar.org/paper/Learning-to-Solve-Problems-with-Technology%3A-A-Jonassen-Howland/30d2e65772455f25f70fcbaaa749c740a1491197?p2df
Kirriemuir, J., & McFarlane, A. (2004). Report 8: Literature review in games and learning. *Futurelab Series, 66*, 1–35.
Korkmaz, Ö., & Bai, X. (2019). Adapting computational thinking scale (CTS) for Chinese high school students and their thinking scale skills level. *Participatory Educational Research, 6*(1), 10–26. https://doi.org/10.17275/per.19.2.6.1
Korkmaz, Ö., Cakir, R., & Özden, M. Y. (2017). A validity and reliability study of the computational thinking scales (CTS). *Computers in Human Behavior, 72*, 558–569. https://doi.org/10.1016/j.chb.2017.01.005
Kuo, W.-C.,& Hsu, T.-C. (2019). Learning computational thinking without a computer: How computational participation happens in a computational thinking board game. *The Asia-Pacific Education Researcher, 29,* 67–83. https://doi.org/10.1007/s40299-019-00479-9.
Kuo, W.-C., & Hsu, T.-C. (2020). Learning computational thinking without a computer: How computational participation happens in a computational thinking board game. *The Asia-Pacific Education Researcher, 29*, 67–83. https://doi.org/10.1007/s40299-019-00479-9
Licorish, S. A., Owen, H. E., Daniel, B., & George, J. L. (2018). Students' perception of Kahoot!'s influence on teaching and learning. *Research Practice in Technology Enhanced Learning, 13*, 9. https://doi.org/10.1186/s41039-018-0078-8
Martyastiadi, Y. S. (2018). The paradox of control: visual clue vs. auditory instruction in game designing. *International Journal of Creative and Arts Studies, 5*(2), 35–47. https://doi.org/10.24821/ijcas.v5i2.2409
Mayer, B., & Harris, C. (2010). *Libraries got game: Aligned learning through modern board games*. American Library Association.
Mnih, V., Kavukcuoglu, K., Silver, D., Rusu, A. A., Veness, J., Bellemare, M. G., Graves, A., Riedmiller, M., Fidjeland, A. K., & Ostrovski, G. (2015). Human-level control through deep reinforcement learning. *Nature, 518*(7540), 529–533. https://doi.org/10.1038/nature14236
Papert, S. (1980). *Mindstorms: Children, computers, and powerful ideas*. Basic Books, Inc.
Pellas, N. (2014). The influence of computer self-efficacy, metacognitive self-regulation and self-esteem on student engagement in online learning programs: Evidence from the virtual world of Second Life. *Computers in Human Behavior, 35*, 157–170. https://doi.org/10.1016/j.chb.2014.02.048
Román-González, M., Pérez-González, J.-C., & Jiménez-Fernández, C. (2017). Which cognitive abilities underlie computational thinking? Criterion validity of the Computational Thinking Test. *Computers in Human Behavior, 72*, 678–691. https://doi.org/10.1016/j.chb.2016.08.047
Rosar, M., & Weidlich, J. (2022). Creative students in self-paced online learning environments: An experimental exploration of the interaction of visual design and creativity. *Research Practice in Technology Enhanced Learning, 17*, 8. https://doi.org/10.1186/s41039-022-00183-1
Sanford, J. F., & Naidu, J. T. (2016). Computational thinking concepts for grade school. *Contemporary Issues in Education Research (CIER), 9*(1), 23–32. https://doi.org/10.19030/cier.v9i1.9547
Schmidhuber, J. (2015). Deep learning in neural networks: An overview. *Neural Networks, 61*, 85–117. https://doi.org/10.1016/j.neunet.2014.09.003

Su, C. H. (2016). The effects of students' motivation, cognitive load and learning anxiety in gamification software engineering education: A structural equation modeling study. *Multimedia Tools and Applications, 75*, 10013–10036. https://doi.org/10.1007/s11042-015-2799-7
Tedre, M., & Denning, P. J. (2016). The long quest for computational thinking. In *Proceedings of the 16th Koli Calling International Conference on Computing Education Research*. https://doi.org/10.1145/2999541.2999542
Tsutsui, K., & Takada, H. (2018). A classroom SNS to promote reflective activity in programming learning for children. *Research Practice in Technology Enhanced Learning, 13*, 2. https://doi.org/10.1186/s41039-018-0069-9
Voogt, J., Fisser, P., Good, J., Mishra, P., & Yadav, A. (2015). Computational thinking in compulsory education: Towards an agenda for research and practice. *Education and Information Technologies, 20*(4), 715–728. https://doi.org/10.1007/s10639-015-9412-6
Vygotsky, L. (1978). Interaction between learning and development. *Readings on the Development of Children, 23*(3), 34–41.
Wang, H. Y., & Wang, Y. S. (2008). Gender differences in the perception and acceptance of online games. *British Journal of Educational Technology, 39*(5), 787–806. https://doi.org/10.1111/j.1467-8535.2007.00773.x
Williams, R. B., & Clippinger, C. A. (2002). Aggression, competition and computer games: Computer and human opponents. *Computers in Human Behavior, 18*(5), 495–506. https://doi.org/10.1016/S0747-5632(02)00009-2
Wing, J. M. (2006). Computational thinking. *Communications of the ACM, 49*(3), 33–35.
Wing, J. M. (2008). Computational thinking and thinking about computing. *Philosophical Transactions of the Royal Society a: Mathematical, Physical and Engineering Sciences, 366*(1881), 3717–3725. https://doi.org/10.1098/rsta.2008.0118
Wu, C.-J., Chen, G.-D., & Huang, C.-W. (2014). Using digital board games for genuine communication in EFL classrooms. *Educational Technology Research and Development, 62*(2), 209–226. https://doi.org/10.1007/s11423-013-9329-y
Yadav, A., Mayfield, C., Zhou, N., Hambrusch, S., & Korb, J. T. (2014). Computational thinking in elementary and secondary teacher education. *ACM Transactions on Computing Education (TOCE), 14*(1), 1–16. https://doi.org/10.1145/2576872
Yağcı, M. (2019). A valid and reliable tool for examining computational thinking skills. *Education and Information Technologies, 24*(1), 929–951. https://doi.org/10.1007/s10639-018-9801-8

Publisher's Note
Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.