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Research of Educational Board Games on Learning Effectiveness and Flow State

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Abstract: In this study, the university-wide compulsory course Information Technology Applications and Literacy at a Taiwanese university is used as an experimental curriculum. The experiment is planned over three weeks, with two hours of instruction each week; the course serves to introduce the main Arduino circuit and its peripheral modules. The control group for this experiment consists of 41 first-year university students from the Foreign Language Studies Department, while the experimental group consists of 41 first-year university students from the Economics and Management Department. The control group is taught using a lecture-based instructional method, while the experimental group is taught using the game-based learning method using two board games that were developed and designed by this study: the Arduino Board Game Icebreaker Card Activity, and Hello, Arduino! In addition, learning outcome tests and flow questionnaires were administered to students. The results of this experiment show that the board games used in this study can not only improve students' learning outcomes, but also significantly increase students' flow states.

Keywords: game-based learning, board game, flow state, learning effectiveness, Arduino

1. Introduction

Since the beginning of the author's doctoral program, in order to incorporate existing secondary education qualifications and learning expertise into new research, the author has used information technology education-related fields as the main axis of their academic research in higher education. Currently, aside from being in charge of professional courses, such as microprocessor systems (and experiments), digital logic design experiments, electronic circuits, social network analysis, and practical and experimental digital technology for the College of Electrical Engineering and Computer Science of the University, the author also supports the Foreign Language Studies and Economics and Management Departments by offering its Information Technology Applications and Literacy course. To date, this course has been offered for thirteen semesters, and is a university-wide compulsory course for first-year students. In addition to instructors from departments of the College of Electrical Engineering and Computer Science, most instructors for this course in other university departments do not have an information technology specialization. The author of this paper is one of the few teachers with expertise in information technology, who serves as an instructor for this course. While serving as an instructor for the Information Technology Applications and Literacy course over several semesters, the author asked students if they had previously taken computer programming courses during junior or senior high school, and found that only about 15% of students had taken courses related to programming. The author then asked these students about their learning outcomes and difficulties in the course, and received mostly negative responses. This shows that with regard to computer programming courses, students find these courses difficult and stressful. Computer programming has become an important standard for developing national competitiveness, and has been identified as a fundamental capability for developing future talent from a young age. Because non-electrical engineering and computer science students are unfamiliar with computer programming, and because they are intimidated and frustrated by the topic, this paper aims to determine methods of managing and improving these problems. In order to improve the programming capabilities of non-electrical engineering and computer science students, the author has used the time spent providing instruction in Information Technology Applications and Literacy

to conduct an experiment on game-based learning. The research objectives of this study are as follows.
(1) To investigate student flow states when studying Arduino using game-based learning.
(2) To investigate students' learning outcomes when studying Arduino using game-based learning.

2. Literature Review

In recent years, game-based learning has improved learning experiences, and has made gradual contributions to education (Connolly, Stansfield, & Hainey, 2011). Researchers argue that games are most effective at eliciting student motivation during education. Games themselves are very active activities, thus, an ideal learning method can be developed by structuring the learning process to be as interesting as a game.

2.1 Game-Based Learning

Game-based learning refers to the deep integration of computer games with educational content (Prensky, 2001). In recent years, games have become ubiquitous throughout society, media, and school computers (Căţălina & George, 2012). Games are capable of generating intrinsic motivation, increasing interest, preserving memories, providing training and feedback, and causing higher-order thinking (Hogle, 1996). Games can also be used as competitions or tests of technical abilities (Webster, 1999), which is the key to eliciting flow in the context of flow learning (Massimini & Carli, 1988). By introducing some information-based hints in multimedia education, thereby offering information to guide learners in the use of multimedia, it may be possible to reduce learners' cognitive load, and improve learning outcomes (Mautone & Mayer, 2001). Many studies related to the application of games in education have found that games exert positive influences on learning and teaching (Anderson & Barnett, 2013; Hou, 2015; Hsu, Tsai, & Liang, 2011; Mayer, Zhou, Lo, Abspoel, Keijser, Olsen, Nixon, & Kannen, 2013). Prensky (2001) stated that digital game-based learning has 12 characteristics: they are a form of fun and play, they have rules and goals, they feature human-machine interaction, they are adaptive, they provide outcomes and feedback, they offer a sense of victory, they provide conflict/competition/challenges, they include opportunities for problem solving, and provide opportunities for social interaction. These characteristics are explained below. The first characteristic is fun: games can create an interesting context in which students are able to enjoy the gaming process, derive pleasure from the activity, and experience feelings of delight. The second characteristic is play: game-based learning can offer a form of fun, which provides learners with intense motivation to play the game and heightens their level of interest. The third characteristic is rules: ordinary rules have their own structure, but learners can easily organize fixed game content such that they can interact with the game as they play it. The fourth is goals: all forms of games have their own goals and tasks, and designers can use these characteristics to guide learners through the game. The fifth is human-computer interaction: game design interfaces allow learners to operate or interact with a game through the interface. The sixth is outcomes and feedback: the gaming process can provide students with learning opportunities at any time. The seventh is adaptiveness: games are designed using distinct difficulty levels, which allow appropriate tasks to be offered to students according to their capabilities, thereby allowing learners to adapt to the game. The eighth is a sense of victory: after the completion of a stage in a game, learners can achieve the experience of success and feel a sense of gratification. The ninth is conflict, competition, and challenge: games with appropriate levels of conflict, competition, or challenge cause players to feel excited during gameplay. The tenth is problem solving: gaming situations are set up during games that can elicit players' creativity and problem solving. The eleventh is social interaction: learners form groups through interaction, thereby generating interactive relationships. The twelfth is representation and story: the stories and images within games allow learners to feel emotion. Hogle (1996) notes that games have the following four functions. The first function is the stimulation of intrinsic motivation and increased interest: games involve curiosity, expectations, interactive control, and story plots, which allow learners to increase their interest and intrinsic motivation. After learners achieve a sense of accomplishment, they are more willing to make multiple attempts in the face of difficulties or challenges. The second function is memory retention:

in terms of memory retention, simulated games are more effective than traditional classes. The third function is training and feedback: instructional tools used specifically for game-based learning often provide opportunities for practice, allowing learners to use this practice and repeated operations, in addition to instantaneous feedback, to assess their own learning outcomes, thereby facilitating the achievement of learning objectives. The fourth function is higher-order thinking: by integrating education into games, students must make judgments during gameplay, which prompts them to consider their own needs when searching for solutions to problems. By repeating teaching content in the game design, games can provide an ideal learning method.

2.2 Flow Experience

Csikszentmihalyi (1975) defines flow as the phenomenon of an individual perceiving intrinsic motivation, such that when they are in the midst of a flow experience, their energy is focused and they are nearly oblivious of anything else, and will not observe changes in their surroundings. This means that a flow experience refers to situations in which individuals are completely invested in an activity and enjoy the process, to the extent that they respond only to the objectives of the activity (Csikszentmihalyi, 1985). The Flow State refers to a situation in which an individual uses advanced techniques to conquer obstacles encountered during a challenging activity, thereby achieving a flow state. In other words, a flow state is a kind of state demonstrated by a person when they perceive skills and challenging processes (Csikszentmihalyi, 1975). Flow experiences refer to experiences in which individuals are focused on an activity, such that their psychological perception of time and space is distorted, reducing their self-consciousness. If an individual responds passionately and actively to an activity, they will not notice sensations or information unrelated to the activity; in such cases, the individual has transformed the activity into an objective, forming a flow experience (Csikszentmihalyi, 1997). Csikszentmihalyi (1990) summarizes the nine traits of flow as follows: clear goals, challenge-skill balance, concentration on the task, sense of control, merging of action and awareness, external neglect, distortion of time, and the experience of self-accomplishmen t. If an individual experiences these nine traits, they will enter a state of flow. In 1997, Csikszentmihalyi argued that when an individual generates flow, they will demonstrate three main characteristics. The first is clear objectives: if an individual has clear objectives for the task that they aim to perform, they can easily enter a flow state. The second is instantaneous feedback: if an individual can derive instantaneous feedback from a task, they can easily enter a flow state. The third is balancing difficult challenges with advanced skills: challenges must often be balanced against an individual’s capabilities, meaning that if a challenge exceeds one’s abilities, the individual will feel anxious. If the difficulty of the challenge is lower than an individual’s abilities, they will feel bored. If one’s abilities are weak and the challenge is also easy, then a weak state of flow is generated. As such, in order for an individual to focus completely on a game and generate a flow state, the difficulty of challenges must be appropriate and the individual must have sufficient capabilities.

3. Research Method

This study uses the university-wide compulsory course Information Technology Applications and Literacy at a Taiwanese university as its experimental curriculum. This course takes place over a single semester and two academic credits are awarded upon its successful completion. Over the 18-week course, ten weeks consist of Computer Programming instruction. Three of these weeks are used to introduce the main Arduino circuit and its peripheral modules. The experiment takes place over three weeks, for two hours each week. The subjects of this experiment consist of 41 first-year university students from the foreign language studies department (control group), and 41 first-year university students from the Economics and Management Department (experimental group). The control group is taught using the lecture instruction method, while the experimental group is taught according to the game-based learning method, using the two unplugged board games developed and designed by this study: the Arduino Board Icebreaker Card Activity and Hello, Arduino! Neither of the two groups has studied Arduino previously, and the experiment is conducted over the course of three weeks, for two hours per week. During the experiment, the main topic of instruction is the introduction of the main Arduino circuit and its peripheral modules. After each group has completed this instruction, a written test on the main Arduino circuit and its peripheral modules is conducted, and a flow questionnaire test is administered to the experimental group. In order to determine the content of this test, this study consulted the flow experience questionnaire scale constructed by Pearce et al. (2005). Questionnaire content includes eleven items, some of which are “interest,” “concentration,” and “sense of control” (Cronbach $\alpha = 0.907$). Scoring was conducted using a five-point Likert scale. The cards used in the board game are introduced below:

(1) Arduino board game icebreaker card, as shown in Figure 1:
Each student holds one card and randomly finds another student to challenge; whoever finds two cards with the same module is the winner, and the loser must sign the winner’s card.

(2) Arduino peripheral module topic cards (top), as shown in Figure 2:
These cards show an image of a module, ranked by difficulty using 1-3 stars, where a higher number of stars indicates a higher degree of difficulty.

(3) Arduino peripheral module topic cards (bottom), as shown in Figure 3:
These cards show a 3D QR code for the module and a textual hint for the correct response.

(4) Arduino peripheral module response cards, as shown in Figure 4:
These cards show matching responses.

(5) Main Arduino circuit topic cards (top), as shown in Figure 5:
These cards show main circuit topics, ranked by difficulty using 1-3 stars, where more stars indicate a higher degree of difficulty.

(6) Main Arduino circuit response cards (bottom), as shown in Figure 6:
These cards show matching responses.

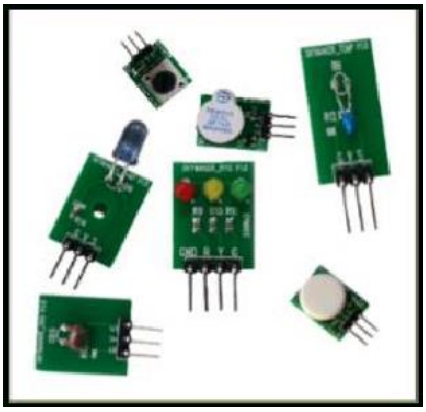

Figure 1. Arduino board game icebreaker card

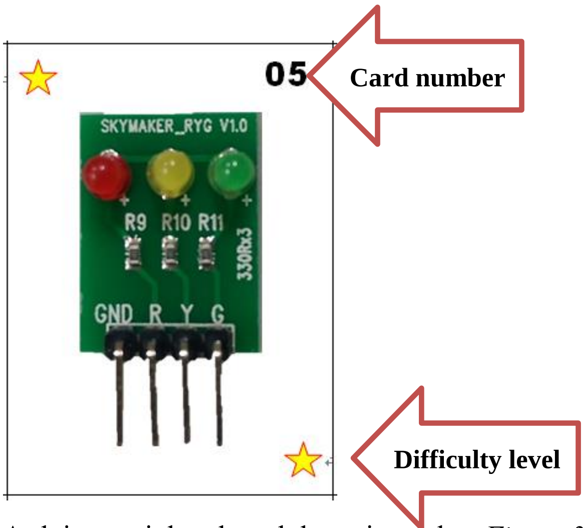

Figure 2. Arduino peripheral module topic cards (top)

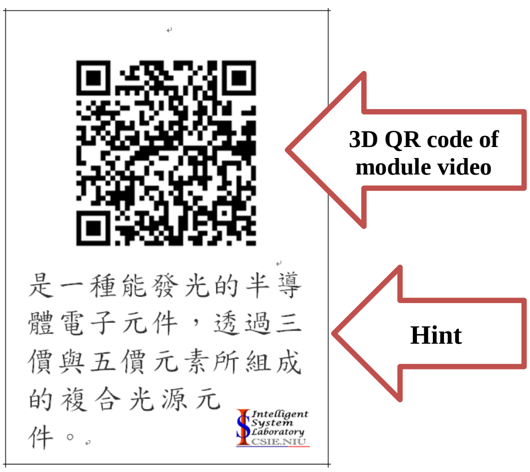

Figure 3. Arduino peripheral module topic cards (bottom)

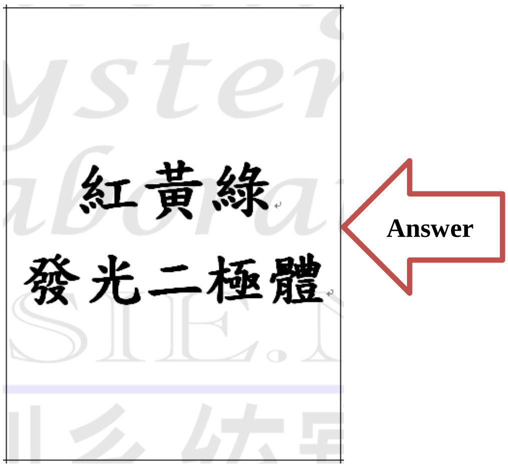

Figure 4. Arduino peripheral module response cards

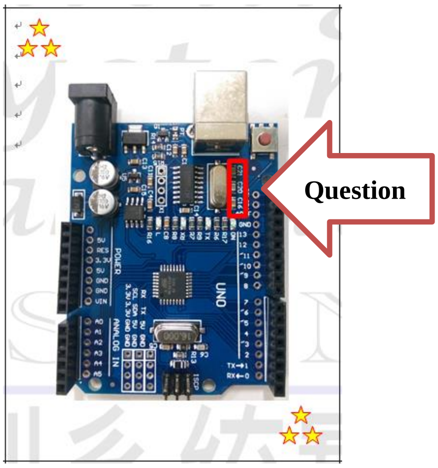

Figure 5. Main Arduino circuit topic cards (top)

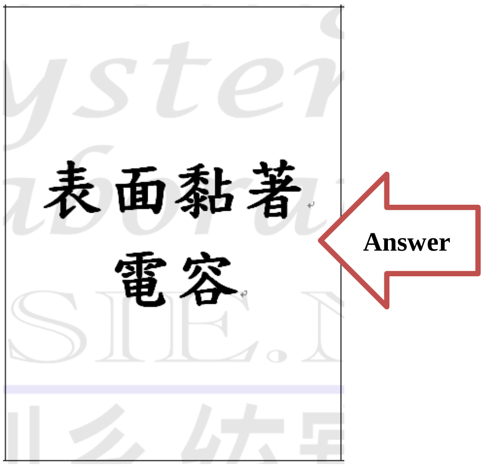

Figure 6. Main Arduino circuit response cards (bottom)

4. Results and Discussion

The results of this experiment show that the two board games developed in this study can improve students' learning outcomes and flow states when studying the main Arduino circuit and its peripheral modules. With regard to learning outcomes related to students' understanding of the main Arduino circuit, the control group, which was taught using the lecture method, had an average test score of 50.00. As shown in Table 1, 24 students had scores lower than 60.00, and five students scored 0 points, as shown in Figure 7. In contrast, the experimental group, which was taught using game-based learning, had an average test score of 76.74, with only six students scoring lower than 60 points and 15 students receiving full marks. However, it is worth noting that in the experimental group, there were five students who scored 0 points, as shown in Figure 8. With regard to learning outcomes related to students' understanding of Arduino's peripheral components, the control group, which was taught using the lecture method, had an average test score of 71.63; as shown in Table 1, six students scored below 60 points, and five students scored 0 points, as shown in Figure 9. In contrast, for the experimental group, which was taught using board games, the average test score was 96.16, with only one student scoring below 60 points, and 33 students receiving full marks. However, one student in the experimental group received a score of 0, as shown in Figure 10. The above discussion shows that students find it more difficult to learn about the main Arduino circuit than to learn about its peripheral modules. This may be because of the depth and number of specialized names of main circuit components, resulting in a heavier cognitive load during learning. In addition, the experimental group demonstrated interest in the board games used in this study, with

85% expressing agreement, as shown in Figure 11. 97% of students indicated that the game could generate concentration, as shown in Figure 12. 83% of students stated that they had a sense of control, as shown in Figure 13. These results show that the board games used in this study significantly increased students' flow states; this outcome was especially clear for concentration.

Table 1

Arduino main control and peripheral modules test average score

	control group	experimental group
Arduino main control circuit	50.00	76.74
Arduino peripheral modules	71.63	96.16

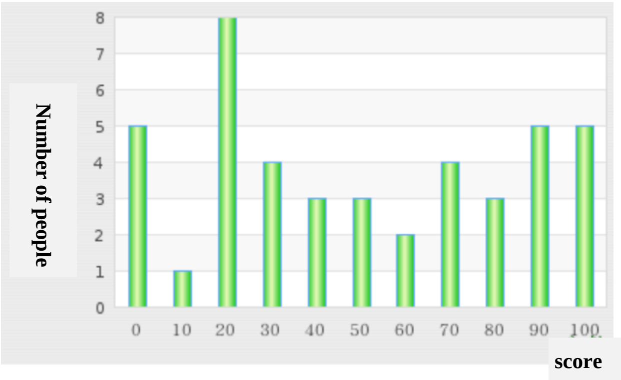

Figure 7. The control group test score statistics of Arduino main control board

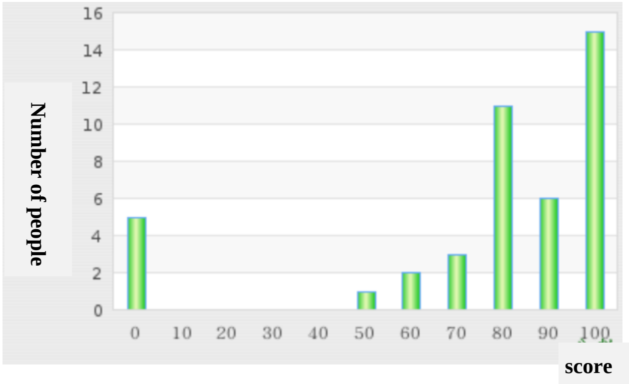

Figure 8. The experimental group test score statistics of Arduino main control board

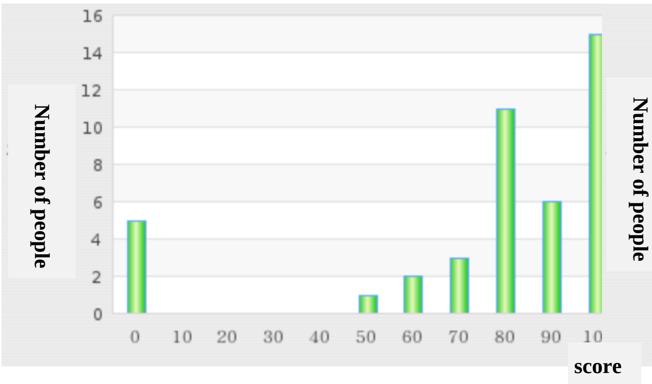

Figure 9. The control group test score statistics of Arduino peripheral module

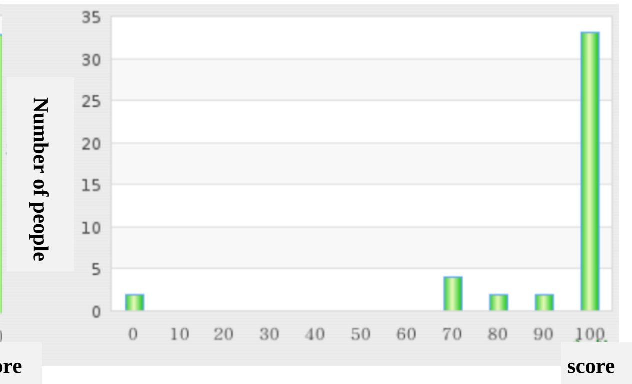

Figure 10. The experimental group test score statistics of Arduino peripheral module

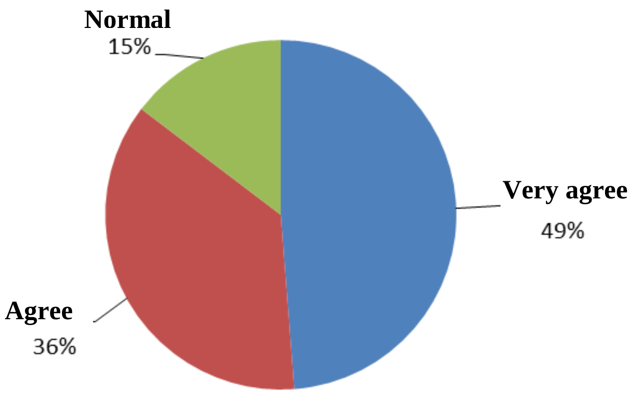

Figure 11. The experimental group is having fun with the game

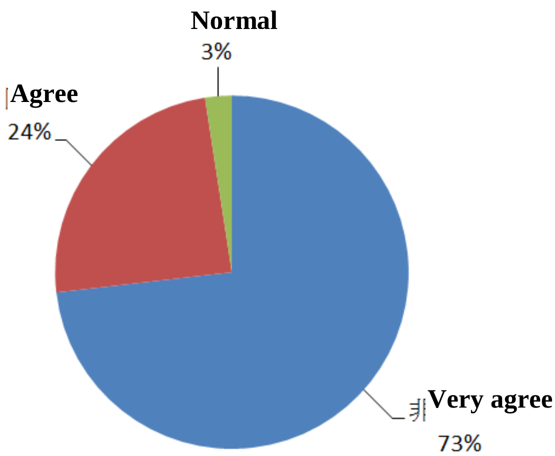

Figure 12. The experimental group of concentration with the game

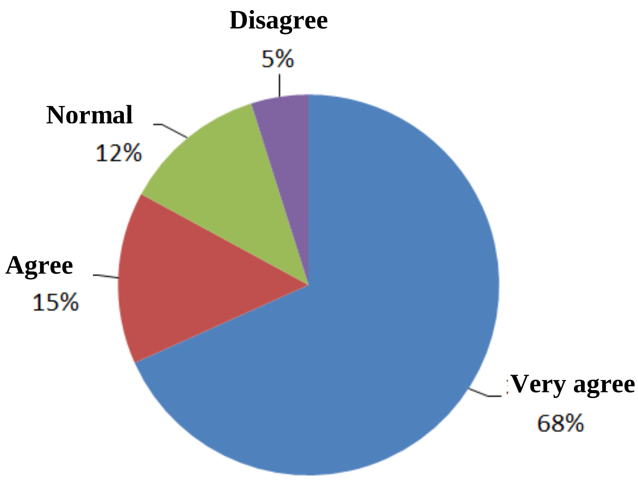

Figure 13. The experimental group of control with the game

5. Conclusions and Suggestions

The purpose of this study is to improve non-electrical engineering and computer science students' fear and frustration related to computer programming. The author of this paper used the instructional time in the course, Information Technology Applications and Literacy, to conduct a teaching experiment using game-based learning methods to help students to learn about the "Main Arduino Circuit and its Peripheral Modules," which is prerequisite knowledge for S4A programming. The goal of this experiment was to better understand students' flow states and learning outcomes. The results of this experiment clearly show that when using the two unplugged educational board games that were developed and designed in this study, Arduino Icebreaker Card Activity and Hello, Arduino!, game-based learning significantly improved students' learning outcomes and flow states. In addition to further improving the quality of these board games, the results of this study can also benefit a greater number of students by serving as a reference for educational research on Information Technology Applications and Literacy curricula.

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