AN INVESTIGATION OF THE STUDENTS' PERCEIVED USEFULNESS OF ADOPTING ARDUINO FOR SCIENCE, TECHNOLOGY, ENGINEERING AND MATHEMATICS LEARNING IN MAKER EDUCATION

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Abstract - This paper presents a quantitative approach to investigate the students' perceived usefulness of adopting Arduino for learning science, technology, engineering and mathematics (STEM) in maker education. The secondary school students and teachers were invited to participate in this investigation. The participating students received STEM lessons and activities in which building Arduino circuit boards was delivered by the participating teachers. Then, the participating students were requested to complete an online questionnaire which was designed to measure their perceived usefulness of using Arduino for STEM learning. 33 participating students completed the questionnaire. The analytical analysis revealed that the participating students had positive perceptions of the usefulness of adopting Arduino for STEM learning.

Keywords - Arduino, STEM Learning, Maker Education, Perceived Usefulness.

I. INTRODUCTION

STEM learning in maker education (Dougherty, 2013, p. 7-16), which is a problem-based approach for students to adopt appropriate tools, experience hands-on practice, collaborate with their peer students to develop a prototype and modify the found objects in order to create inventions for solving authentic problems, involves an applied and interdisciplinary approach to educate students in STEM discipline. Through this approach, the students develop skills like problem solving, independent thinking, critical analysis and creativity. STEM maker education is not about simply equipping students with technology or science related knowledge, but encourages the students to utilize their creativity as well as scientific knowledge to create and innovate.

In accordance with Education Bureau (2016), STEM education improvements rely on the cooperation among the government, schools and the society. With reference to Education Bureau's (2016) STEM education promotion andKoehler and Mishra's (2009)Technological Pedagogical Content Knowledgeframework in which teachers are required to be equipped with knowledge of technology, pedagogy, and content to deliver teaching with effective usage of technology, the researchers proposed a STEM maker education project whichuses "train-the-trainer"approachto assist teachers to apply Arduino to regular classes in order to raise students' interest in STEM and let students experience the problem solving process while acquiring interdisciplinary knowledge. The project launched series of lessons and workshops for some Hong Kongsecondary school teachers to learn how to build Arduino circuit boards, as shown in Figure 1, and develop programs for the circuit boards. In addition to technological knowledge, the participating teachers acquired teaching approaches and methods and experienced the entire maker education processfrom designing teaching materials and activities to implementing active learning classroom.It was expected that the STEM maker educationproject would be effective in enhancing students' creativity, collaboration and problem-solving skills in order to lay groundwork for life-long learning. Throughout the project, the research team helpedimprove the professional development in STEM for teachers and investigated the feasibility and effectiveness of incorporating Arduino with different subjects.

Figure 1:Arduino Circuit Board

II. RESEARCH PROBLEM

The researchers were curious about whether the participating students accept using Arduino for STEM learning and adopted a quantitative approach to investigate the students' perceived usefulness (PU) of using Arduino for STEM learning in maker education. According to Davis' (1989) Technology Acceptance Model as well as its extended models such as the models by Venkatesh and Davis' (2000), by Park, Nam and Cha (2012) and by Wong, Wong and Yeung (2019), PU, which is a student's belief in using Arduino can enhance his or her performance, influences the student's behavioral intention to use Arduino for learning. In turn, the student's behavioral intention determines his or her actual behavior of using Arduino.

III. DATA COLLECTION

The researchers conducted asurvey by asking the participating secondary students to complete the online questionnaire.The online questionnaire questions include the measuring items for PU. The PU construct was operationalized by the items in Table 1 measured on a 5-point Likert's (1932) scale ranging from "strongly agree" = 5 to "strongly disagree" = 1.

Table 1: Measuring items on the online questionnaire

Construct Code	Measuring Items
PU1	Learning with Arduino is a good way to make me understand science, technology, engineering and/or mathematics.
PU2	Learning with Arduinocan enhance my understandingof science, technology, engineering and/or mathematics.
PU3	Learning with Arduino has given me insights to apply ideas.
PU4	Learning with Arduino emphasizes on practical value of science, technology, engineering and/or mathematics.
PU5	Learning with Arduino is helpful for my learning in science, technology, engineering and/or mathematics.
PU6	Learning with Arduino can enhance co-operation.
PU7	I have developed the ability to function as a member of a team when learning with Arduino.
PU8	Using Arduino has aroused my interest in science, technology, engineering and/or mathematics.
PU9	Learning with Arduino can enhance interaction.
PU10	Using Arduino in learning activities can make the lessons interesting.
PU11	Learning with Arduino enhances my application skills.

The participating students are all secondary students aged 16 years old or above. So, parents' consent was not required. When conducting the survey, the purpose, procedures and scope of the research were given to the participating students. The participating students responded with implied consent by completing the online questionnaire (Berg and Lune, 2012, p. 92). To ensure informant anonymity and confidentiality, the participating students were not required to provide their names and any other identities when completing the online questionnaire. Besides, data collected from this survey were stored securely. Any information (e.g., the schools attended by the participants) that may identify the participants is not disclosed in any publications of this study. The participating students experienced using Arduino for STEM learningfrom late August to November 2018. They were all invited to complete the online questionnaire in October and November in 2018. This online questionnaire was designed to capture their PU. 36 responses were collected, but only 33 participating students completed the online questionnaire.

IV. ANALYSIS AND FINDINGS

The statistical tool Statistical Package for the Social Sciences (SPSS) version 25 was used for generating the PU mean scores, as shown in Table 2.The analytical results also indicated that the internal consistency reliability is acceptable as reflected by that the value of Cronbach's (1951) coefficient alpha for PU is above 0.7 (Nunnelly, 1978). The mean of the participating students' ratings for each PU measuring item (i.e. PU1, PU2, … or PU11) as well as the mean of the combined ratings (that is, combined mean) are both shown in Table 2. All these values are above 3.5 on a 5-point scale (that is, the maximum value is5 while the minimum value is 1).

The following breaks down the participating students' PU of learning with Arduino. PU1, PU2 and PU5 were designed to measure whether learning with Arduino could help the participating students understand STEM. PU3, PU4 and PU11 were used to measure whether learning with Arduino could enhance the participating students' application skills. PU6, PU7 and PU9 measured whether learning with Arduino could enhance collaboration among the participating students while PU8 and PU10 were used to measure whether learning with Arduino could arouse the participating students' interest in learning STEM.

Table 2: Mean scores and internal consistency reliability of the measuring items

Measuring Items	Item Mean (Standard Deviation)(n = 33)	Combined Mean	Construct Reliability(Cronbach's coefficient alpha)
PU1	3.64 (0.70)	3.65	0.712
PU2	3.67 (0.74)		
PU3	3.61 (0.83)		
PU4	3.61 (0.79)		
PU5	3.70 (0.85)		
PU6	3.67 (0.78)		
PU7	3.58 (0.90)		
PU8	3.52 (0.83)		
PU9	3.82 (0.64)		
PU10	3.70 (0.95)		
PU11	3.67 (0.74)		

V. DISCUSSIONS AND CONCLUSIONS

The analytical results revealed that the participating students had positive perceptions of the usefulness of adopting Arduino for STEM learning, as reflected by the mean of the combined ratings by theparticipating students for all PU measuring items (i.e. PU1, PU2, … or PU11) above 3.5 out of the maximum value 5, as shown in Table 2. Furthermore, Table 2 shows the findings in this studythat the participating students perceived positively that learning with Arduino could help them understand STEM (as reflected by PU1, PU2 and PU5 mean scores), enhance applicability (as reflected by PU3, PU4 and PU11 mean scores), enhance collaboration (as shown in PU6, PU7 and PU9 mean scores) and arouse learning interest (as indicated in PU8 and PU10 mean scores). Besides, maker education emphasizes to offer hands-on learning experience to students, this study can be extended to explore the relationship between maker education and active learning. For example, in this study, the participating teachers introduced the Arduino with basic knowledge, then the participating students were required to form groups and cope with challenges by themselves, which might enhance the students' active and learning skills.

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