The Role of Arduino Coding Workshop in Enhancing Medical Students' Literacy on Health-related Technology*

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ARTICLE INFO	ABSTRACT
	Purpose: There are several barriers to medical students being conversant with current digital health tools. A few examples of them are an overburdened curriculum, inadequate resources, and financial challenges. The conventional educational environment was unable to fully unleashed students' literacy on health-related technology. Thus, this study was intended to evaluate whether Arduino coding can enhance students' literacy towards health-related technology as a teaching and learning tool. **Methods:** In this study, a quasi-experimental model of a pretest and a posttest with a single group was applied. A total of twenty-nine students from medical faculty in Universiti Malaysia Sabah were selected via convenience sampling technique. All participants attended the Arduino coding theory session and were divided into 14 pairs during the hands-on session.

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Results: There was a significant improvement in the students' literacy on health-related technology. The posttest results were significantly improved compared to the pretest performed before the workshop (p <0.001). The majority of participants (n=26, 91.0 %) were generally satisfied with the workshop. **Implication for Research and Practice:** The findings of this study indicated that the Arduino coding workshop increased medical students' literacy on health-related technology. The majority of students expressed their satisfaction with the workshop's content. It can therefore be suggested to incorporate Arduino coding program in the medical curriculum as an elective module. Further studies may be conducted to determine the long-term impact of Arduino coding program for enhancing medical students' skills to create technical solutions for encountered health problems.

Introduction

Technology in the modern era has made unanticipated influences on people's lives. Billions of dollars are being invested in technology innovations across various industries. Among the most influential of these are innovations in the healthcare industry. The medical education should also therefore remain abreast with technological innovations in the field of healthcare. The healthcare industry much depends upon the relative research and development that takes place in medical education institutions. Hence, all curricular and pedagogical aspects must ensure that medical education is designed adequately to prepare medical students for the growing health care system of the twenty-first century. In other words, by preparing medical students for the digital era requires teaching the medical curriculum through digital learning tools and with high-fidelity simulators.

Technological innovation also involves preparing students' minds for learning to use future medical instruments and gadgets (Paton, 2018). Medical pedagogy has been so evolved in response to significant changes in medical know-how and technological innovations such as medical robotics. In addition, the emergence of diagnostic, therapeutic, and non-therapeutic technologies in health care such as information technology, telehealth, and communication technology, have also assisted to formulate medical education strategies and produce professional e-health care providers (Aretz, 2016).

In the wake of technological innovations and rising demand for digitalization, medical graduates are expected to work and fully function as e-physicians in respect of digital health. They are under a pressure to incorporate health technologies innovations into their jobs and simultaneously stay conversant with the latest technologies. For this reason, medical educators and practitioners must ensure that preclinical students are exposed to health-related technology courses such as Arduino programming, Artificial Intelligence (AI) in health care, and Health Information Systems (HIS). High levels of literacy in health-related technologies and creative and innovative skills are also necessary for medical and health sectors, necessitating that the medical curriculum assures students to have a good grasp on digital age culture, tools, and technology.

World Health Organization (WHO) has designated information and communication technology as a necessary skill for future healthcare practitioners (Aretz, 2016). A few studies have been reported suggesting a trend towards teaching

basics and applications of technology to medical students in a meaningful and clinically relevant manner (Aretz, 2016; Cleary, 2004). However, best to our knowledge, little is discussed about using Arduino coding as a teaching and learning approach to enhance literacy of health-related technology among medical students.

It is also stated that having a platform that fosters students' technological literacy and integrating this knowledge into medical applications can help strengthen becoming an e-physician. The e-physician is defined by five "Es" namely: "equipped," "empowered," and "expert," in the use of electronic records and analytics that could assist an e-physician in decision-making, "enabled" by clear regulations and procedures that facilitate the use of this technology; and finally, "engaged" with patients in empathy and understanding of patients' point of view and feelings (Mesko & Győrffy, 2019).

The medical curriculum itself encompasses such a large number of subjects and courses that additional topics like digitalization related to healthcare technology are very challenging to accommodate (Aretz, 2016; Dyche & Epstein, 2011). Current medical education focuses exclusively on clinical and preclinical sciences, and students are already inundated with information. As a result, doctors are already predominantly technology-users (Mylopoulos & Scardamalia, 2008). However, to cope up with the challenges and meeting the demand to develop digital literacy, medical educators must devise an alternative strategy for instilling technology literacy in students. Researchers believe that having a platform which enhances students' digital literacy and engages them in medical applications will help increase their readiness to be an e-physician (Mesko & Győrffy, 2019).

Having a workforce capable of addressing imminent health problems with latest technologies is critical during the COVID epidemic. Additionally, the challenges associated with large-scale technical practices are much greater due to the overburdened medical curriculum, and internal obstacles such as lack of resources and financial challenges (Mesko & Győrffy, 2019). Moreover, innovation, technology practice, and creativity domain are not integrated with the traditional teaching approach, which makes many learners adopt a passive role in the educational process (Dyche & Epstein, 2011). Consequently, medical graduates too perceive it to be safer to be users of information rather than inventors (Mylopoulos & Scardamalia, 2008). For this reason, until recently, only a few reforming trials have taken place to provide an opportunity for innovation and discovery in the formal medical school curriculum (It, 2016).

This study was initiated by assessing first the impact of an Arduino coding workshop on medical students' literacy towards technological applications in health-related domains. The objective was to assess medical students' abilities to comprehend the construction of medical devices, basic electronic circuits, and programming language. The secondary objective of this study was to determine students' satisfaction with technical and artistic workshops that are often not related to the medical curriculum. The Arduino coding workshop was designed to provide an opportunity to medical students to enhance their literacy towards health-related technologies. It is

hoped that findings of this study would add to the body of knowledge and demonstrate the influence of exposing medical students to technological applications in the health field.

Method

Research design

A quasi-experimental model with a pretest and a posttest was used in this study to determine the role of the Arduino coding workshop on participants' literacy of health-related technologies. It was an eight-hour workshop organized over the course of a weekend day. The DaVinci Club of the Faculty of Medicine and Health Sciences organized this session in partnership with Kota-Kinabalu Coders (KK coders). The workshop included a brief theoretical overview and a hands-on session. An expert in Arduino coding facilitated the technical portion of the workshop assisted by five facilitators. The pre- and post-test survey questionnaires comprised both closed and open-ended questions to assess students' literacy of health-related technology, measure students' satisfaction, and collect feedback for the Arduino workshop.

As a part of its research design, an Arduino Coding Workshop was organized. Right at the outset, the instructor introduced the notion of coding to the participants in a theoretical session. They were explained how coding was a fundamental step of software programming and hardware wiring. Next, students were divided into 14 groups of two each to conduct hands-on sessions to perform coding activities, using the instructions learned during the theoretical session. Each group received an Arduino Nano training kit as a part of workshop's teaching material. The Arduino Nano was chosen as a teaching tool due to its inexpensive cost and relative ease of assembly. For this reason, it enabled students to repeat classroom experiences at home and experiment with some useful applications (Agatolio & Moro, 2017; Yang et al., 2019; Zubrycki & Granosik, 2014). Each group was required to maintain a reference book.
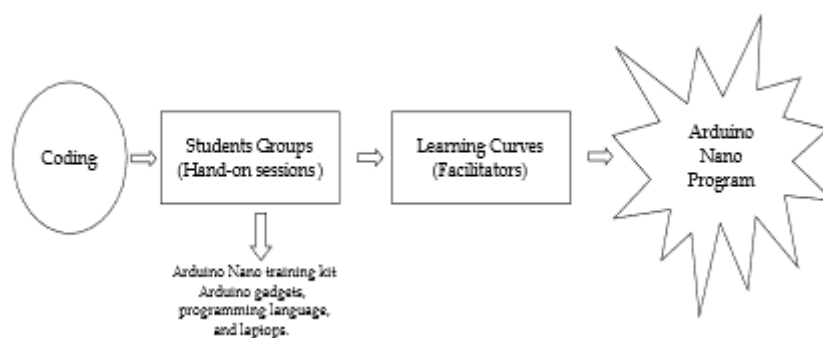

Figure 1: Research Design Framework

The workshop's hands-on session aimed to accelerate students' learning curves by raising the complexity of technical exercises relating to their areas of interest (Zubrycki & Granosik, 2014). Five facilitators assisted students by completing three mini-projects that required them to connect circuits and codes into an Arduino program. Later in the afternoon session, the students used an Arduino Nano and a temperature sensor to develop a medical application prototype. The workshop utilized Arduino gadgets, the processing programming language, and laptops. The facilitators demonstrated how to make the circuit, and students returned the favor by constructing it independently. Finally, the trainers discussed Arduino's numerous medical applications. For instance, they demonstrated how an accelerometer sensor could be used to monitor a patient's movements during seizure attacks.

Research sample

The target sample of this research was undergraduate medical students in their first and second years selected through random sampling technique. A total of 191 medical students of Year 1 and 2 were invited via the faculty to participate in this research. The study took place in March 2020. Out of the total population, twenty-nine students (n=29) agreed to participate voluntarily. They were explained the purpose of the research and how the workshop would be conducted.

Data Collection Instruments and Procedures

The questionnaire was developed and validated by a medical academic and a technical instructor, aiming at assessing students' literacy on Arduino coding and its technological applications in the health-related field. The content of the questionnaire focused on the notion of Arduino programming and its real-world applications. Each accurate response earned one point, with the best possible score being 11 and the lowest possible score 0. Cronbach's alpha coefficient study was conducted to determine students' literacy on Arduino Coding on medical technology, within an acceptable range (α=0.77). A survey based on the Freiberg scale,1998 (Harden & Laidlaw, 2020) was distributed to measure students' satisfaction with the Arduino coding workshop. This survey had evaluated students' satisfaction towards educational environment and learning component in a previous study where the test of reliability for questionnaire items on students' satisfaction was reported (α=0.83). Therefore, it was deemed reliable for the current study as well. The Likert scale of 1 to 5 measuring strongly satisfactory to strongly unsatisfactory was utilized. Though al questions were closed-ended, but one open-ended question was also included in the end to reflect upon students' overall satisfaction with the workshop. Ten minutes prior to the start of the workshop, a pretest questionnaire was distributed to evaluate students' literacy in Arduino coding and application. Another posttest literacy questionnaire was collected at the end of the workshop. A google-form link was used to disseminate the questionnaire related to students' satisfaction about the workshop. Additionally, they were given a sheet of paper to write their reactions and feedback of the workshop.

Data analysis

The data of pretest and posttest were expressed as mean and standard deviation using Excel Microsoft. Students' satisfaction feedback was extracted and displayed in bar charts. To facilitate the evaluation of the Arduino coding workshop, the Kirkpatrick's learning model was used. This model has served as a primary organizing design for the evaluation of medical training for more than three decades. This model comprised four basic levels of evaluation, with each level having an impact on the next level (Abdulghani et al., 2014). The first level represented "reaction." In this study, students' satisfaction of the Arduino coding workshop indicated "reaction." It was measured using a questionnaire adapted from Harden and Laidlaw (2020). The second level represented "learning," which was measured using a developed questionnaire formulated by medical academia and technical expert. The third level represented "behaviors" and the fourth level "results" of Kirkpatrick's learning model. These two levels could not be measured as they were related to the long-term impact of workshops in the workplace, and was beyond the scope of this study (Abdulghani et al., 2014). The study was approved by the local ethics committee of Universiti Malaysia Sabah (Approval code: JKEtika 4/20[7]). All the participants were promised anonymity to protect their privacy.

Results

A total number of twenty-nine students had attended the workshop. Twenty-two (75%) were females, and seven (25%) were males, ranging between 21 to 22 years. The pretest and posttest scores were compared using the paired t-test to study the workshop's impact on students' literacy. There was a significant improvement in the students' literacy of health-related technology after the Arduino workshop (p <0.001), as shown in table 1. The mean score increased significantly from 5.58 to 8.62 after the Arduino workshop as seen in the posttest.

Table 1

Paired t-Test Results of Students' Literacy on Health-related Technology Applications in the Health Field

Item	Mean score	Standard deviation	t	p-value
Knowledge				
Pre-test	5.48	1.33	12.45	< 0.001*
Post-test	8.62	1.12		

*p<0.05. Data presented as mean (standard deviation).

The fourteen groups of students also managed to accomplish three assigned mini-projects and the medical application project, a temperature detector (see Figure 1), and a project to alarm the myocardial infraction patients during attacks. Expert facilitators guided students to complete their projects.

Another objective of this study was to measure student's satisfaction with the workshop organized. Most students (24, 91.0 %) were satisfied with the Arduino

workshop. The student's perceived satisfaction was based on two domains: viz., the educational environment and the learning component. It was further categorized into five items: training methods, facilitator, objective achieved, hospitality, and time. Based on the results, 81% rated the measure 'strongly satisfied' with the workshop training method. They mentioned that *"workshop was useful (good)'', "inspiring'',* and *"we had fun activities."* The facilitators appointed by organizers were rated "very satisfied" by 85% of the students. All students (100%) were "very satisfied" and accepted that the workshop's objective was achieved and that it was carried out in a conducive environment of learning.

Figure 2. Hands-on Session in Arduino-Coding Workshop

A total of 25% of students rated "strongly satisfied" with the workshop and recommended *"to repeat the workshop in future"* and *"to keep it as an annual event."* Besides, one candidate suggested *"to make the workshop longer."* A total of 15% suggested to *"provide more training kits for the group,"* and another 15.0 % recommended to *"recruit more facilitators in the session," "to reach more people to learn about it,"* and to *"include medical-related projects such as (heartbeat detector)."*
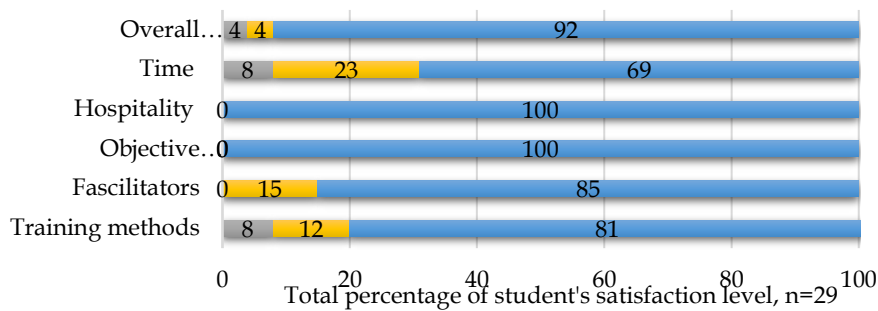

Figure 3. Students' Perceived Satisfaction on the Arduino Coding Workshop

Key legend: ■ Strongly ■ unsatisfactory ■ Neutral ■ Satisfactory ■ Strongly satisfactory

Discussion, Conclusion and Recommendation

The current study looked into the role of Arduino coding workshop in enhancing the medical students' literacy on health-related technology and satisfaction. The Kirkpatrick Model was chosen as a guide to evaluate the outcome and the impact of practicing basic Arduino coding model. The Kirkpatrick Model is a widely recognized method for assessing training and development initiatives (Aretz, 2016). Kirkpatrick's learning model can be divided into internal and external criteria. Reaction and learning criteria are considered internal because they are concerned with what occurs within the training program. Behavioral and results criteria are used to assess changes outside of (and often after) the program and are thus considered external criteria. It is also helpful to keep in mind that external criteria that are likely influenced by factors other than learning, such as larger organizational or economic contexts.

The first, i.e., the basic level of the Kirkpatrick framework evaluated the change in students' reactions in the form of their satisfaction level. The students' feedback reflected their high satisfaction rates with different aspects of the workshop. Students' satisfaction was partially related to the sense of achievement and the educational environment (Martín-Ramos et al., 2017). The second level in Kirkpatrick's model measured the learning outcome of educational intervention. It was a measure of the impact of Arduino coding on students' literacy, and was derived by comparing the pretest and posttest results. This proved the fact that behavioral criteria determine the effects of training on job performance (Praslova, 2010). In higher education settings, such criteria may include the evidence like application of knowledge and skills by students learned in previous classes. In Italy and Portugal, the researchers have found that trainees can acquire soft skills and technical experiences by keeping themselves engaged in sustainable training and are motivated to increase the complexity of learning curve step by step (Martín-Ramos et al., 2017). Both the third and fourth levels of Kirkpatrick are long-term impacts of the event, which were beyond the scope of this study.

After the data on students' literacy on health-related technology was obtained from the present study, it was found that the intervention Arduino coding workshop demonstrated a significant impact. The increase in the mean scores after the workshop indicated an enhancement in their literacy of health-related technology. These findings are consistent with previous research (Baird & Munir, 2015; Darmawan, 2017; Hutchinson, 1999). These studies too discovered that early exposure to Arduino coding among high school students boosted their knowledge, interest, cooperation, and creativity.

(Darmawan, 2017), for instance, added that while the students' understanding of Arduino programming increased, behavioral changes were also seen in the form of active involvement, inventiveness, and enjoyment. The increase of students' satisfaction has also been reported in other workshops held in Portugal and Italy that introduced Arduino coding (Martín-Ramos et al., 2017; Zubrycki & Granosik, 2014).

Ntourou, Kalogiannakis, and Psycharis (2021) also reported similar findings on students' satisfaction and an increase in their satisfaction after exposure to the Arduino

coding program. In their study, the students described it as *a "nice experience,"* *"interesting,"* and *"it was a nice experience, and it was something interesting. If I could, I would like to do it again."*.

Arduino or sometimes known as Arduino-Nano utilizes a widely available and utilized open-source microcontroller because of its lower cost and ease of building even by a novice with no prior experience of electronics or programming (Yang et al., 2019; Zubrycki & Granosik, 2014). The Arduino coding session in the current study focused on the fundamentals of coding utilizing the Arduino–Nano microcontroller. This is sometimes referred to as the brain of medical equipment. It was utilized in the current study to bridge the gap between biology and technology, as students at our medical college had little experience of technology in high school. Portugal and Italy medical institutions had also reported similar limitations of very little or occasional exposure to digital technology and a lack of resources of their students during the pre-university period (Agatolio & Moro, 2017; Martín-Ramos et al., 2017).

As mentioned earlier, Kota-Kinabalu Coders (KK coders) collaborated in this study because they foresaw that Arduino-coding was very useful and that it could serve as an essential design thinking tool to help medical students solve diagnostic or therapeutic health problems. The faculty engagement with a non-profit third party (KK Coders) helped us to overcome the financial constraints as well as the lack of expert content. Both these obstacles are a hindrance to the dissemination of technological experiences in any educational environment, either at the university or the pre-university level (Zubrycki & Granosik, 2014).

Despite the positive effect of this workshop shown in this study, it would still be challenging to introduce Arduino-coding in the medical program curriculum. One of the challenges that most medical institution would face is their student learning time. It was felt during this experiment that both students and medical educators were overwhelmed with the abundance of topics in the curriculum. In order to overcome this constraint, one-day hands-on workshop was organized during the weekend to avoid any clash with the busy curriculum schedule (McAleer, 2009), since such an elective workshop is the most enjoyed part of medical courses (McAleer, 2009). The convenience of the day and time further attracted the students to join the workshop.

The findings of this research, however, do not strive for another specific medical education intervention or concluding judgment concerning the educational approach in enhancing literacy health-related technology. Most of the previous studies focused on single-site implementation of educational outcomes; though a few had a cross-sectional design. However, to the best of our knowledge, the current study is among the first ones to examine medical students. Therefore, the quality of the evidence was rather limited. Numerous factors such as educational background and students' socio-demographics influenced the research outcomes; thus, these areas need further exploration. In conclusion, the Arduino coding workshop successfully achieved the planned objectives in this research, as evident in the positive reaction (students' satisfaction) and increase in the learning process (literacy of health-related

technology). However, the experience of our medical students cannot be generalized to all medical students of other institutions.

Despite a good success of the study, there were a few limitations too. First, the control group of medical students added to this study lacked exposure to Arduino coding; second, a random sampling technique was used that limited the sample size but it also reduced the study bias. Third, the assessment of the Arduino coding workshop which showed a positive impact in the form of improvement in students' literacy of technology was for short-term. Such long-term assessment like results and learning behavior were outside the scope of this study. Lastly, the duration of one single session of Arduino coding workshop was not long enough to acquire the required skills and experience to solve complex problems.

The study recommends that higher education institutions should design an intensive Arduino coding study module in order to close the gap between traditional medical sciences and technology literacy. The module can be offered to new graduates as an added value in the curriculum, which can also increase graduate employability. The positive feedback and students' satisfaction of the Arduino coding workshop are enough evidence for the faculty and medical educators to consider designing this program as an elective course in the medical curriculum. Having this program in the curriculum will not only enhance the students' literacy of technology, but will also give them an opportunity to master technical skills parallel with deeper learning of medical sciences. It will also help them to shift the mindset of medical students to be more creative and innovative. It is also suggested to organize a series of technical workshops at different levels of competency to facilitate creative learners to sharpen their technical skills (Martín-Ramos et al., 2017). In this way, the creative graduates will have the opportunity to become equipped e-physicians capable of facing the proliferation of technologies in the healthcare field. High-quality medical graduates will benefit the health sector and give a more significant contribution to the growth in developing economies (Dasci Sonmez & Cemaloglu, 2021). Future research studies may look into the impact of Arduino coding on the behavior and results criteria in a longitudinal study.

Acknowledgment

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