Arduino-based real-time data acquisition systems: boosting STEM career interest

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Article Info

Article history:

Received Mar 6, 2023
Revised Sep 6, 2023
Accepted Oct 1, 2023

Keywords:

ADDIE
Arduino
Chemistry
STEM career interest
Temperature monitoring

ABSTRACT

This study examines the development of an Arduino-based real-time data acquisition system and its effect on secondary students' STEM career interest (STEM-CIS). A total of 74 students were sampled from a prestigious private school in Jakarta, Indonesia, and a learning device was developed using the A.D.D.I.E. method. A one-group pretest-posttest research design was used to evaluate the effect of using the device during blended classroom activities. Data were collected through surveys using the STEM-CIS instrument and interviews. The study was based on the general practice of using Arduino software and hardware for practical purposes in Chemistry Laboratories and Sick Bay. The setup was successfully used in these different environments as a temperature monitoring system to record thermochemistry data and monitor a patient's body temperature. The findings are consistent with prior research indicating that hands-on robotics activities can increase STEM interest and inspire students to pursue STEM careers. The results suggest that strong engagement in this activity facilitated the development of digital literacy and STEM skills. The STEM-CIS score at the 5% significance level was significantly increased after the experimentation with the device, with a paired t-test result of $p<0.001$. The effect size (Cohen's d) showed a moderate effect of 0.74.

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1. INTRODUCTION

The Fourth Industrial Revolution necessitates the development of a workforce proficient in science, technology, engineering, and mathematics (STEM) and capable of utilizing critical thinking and problem-solving skills to address everyday challenges [1]. In today's rapidly evolving world, the demand for students to possess engineering skills and practical experiences is increasingly crucial for success [2]. Agasisti and Bertoletti [3] highlighted that there is a positive correlation between STEM career interests (STEM-CIS) and economic growth and innovation in the industry and education sectors. Despite the importance of STEM careers, persistent challenges have arisen in encouraging individuals to pursue them [4]. Research on career choices in STEM fields has been extensive, indicating the significance of this issue [5]. In recent studies, a concerning trend has emerged, showing a decline in science interest during secondary education [6]–[8]. This decline can be attributed to a lack of science identity [9] and a low perceived value of science [10]–[12]. To address this issue and ensure the future workforce's competitiveness, it is crucial to understand the factors influencing students' interests in STEM careers and to develop effective strategies to promote their engagement in STEM fields.

Recent research suggests that the students' beliefs, interests, and performance during their secondary education can be significant indicators of their intentions to pursue science-related college programs [9] and career goals [13]. This is especially relevant in the field of chemistry, where students may be motivated to conduct experiments but lack interest in pursuing chemistry-related professions [8]. Researchers discovered that students' interest in chemistry tends to decline as they progress through their education [8], [14]. According to chemistry education research, most students struggle to understand various chemical concepts and frequently fail to master them properly. Numerous research studies have found that the concept of thermodynamics in chemistry is challenging to master [15]–[17]. Furthermore, a literature study shows that physical chemistry and thermodynamics, including thermochemistry, represent a considerable barrier to the students. Thermodynamics is a complex topic that presents difficulties for both educators and learners [15]. Despite these challenges, Perets *et al.* [18] proposed that fostering students' engagement and interest in chemistry during their formative years can serve as a catalyst for pursuing careers in chemistry-related fields later on.

To encourage chemistry students to pursue STEM careers in the future, we sought to promote their interest in STEM using a learning tool that incorporates circuitry and robotics. A learning tool with Arduino boards is often used to build an electronic project with specific tasks for science application and experimentation [19]. It is a popular microcontroller board used in robotics [20] and environmental science [21], [22]. It is inexpensive, user-friendly, and suitable for people with little knowledge of electronics [23]. The popularity of Arduino has caught the attention of many educators, giving rise to a new terminology between "Chemistry" and "Arduino", ChemDuino [24]. The phrase "ChemDuino" is used to refer to the application of Arduino hardware and software (such as Wiring and OneWire) to enhance the teaching and learning of chemistry. Through STEM pedagogy, it has been used as a control system in a bioreactor to make biochar [25], CO2 sensor for plants [26], and a data acquisition device for online laboratory experiments [24]. Moreover, the application also serves as an impactful breakthrough in health monitoring systems [27]. Arduino boards have been used to facilitate remote health monitoring via the Internet of Things (IoT) [28], real-time health care for elderly patients and children [29], [30], and the engineering aspect of biomedical instrumentations [31].

In particular, incorporating a data acquisition system (DAQ) using Arduino boards has been found to play a significant role in bridging the analog and digital worlds [32], [33]. Previous studies using Arduino sensor kits have suggested that the incorporation of data acquisition systems in STEM classrooms promotes motivation and engagement among secondary students [34], [35]. The learning process enabled students to understand how scientists collaborate to collect and analyze chemical data from various environments, highlighting the importance and necessity of combining circuitry, and programming in this study.

Furthermore, the variables of interest in both chemistry and the health system are similar. One of the main connections in the measurements is temperature data. Body temperature is an important clinical parameter [36]. Measuring body temperature has become even more crucial during the post-pandemic era for early detection of fever and infection [37]. To address the need for an affordable and flexible device for measuring temperature, we developed an Arduino-based system in a secondary school setting that can be used for thermochemistry experiments in the laboratory and temperature observation in Sick Bay. Previous research in STEM career and interest has focused more on integrative STEM-robotics curriculum and robotics programming [38]–[41], but little attention has been given to the effect of using STEM-focused Arduino kits for hands-on activities in both laboratory and clinical settings to promote STEM interest and careers. Morais and Araújo [42] have a similar research and development (R&D) approach, describing the development of an experimental apparatus, with automatic data acquisition using Arduino board, which was used to determine the variation of the solubility of potassium nitrate in water as a function of temperature. The learning process effectively fostered the development of secondary students' skills, notably enhancing their proficiency in assembling electrical circuits and utilizing technological devices and software for automated data acquisition. It is worth mentioning, however, that this study did not specifically investigate the influence of STEM interest and its potential implications for future careers.

The significance of the current study is that, to the best of our knowledge, there has been no previous research related to the STEM-focused Arduino kit for hands-on activities in both the Chemistry Laboratory and Sick Bay, with a specific aim of promoting students' interest in STEM and their pursuit of STEM careers. Therefore, this study aims to develop an alternative pocket-sized device that is affordable and flexible for use in both settings and to investigate whether there is an increase in STEM career interest after using the device in teaching-learning activities. The research questions are: i) How to develop an Arduino-based real-time data acquisition system that can be used as a learning tool in both Chemistry Laboratory and Sick Bay? (RQ1); ii) Does the use of an Arduino-based real-time data acquisition device in the laboratory and clinical settings lead to an increase in secondary students' STEM career interest? (RQ2); and iii) How does allowing students to use the Arduino-based real-time data acquisition device impact their STEM career interest? (RQ3).

2. RESEARCH METHOD

The research was conducted at a prestigious private secondary school in Jakarta, Indonesia. This study used the research and development (R&D) approach and was followed by a group pretest-posttest design to understand the effect of using the device in the teaching-learning activity. The development model adopted in this study was the analysis, design, development, implementation, and evaluation (A.D.D.I.E.) method. The research and development steps in A.D.D.I.E. were straightforward and easy to evaluate [43], especially for circuitry and programming lessons [44].

In the analysis phase, problems were identified and possible solutions were brainstormed. The interview was used as a data collection technique. Four senior educators and two medical personnel were involved in the online interview. During the interview, users were asked to describe a tool or learning media that could assist them in obtaining real-time experiment data in a blended learning environment. The description of the technology was narrowed down to the use of Arduino in a real-time data acquisition and monitoring system. In the design phase, the setup illustration was drafted using Fritzing software, and lists of materials were prepared. Fritzing is a powerful open-source application that is used for designing and building electronic prototypes, especially those involving Arduino boards [45]. During the development phase, the codes were developed based on the user's specifications, encompassing the complete production process that involved setting up the device's electronics and programming the Arduino board. To ensure quality, the validation of this phase was conducted by Arduino experts, seasoned practitioners including senior chemistry and STEM teachers, and linguistic experts well-versed in the English language. The validity of the resulting product was assessed using a Likert scale validation questionnaire, and the average score obtained represented the percentage of product validity. Refer to Table 1 for a detailed overview of the criteria used in the evaluation. The interpretation of the criteria of the evaluation is presented in Table 2 [46].

Table 1. The Likert scale evaluation criteria [47]

Score	Explanation/Description of the scale
1	The validator strongly disagrees with the evaluation or statement or indicator (Scale 1)
2	The validator disagrees with the evaluation or statement or indicator (Scale 2)
3	The validator agrees with the evaluation or statement or indicator (Scale 3)
4	The validator strongly agrees with the evaluation or statement or indicator (Scale 4)

Table 2. Feasibility criteria for the developed device

Percentage	Interpretation
0%-20%	Not feasible/Not worthy
21%-40%	Less feasible/Less worthy
41%-60%	Quite feasible/Decent enough
61%-80%	Feasible/Worthy
81%-100%	Strongly feasible/Very worthy

Equation (1) expresses the analysis of the results. In (1), P, $\sum$ x, and $\sum$ xi are the percentage scores, the number of total scores from the user in one question item, and the maximum score of one question item respectively. The device was tested and declared suitable for use. The evaluation has been achieved as feasible when the interpretation is above 60%.

$$P = \frac{\sum x}{\sum xi}\ x\ 100\% \quad (1)$$

In the implementation phase, the prototype was used in the chemistry class to determine the enthalpy change of dissolution (ΔH) for NaOH in water and at Sick Bay to monitor a patient’s body temperature. For each experiment to measure the enthalpy change of dissolution, 0.500 grams of analytical grade NaOH (Merck) and 100.0 cm^3 of distilled water were used. During the evaluation phase, feedback on the results was collected. There were 30 students (aged 18-19) piloted in the implementation and evaluation phase. They were STEM students in the category of having medium to high prior knowledge of robotics. This was part of the small group testing before releasing the final product.

After the device was successfully developed, it was used as a tool to introduce engineering through STEM in the chemistry class. One group pretest-posttest design was used and 44 students (aged 18-19) were involved at this stage. This group of students has no experience with Arduino boards. The students were asked to assemble and disassemble the electronic parts of the device and manipulate the codes for the Arduino board. Students deployed and utilized the device in Sick Bay and Chemistry Laboratory. Students reflected on the activity and wrote an essay on how the entire activity connected to their future careers. The student feedback was then collected. The effective exposure with the device was two weeks. Data collection was taken via a survey with the STEM career interest (STEM-CIS) instrument. It was deployed and used as a pre-test and post-test. STEM career interest was adopted from previous research [48] and a 5-point semantic differential scale was used in the survey. The STEM career interest scale consists of 44 items. The instrument has been reviewed by experts. In this study, the internal consistency of the scale in Cronbach alpha was 0.95 for both pre-test and post-test. The results are aligned with previous research conducted by Shahali *et al.* [49] with 129 participants. Both pre-test and post-test scores of STEM-CIS had passed the preliminary Shapiro-Wilk test for normality. A paired t-test was then used to compare whether there was a significant difference between the pre-test and post-test scores of STEM-CIS using IBM SPSS Statistics 27.0.

3. RESULTS AND DISCUSSION

3.1. RQ1: the setup and codes development

3.1.1. Step 1: analysis

The analysis aimed to understand the overall needs of users, including educators, students, medical personnel, and patients in the laboratory and Sick Bay. Through interviews, requirements were identified and a system block diagram, as seen in Figure 1, was created to develop the system workflow. During the interviews, teachers highlighted the need for an affordable and flexible tool for measuring temperature and enthalpy change of reactions that could be automated and shared in real time. The results must be able to be shared in real-time on other devices, allowing collaboration among users. Arduino UNO Wi-Fi Rev2 with ESP8266 integrated Wi-Fi module can be a solution. However, this version of Arduino is more expensive compared to the price of Arduino Uno R3 [50]. Based on the analysis, we can simply use screen-sharing features from common online video conferencing platforms to support the activity in the laboratory, as suggested by Svatos *et al.* [51]. We used Parallax Data Acquisition (PLX-DAQ) to conjunct the Arduino board to a computer [52]. PLX-DAQ can also export data to Microsoft Excel, which can be useful for further analysis and visualization [53]. There was a need to have an alternative tool with certain criteria, e.g., low-cost, easy setup, and able to measure the body temperature of patients over a certain period. A PC or laptop must be involved in the measurements, allowing a possible connection to a projector in a blended learning environment. The data displays were coming from the graph in Microsoft Excel and the LCD I2C.

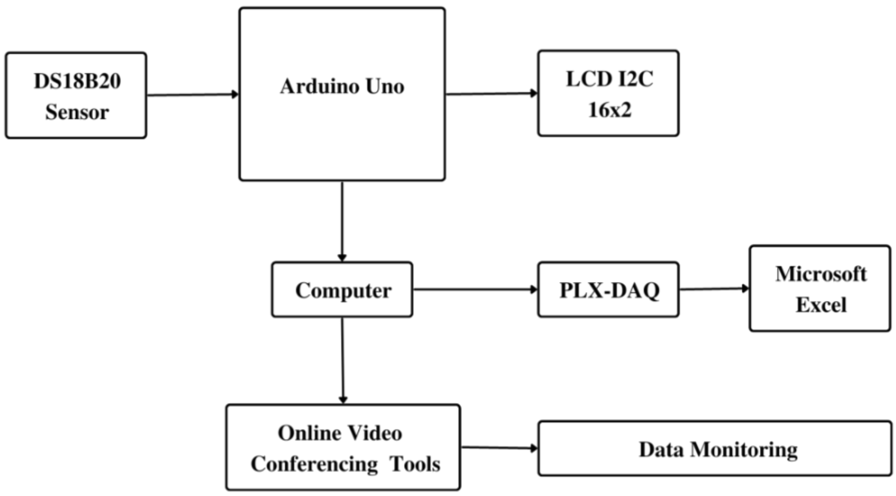

Figure 1. The overall system block diagram described in the present work

3.1.2. Step 2: design

In this step, we made lists of materials with the quantity for the setup. We used Arduino Uno R3 Atmega328P DIP, DS18B20 sensor, breadboards, Arduino USB Port, LCD I2C 16x2, pin wires, 10,000 resistors, and a computer. For the software, we used Arduino IDE, PLX-DAQ in Microsoft Excel, and online video conferencing platforms for monitoring. It supports multiple sensors for laboratory analysis and real-time monitoring. In the design phase, the system workflow must be supported with a suitable sensor. Several sensors were compared in Table 3. Thermocouple is a reliable industrial sensor with a wide temperature range. However, to measure body temperature and solution, this is not suitable. LM 35 is a good candidate. It is low-cost and has the right temperature range. However, most LM 35 sensors are sold without wires, just pinheads. In order to measure the temperature of solutions, the sensor must be made waterproof. Users are required to solder and cover the wires with plastic cables or shrinkable sleeves, and epoxy resin [53]. In this study, the sensor has to be waterproof and easy to use. The suitable sensor for the setup is DS18B20. It is economical, readily available in the market with long wires attached, and has the temperature range for both uses in the Chemistry Laboratory and Sick Bay.

Table 3. Lists of different temperature sensors

Sensor	Comparison		
	Temperature range	Price ($)	Reference
Thermocouple	-50 to 700±1˚C	20-45	Datasheet [54]
DS18B20	-55 to 120±0.5˚C	1-2	Datasheet [55]
LM 35	-50 to 155±0.5˚C	1-2	Texas instruments [56]

3.1.3. Step 3: development

We engaged in a collaborative effort with Arduino expert validators, practitioner validators, and linguistic experts proficient in English to develop electronic circuits and codes. The expert validation assessment yielded favorable reviews for the device, as demonstrated by the results presented in Table 4. Several Arduino setups were used in the laboratory and sickbay. The codes were developed, as simply as possible, so that the novices could easily troubleshoot them. The students were encouraged to write the Arduino codes using Arduino IDE software.

Table 4. Summary of assessment from experts

Validator	Percentage	Interpretation
Arduino expert 1	90%	Strongly feasible/Very worthy
Arduino expert 2	100%	Strongly feasible/Very worthy
Practitioner 1	80%	Feasible/Worthy
Practitioner 2	85%	Strongly feasible/Very worthy
English language validator 1	90%	Strongly feasible/Very worthy
English language validator 2	95%	Strongly feasible/Very worthy

3.1.4. Step 4: implementation

The device was tested in the laboratory by users to determine the enthalpy change of dissolution (ΔH) for NaOH in water. It was tested to monitor the increasing temperature from the dissolution process of NaOH in water. This was a common calorimetric method to determine the enthalpy change of dissolution (ΔH) [57]. Thermochemistry experiments require stringent control of the system and environmental parameters. The tip of the sensor needed to be fully immersed in the solution, in order to achieve a stable temperature measurement. In Microsoft Excel, the data field was directly converted into a scatter plot, a thermogram. At this stage, users were asked to assemble and disassemble the electronic parts. They found out that the VCC, DQ, and GND jacketed cables of DS18B20 were easily dislodged from the breadboard. The evaluation was to solder the cables. The soldering process took less than 10 minutes, allowing the molten tin to solidify on the surface of the wires. However, students should be encouraged to wear protective gear to prevent burns and eye damage from hot solder and flying debris. Additionally, it is important to have proper ventilation in the workspace to prevent inhaling toxic fumes from the soldering process.

The temperature data in Microsoft Excel was then converted into an enthalpy change of dissolution. The experiment results are presented in Table 5. The average enthalpy changes of dissolution (ΔH) for NaOH in water using DS18B20 provide a smaller estimated standard deviation, reflecting that the data are less spread out. In that comparison, a calorimeter with an analog thermometer gave a relatively higher estimated standard deviation. The percentage differences were calculated from the instructor value (-42.0 kJ mol^{-1}) of another similar experiment with paper cup calorimetry [53]. The theoretical value of the enthalpy change of dissolution of NaOH in water is -43.0 kJ mol^{-1} [57]. This value was used to measure the percentage errors for both experiments.

In Sick Bay, the usability test was conducted together with the patient. The medical personnel were also provided with a manual booklet to use the device. It was tested to measure the body temperature of patients under the supervision of medical personnel. The measurement was repeated several times on different days over two weeks. A thermogram from PLX-DAQ was produced and monitored. The monitoring was conducted remotely between a nurse and a physician at two different locations. Stable body temperatures were obtained within less than 5 minutes, as detected from a plateau on the thermogram. The overall setup has assisted the work of medical personnel to monitor the body temperature of patients. The concept of a thermogram, as perceived by medical personnel, refers to a time series of body temperature that can be used to identify patterns for diagnosing infections or diseases. Therefore, it is a vital clinical tool for healthcare professionals. Previous research has explored the use of statistical methods for analyzing thermograms to differentiate between fevers caused by malaria and dengue patients [58].

Table 5. The laboratory experiment results

Parameter	Experiments (n=30)	
	Using an analog thermometer	Arduino with DS18B20
Average values, kJ mol^{-1} (± estimated standard deviation)	−38.6 ±5.0	−44.7±4.3
Difference, %*	8.10	6.43
Error, %**	10.23	3.95

* The percentage difference with the instructor value (−42.0 kJ mol^{-1}) [53]
** The percentage error from the theoretical value of enthalpy change of dissolution (ΔH) of NaOH in water (−43.0 kJ mol^{-1}) [57]

3.1.5. Step 5: evaluation

After gathering feedback and input from users to assess the setup and measurements, we proceeded with the necessary adjustments. The primary modification involved creating a transparent protective case for the device, encompassing the circuitry of Arduino boards. During the evaluation phase, the students conveyed that the learning activity took on significant meaning:

> "*In a STEM class like this, I have the opportunity to modify the setup and codes according to my own design. I am planning to take engineering for my future study. For me, I want to study abroad in mechatronics engineering. The lesson that we had inspired me to find connections between concepts in other subjects. I want to take STEM subjects later in the university. And I think what we have done with the lesson here with the device is just an example of what an Arduino board is capable of doing. After the lesson, I stumbled upon an incredible online resource called https://www.instructables.com! It's a treasure trove of amazing examples that showcase how to set up intricate Arduino boards and electronics. I think I've found my new hobby here.*" (Student 3)
>
> "*I felt like I was never good at chemistry. But this activity that I'm currently doing with an Arduino board is very interesting and it makes me willing to learn chemistry more. At home, I have bought my own Arduino box. I was able to assemble and build an LPG gas leakage sensor. So, it will automatically turn on like an alarm, when there is a gas leak in my kitchen. I used the codes from the class activity and I added more codes into it. Together with my classmates, I have learned to test my Arduino setup and codes using Tinker cad simulation. I think this is the connection to my future study. I want to make portable sensors for household appliances.*" (Student 5)
>
> "*My thermochemistry data was inconsistent. So, I needed to repeat the experiments. I tried to troubleshoot the codes. I asked my classmates for help and used ChatGPT to help me correct the codes. Apparently, the problem was not coming from the code, but from the loose wires that were detached from the sensors. I think, for a commercial application, like in Sick Bay, we need to make the wiring permanent and make it more reliable. So, the parts will not fall off. Now, I know how scientists work in the engineering field. It takes problem-solving skills too.*" (Student 14)
>
> "*Thermochemistry is challenging. But the real fun came when we got to use that Arduino board and sensor for some experiments. That tinkering and data gathering made me feel like a real scientist. It increased my confidence and understanding in chemistry practicals. Like, I was actually able to apply the theories we've been learning so far. I made a working prototype and my coding skills were getting a little better since I added more sensors to my setup.*" (Student 20)
>
> "*I like the part where we are allowed to modify the codes and setup. I think I am going to take a STEM course at the university. I like to do trial and error. Actually, I want to be a physician for my career. I believe what we have learned in the class is useful for preparing me for the university level. After learning to assemble and disassemble the device in Sick Bay, I want to learn more about medical devices. Building a device like this will make us think of the science concepts behind it and how the data can be recorded.*" (Student 24)

3.2. RQ2 & RQ3: the impact on the students' STEM career interest

3.2.1. STEM-CIS pre-test and post-test

Table 6 shows the t-test results from the pre-test and post-test scores of STEM-CIS. The pre-test indicates a mean score of 3.53 (SD=0.468) for interest in STEM careers, while the post-test shows a mean score of 3.83 (SD=0.336). The use of the device in the teaching-learning activity has provided a significant increase in STEM-CIS scores, resulting in a paired t-test result of $p<0.001$ at the 5% significance level. Overall, the results suggest that the use of the device has a positive impact on the cultivation of interest in STEM careers among the students. Shahali *et al.* [49] conducted a study on the effectiveness of an integrative STEM program, which yielded similar results. The STEM activities had a significant impact on the STEM-CIS scores, with N=129 (t=2.5, p=0.014 at a 5% significance level) [49].

Moreover, Nite *et al.* [59] demonstrated that incorporating microcontrollers into STEM pedagogy can increase students' interest in STEM careers. The use of technology in the learning process can positively impact students' perspectives on STEM, and may also improve their skills in mechanical design, electronics, and robotics programming. As reported by Sisman *et al.* [60], students must be given an active role in every step of the learning process to effectively learn programming languages. This means that they should have the opportunity to engage in hands-on activities, solve problems, and explore new concepts in a meaningful and interactive way. In this case, we allowed the students to have frequent group discussions related to writing codes using Arduino IDE software.

Table 6. The paired t-test results from STEM-CIS pre-test and post-test

Result	N	Mean	Standard deviation	At 5% significance level	
				t	sig. (1-tailed)
Pre-test	44	3.53	0.468	10.606	<0.001
Post-test	44	3.83	0.336		

The use of the device was effective when students were allowed to make trial and error of the setup. Students were encouraged to make a large number of mistakes in the circuitry and codes. However, they must find out the consequences of the output data. Instructors should intervene less intervening in the process. Students learned how electronic sensors work and it could substitute analog thermometers with better performance and precision. The overall experimentation using the device increased the student's interest in STEM. Therefore, it contributed to a significant increase in the STEM careers scores. It is supported by the finding in a meta-analysis study that the use of Arduino software and hardware in classroom interventions had an overall positive effect (d=0.67 (CI: 0.40, 0.95)) on students' STEM academic achievement and their perceptions towards STEM [61]. Cohen's d from Table 6 was found to be 0.74, which exceeded Cohen's d for a moderate effect [62]. Despite these findings, some students were reported to have difficulties when writing the codes using Arduino IDE. An introductory session to familiarize the menu in Arduino IDE will be advised for novices [63].

Based on student feedback, it is highlighted that allowing students to modify and manipulate the setup and code collaboratively is critical to increasing engagement and interest in STEM using Arduino boards and sensors. One student mentioned the use of ChatGPT to test their code for errors. ChatGPT, an artificial intelligence (AI) innovation developed by OpenAI, has the potential to play a role in coding and solving programming bugs [64]. Arguably, this might transform the learning experience in STEM education, especially as a tool to encourage independence and self-regulation. Tlili *et al.* [65] have reported on the use of ChatGPT in educational settings and emphasized the need for a safe and responsible adoption of chatbots in the learning process.

In addition, students mentioned online Makerspace and Arduino online community websites, such as https://www.instructables.com and https://www.tinkercad.com. These e-learning platforms are designed to promote a hands-on learning approach through do-it-yourself (DIY) projects, providing the students with an opportunity to design and prototype using virtual Arduino circuits [66]. Incorporating online learning platforms may contribute to the effectiveness of promoting student engagement and interest in STEM. Recent research by Abouhashem *et al.* [67] supported this finding, showing that interactive online learning environments have a significant positive impact on students' involvement, memory retention, active participation, and motivation to pursue STEM innovations. This might suggest that the students, who have experienced a strong engagement in this activity, have developed certain digital literacy and STEM skills, which enable them to support their learning process. Therefore, the overall learning process is able to promote interest and careers in STEM.

4. CONCLUSION

The study has provided an example of how secondary-level students can engage in the process of developing and using the setup and codes of Arduino boards and sensors. The device provides alternative assistance to measure, collect, and display temperature data in the form of a thermogram. Several functionalities might be added to deliver innovative engineering solutions in the technology-enhanced learning environment using Arduino boards. The integration of the device in the teaching activity has resulted in a significant increase in the overall STEM-CIS score, as evidenced by a paired t-test result of $p<0.001$ at a 5% significance level. The findings support the notion that such exposure can enhance interest and potentially increase the likelihood of pursuing related STEM careers.

To foster active participation in the learning process, it is advisable to encourage students to experiment with both the code and setup, specifically by utilizing the Arduino IDE. Facilitators should do minimum scaffolding or intervention. However, this study is subject to certain limitations. Due to practical constraints, we used a pre-experimental design, without considering the disparities between males and females. This might be a contributing factor in STEM career and interest. It is also necessary to further investigate how far the students' STEM interest effect will be sustained. It is recommended to evaluate this influence on a delayed post-test design in the future.

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