Shih, JL. et al. (Eds.) (2023). Proceedings of the 31st International Conference on Computers in Education. Asia-Pacific Society for Computers in Education

Review Process to Investigate Trends of Using Arduino to Enhance AI Study

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Abstract: In the industrial sector, Artificial Intelligence (AI) technology has been extensively utilized and integrated into educational curricula and teaching methodologies to enhance educational effectiveness and respond to the needs of entrepreneurs. However, due to its costliness, more learning tools and technology are needed to ensure AI education. The Arduino board offers a user-friendly and cost-effective solution that enables the study of complex applications involving the integration of artificial intelligence with Arduino programming. This study presents a review process to investigate trends of using Arduino to enhance AI study. This study highlights the increasing complexity of using Arduino boards with artificial intelligence algorithms. Specifically, it explores their applications in domains such as multiple linear regression (MLR), particle swarm optimization (PSO), adaptive neuro-fuzzy inference systems (ANFIS), and Node-RED. The findings of this study will serve as a valuable reference for scholars interested in this domain and as a guide for AI education in the future.

Keywords: AI education, Machine Learning, Arduino, Neuro-Fuzzy, Node-RED

1. Introduction

Industry in the era of Industry 4.0 has undergone rapid changes and advancements driven by the widespread adoption of various technologies (Pajpach et al., 2022). These technologies have been extensively applied across agricultural, manufacturing, transportation, service, and other industrial sectors. By incorporating technology into industrial processes, efficiency has been increased, production costs have been reduced, time has been saved, and convenience has been enhanced, utilizing the benefits of 21st-century technology to address economic challenges and difficulties (Sarı et al., 2022). Integrating technology into education and teaching methods has been a critical aspect of leveraging the advantages of Industry 4.0 (Görgülü et al., 2021). However, a significant issue in education is the high cost of technology-related devices. Consequently, the Arduino board has been chosen as an affordable solution (Bullis et al., 2021; Guzmán-Fernández et al., 2021). This board offers professional-grade usability with the required precision and reliability (Lee, 2020; Makan et al., 2021).

Arduino microcontrollers have gained popularity in smart home systems, security applications, and STEM education, encompassing science, technology, engineering, and mathematics. They facilitate problem-solving skills, practical training, and activity-based learning (Sarhan, 2020; Sari et al., 2022). Arduino microcontrollers have also been employed in various dimensions of education, ranging from primary and secondary education to vocational and higher education levels. Their utilization aims to foster positive educational outcomes, increased student engagement, and a more enthusiastic approach to learning (Budi et al., 2021). These microcontrollers promote students' systematic thinking, creative ideation, and time management skills by possessing technological literacy and learning collaboratively in the classroom, and they can develop programming skills and apply them practically (Medeiros et al., 2018; Roumen et al., 2021). Additionally, Arduino facilitates the creation of simple learning devices in laboratories (Ueyama et al., 2022; Vidal et al., 2022) and enables the design of increasingly complex systems by incorporating innovative expertise or artificial

intelligence into Arduino programming, exploring the usage of advanced technologies (Tupac-Yupanqui et al., 2022).

Therefore, integrating technology, mainly through using Arduino microcontrollers, has significantly enhanced education, fostering positive learning outcomes and the development of programming skills. Arduino provides an affordable and reliable solution and empowers students to actively engage in learning, cultivate problem-solving abilities, and explore the vast possibilities of advanced technologies.

Artificial Intelligence (AI) involves designing and developing algorithms and models that enable machines to acquire and process information, extract meaningful insights, and make informed decisions or take appropriate actions based on the available data. Advanced technologies and many techniques are used in artificial intelligence, such as Multiple Linear Regression (MLR), Particle Swarm Optimization (PSO), and Adaptive Neuro-Fuzzy Inference Systems (ANFIS), especially in engineering education. In addition, Node-RED is an intelligent and agile system based on innovative communication for monitoring and control with industrial communication (Chookaew & Howimanporn, 2022).

In this study, a literature review was conducted to investigate trends in this field encompassing the following research questions:

RQ1: What research studies employ artificial intelligence with the Arduino board?

RQ2: What types of Arduino boards are utilized in the research study?

RQ3: What is the method to assess the accuracy of artificial intelligence research with the Arduino board?

2. Research Methodology

2.1 Process of data searching and collection

A systematic search was conducted on the Scopus database using a predefined set of search keywords: (“artificial-intelligence” OR “machine-intelligence” OR “machine-learning” OR “multiple-linear-regression” OR “particle-swarm-optimization” OR “adaptive-neuro-fuzzy-inference-system” OR “Node-RED” AND “Arduino”). A total of 162 articles were found in selected education-related fields (i.e., “engineering”, “computer science”, “mathematics”, “social sciences”, “environmental science”, “decision sciences”). Only articles with at least two keywords related to “MLR”, “PSO”, “ANFIS”, “Node-RED”, and “Arduino” in their titles, abstracts, or keywords were included in the study. After applying these criteria, the number of articles was reduced to 130 for further consideration. Subsequently, after further reviewing the complete text, ten articles were unrelated to the study, and four needed to be written in English. Finally, 18 articles remained that specifically addressed topics related to MLR, PSO, ANFIS, Node-RED, and Arduino, as shown in Figure 1.

2.2 Data Analysis

Conducting a systematic literature review and analysis in this study is based on the principles and guidelines proposed by Chu et al. (2022). It encompasses data collection, inclusion and exclusion criteria, data coding, and analysis techniques. The publication of selected studies was analyzed, including the research article published in an international journal between 2018-2022. The criteria were used when choosing the valid article to make sure that there is consistency in the studies for data analysis that follow as:

1) The article must have been published in the last five years.
2) The article must have studied using the Arduino board for operating artificial intelligence with MLR, PSO, ANFIS, and Node-RED topics.
3) Each study assessed the accuracy applied to an Arduino board related to machine learning and artificial intelligence.

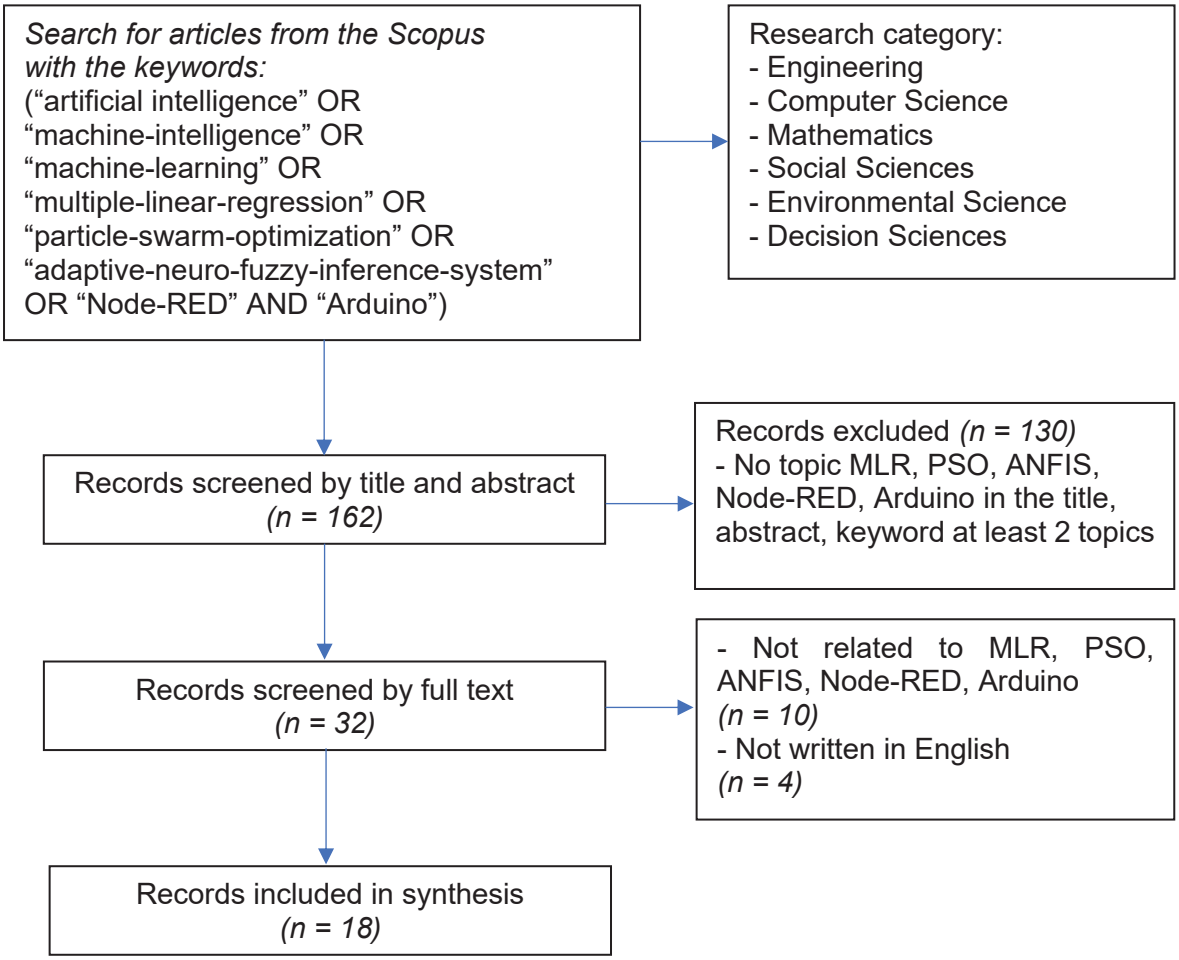

Figure 1. Research literature review process

3. Results

3.1 RQ1: What research studies employ artificial intelligence with the Arduino board?

In the field of MLR, several research studies were identified that integrated the use of MLR, PSO, ANFIS, and Node-RED with Arduino board in various contexts. For instance, Setyawan et al. (2022) analyzed MLR to determine the hydroponic nutrient solution from the water quantity and pump operation time. Songara and Patel (2022) compared three types of soil sensors to find the most suitable value for soil moisture. Bhoi et al. (2022) employed IoT-EMS to analyze the MLR values. Suresh et al. (2022) utilized an IoT-enabled deep-learning innovative irrigation system (IoTDL-SIS) to control an intelligent canal system. Deberneh and Kim (2018) focused on harvesting energy from a Wave Energy Converter (WEC) and predicting shore-side power by specifying the characteristics of sea waves using floating buoys.

In the area of PSO, Sheikh Ahmadi et al. (2022) aimed to maximize the energy yield of solar cells (PV) by combining the advantages of the incremental conductance (IC) method and PSO for Maximum Power Point Tracking (MPPT) control. Delavari and Naderian (2020) sought to enhance the robustness, flexibility, and level of independence of a microgrid inverter with parameter bounds of disturbances using PSO. De Moura Oliveira et al. (2022) designed a PSO-based Proportional Integral Derivative (PID) controller with the lowest absolute error and the slightest overall control signal variation. Sutyasadi and Wicaksono (2020) applied PSO to low-cost robot arm design and PID parameter tuning for small or medium-sized embedded

controllers. Daouadi et al. (2020) utilized the Takagi-Sugeno (T-S) fuzzy system combined with PSO to improve the stability of DC-DC boost converters.

Regarding ANFIS, Songara and Patel (2022) used ANFIS to determine suitable values for soil moisture. Sanjaya et al. (2019) designed a four-sensor robotic arm with ANFIS integration. Pandey et al. (2019) developed and employed a Multi-Adaptive Networked Fuzzy Inference System (MANFIS) for mobile robot navigation in different two-dimensional environments. Mujiarto et al. (2019) designed and implemented a five-sensor robotic arm with ANFIS integration.

Regarding Node-RED, Mohd Shaari Azyze et al. (2021) showcased the display of IoT data using the Node-RED platform for controlling air pollution and updating data every 5 minutes. Cgseong et al. (2020) designed and utilized a real-time object control system using Node-RED. Effendi et al. (2020) developed an intelligent farm and agriculture project that employed various internet-connected devices in the farm, including IoT for monitoring, with data inspection through Node-RED. Tedla et al. (2019) addressed the issue of crop loss during storage by using sensors to monitor environmental conditions in the storage facility and displaying real-time web applications via Node-RED. Huang et al. (2019) implemented a multi-agent system that used Node-RED to display real-time data on a screen.

According to Table 1 in the literature review, four articles utilized MLR, five employed PSO, three utilized ANFIS, five incorporated Node-RED, and 1 article combined MLR and ANFIS, as shown in Figure 2.

Table 1 *Summary of the 18 included studies.*

ID	Year	Authors	Source	AI Topic/Techniques
P1	2022	Setyawan et al.	Journal of Engineering Science and Technology	MLR
P2	2022	Songara & Patel	Measurement	MLR+ANFIS
P3	2022	Bhoi et al.	Intelligent Automation & Soft Computing	MLR
P4	2022	Suresh et al.	Computers, Materials & Continua	MLR
P5	2018	Deberneh & Kim	Applied Sciences	MLR
P6	2022	Sheikh Ahmadi et al.	Iranian Journal of Science and Technology	PSO
P7	2020	Delavari & Naderian	IET Generation	PSO
P8	2020	De Moura Oliveira et al.	Algorithms	PSO
P9	2020	Sutyasadi & Wicaksono	Telecommunication Computing Electronics and Control	PSO
P10	2020	Daouadi et al.	Electrotehnica	PSO
P11	2019	Sanjaya et al.	International Journal of Recent Technology and Engineering	ANFIS
P12	2019	Pandey et al.	World Journal of Engineering	ANFIS
P13	2019	Mujiarto et al.	Indonesian Journal of Electrical Engineering and Computer Science	ANFIS
P14	2021	Mohd Shaari Azyze et al.	Asian Research Publishing Network	Node-RED
P15	2020	Cgseong et al.	Indonesian Journal of Electrical Engineering and Computer Science	Node-RED
P16	2020	Effendi et al.	International Journal of Integrated Engineering	Node-RED
P17	2019	Tedla et al.	International journal of scientific & technology research	Node-RED
P18	2019	Huang et al.	Journal of Manufacturing Systems	Node-RED

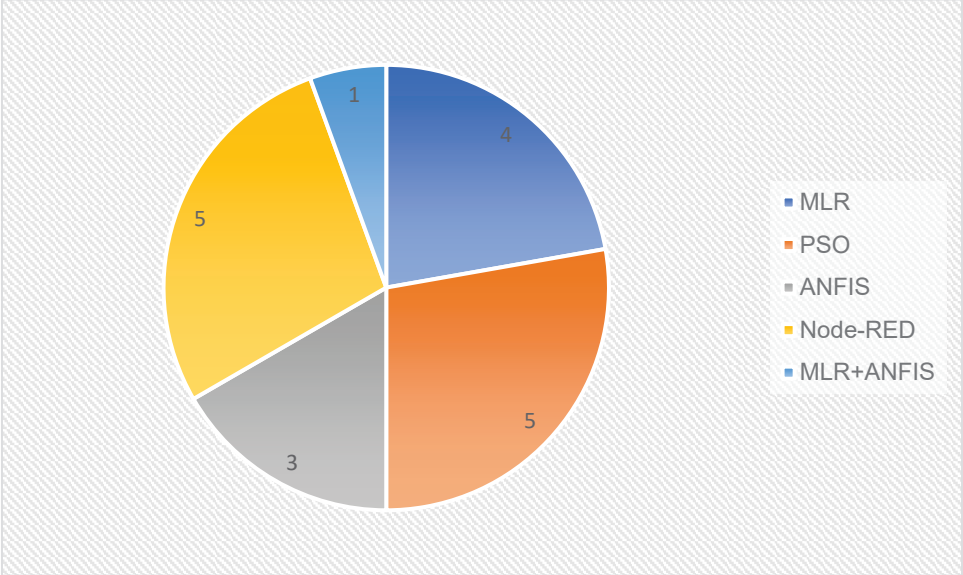

Figure 2. Research studies utilizing AI topics/techniques

3.2 RQ2: What types of Arduino boards are utilized in the research study?

Upon reviewing the literature, it was found that 18 articles utilized several types of Arduino boards for the research study. Most article uses Arduino Uno (6 articles), Arduino Mega 2560 (4 articles), Arduino Nano (2 articles), Arduino ESP-32 (2 articles), Arduino ESP8266 (1 article), Arduino Leonardos (2 articles), and two articles did not specify the Arduino board used, as shown in Figure 3.

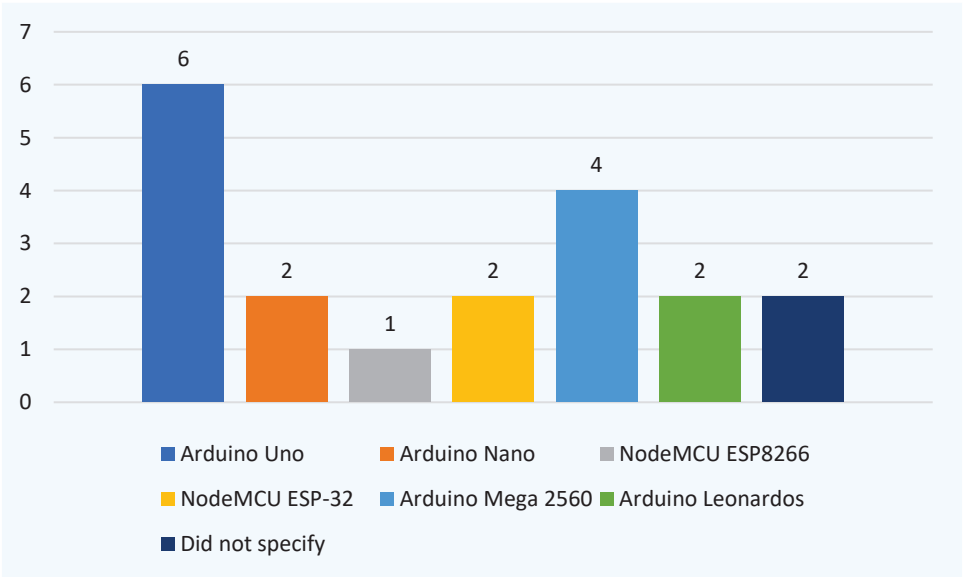

Figure 3. Types of Arduino boards used in research studies.

3.3 RQ3: What is the method to assess the accuracy of artificial intelligence research with the Arduino board?

In the reviewed research studies that employed Arduino boards, the accuracy was assessed using various metrics, including R-squared (R^2), Mean Squared Error (MSE), Root Mean Square Error (RMSE), Mean Absolute Error (MAE), Mean Absolute Percent Error (MAPE), and Integral Absolute Error (IAE). Among the 18 articles included in the literature review, the evaluation of accuracy revealed the following distribution: R^2 was utilized (2 articles), MSE (4 articles), RMSE (1 article), MAE (2 articles), MAPE (2 articles), IAE (2 articles), and other evaluation methods were employed (10 articles). It is worth noting that some articles conducted multiple evaluations to assess accuracy, as shown in Figure 4.

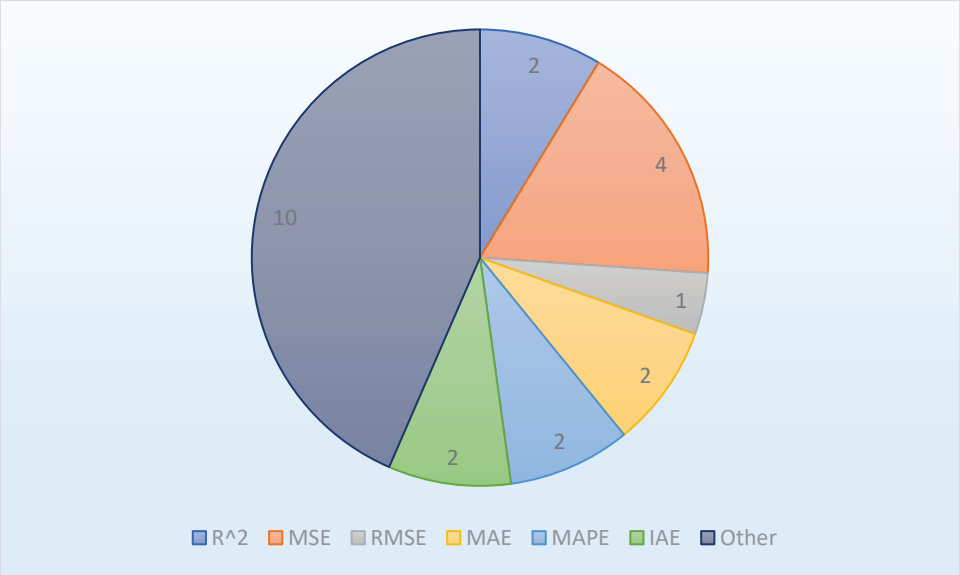

Figure 4. The methods of accuracy assessment.

4. Conclusions

The findings reveal that MLR is utilized in four research articles, PSO in five articles, ANFIS in three articles, Node-RED in five articles, and a combination of MLR and ANFIS in one article. Moreover, the Arduino boards used in these studies consist of Arduino Uno in six articles, Arduino Nano in two articles, Arduino ESP8266 in one article, Arduino ESP-32 in two articles, Arduino Mega 2560 in four articles, Arduino Leonardo in two articles, and unspecified Arduino boards in two articles. The evaluation of research accuracy involves different metrics, including R-squared (r^2) in two articles, Mean Squared Error (MSE) in four articles, Root Mean Squared Error (RMSE) in one article, Mean Absolute Error (MAE) in two articles, Mean Absolute Percentage Error (MAPE) in two articles, Integrated Absolute Error (IAE) in two articles, and other evaluation methods in ten articles. Notably, some research articles employ multiple evaluation methods to assess accuracy.

This research highlights the increasing complexity of utilizing Arduino boards with artificial intelligence algorithms, particularly in MLR, PSO, ANFIS, and Node-RED domains. The findings contribute valuable insights for researchers interested in utilizing Arduino boards in various disciplines and facilitate the development of Arduino-based microcontroller applications. The study aims to serve as a comprehensive reference for future researchers in this field, providing them with a solid foundation for further investigations and advancements.

Acknowledgment

The authors thank the Department of Teacher Training in Mechanical Engineering, Faculty of Technical Education, King Mongkut's University of Technology North Bangkok for support.

References

Bhoi, S. K., Panda, S. K., Jena, K. K., Sahoo, K. S., Jhanjhi, N. Z., Masud, M., & Aljahdali, S. (2022). IoT-EMS: An Internet of Things Based Environment Monitoring System in Volunteer Computing Environment. *Intelligent Automation & Soft Computing*, *32*(3).

Budi, A. H. S., Juanda, E. A., Fauzi, D. L. N., Henny, H., & Masek, A. (2021). Implementation of Simulation Software on Vocational High School Students in Programming and Arduino Microcontroller Subject. *Journal of Technical Education and Training*, *13*(3), 108-114.

Bullis, R., Coker, J., Belding, J., De Groodt, A., Mitchell, D. W., Velazquez, N., ... & Gunderson, J. E. (2021). The Fluorino: A Low-Cost, Arduino-Controlled Fluorometer. *Journal of Chemical Education*, *98*(12), 3892-3897.

Cgseong, C. G., Kim, J. Y., & Park, D. J. (2020). Real-time object control system using open source platform. *Indonesian Journal of Electrical Engineering and Computer Science*, *20*(1), 313-319.

Chookaew, S., & Howimanporn, S. (2022). Upskilling and reskilling for engineering workforce: implementing an automated manufacturing 4.0 technology training course. *Global Journal of Engineering Education*, 24(1).

Chu, S. T., Hwang, G. J., & Tu, Y. F. (2022). Artificial intelligence-based robots in education: A systematic review of selected SSCI publications. *Computers and education: Artificial intelligence*, 100091.

Deberneh, H. M., & Kim, I. (2018). Predicting output power for nearshore wave energy harvesting. *Applied Sciences*, *8*(4), 566.

Delavari, H., & Naderian, S. (2020). Design and HIL implementation of a new robust fractional sliding mode control of microgrids. *IET Generation, Transmission & Distribution*, *14*(26), 6690-6702.

De Moura Oliveira, P. B., Hedengren, J. D., & Solteiro Pires, E. J. (2020). Swarm-based design of proportional integral and derivative controllers using a compromise cost function: An Arduino temperature laboratory case study. *Algorithms*, *13*(12), 315.

Daouadi, R., Ounass, D., Soufi, Y., Metatla, A., & Guiza, D. (2020). Real-time Implementation of a Takagi-Sugeno Fuzzy Controller for a DC-DC Boost Converter. *Electrotehnica, Electronica, Automatica*, *68*(4).

Effendi, M. K. R., Kassim, M., Sulaiman, N. A., & Shahbudin, S. (2020). IoT smart agriculture for aquaponics and maintaining goat stall system. *International Journal of Integrated Engineering*, *12*(8), 240-250.

Görgülü Arı, A., & Meço, G. (2021). A New Application in Biology Education: Development and Implementation of Arduino-Supported STEM Activities. *Biology*, *10*(6), 506.

Guzmán-Fernández, M., Zambrano de la Torre, M., Ortega-Sigala, J., Guzmán-Valdivia, C., Galvan-Tejeda, J. I., Crúz-Domínguez, O., ... & Durán-Muñoz, H. A. (2021). Arduino: a Novel Solution to the Problem of High-Cost Experimental Equipment in Higher Education. *Experimental Techniques*, 1-13.

Huang, Z., Kim, J., Sadri, A., Dowey, S., & Dargusch, M. S. (2019). Industry 4.0: Development of a multi-agent system for dynamic value stream mapping in SMEs. *Journal of Manufacturing Systems*, *52*, 1-12.

Lee, E. (2020). A Meta-Analysis of the Effects of Arduino-Based Education in Korean Primary and Secondary Schools in Engineering Education. *European Journal of Educational Research*, *9*(4), 1503-1512.

Makan, G., Mingesz, R., & Gingl, Z. (2021). Reliable readings from Arduino voltmeters. *Physics Education*, *56*(4), 043001.

Medeiros, R. P., Ramalho, G. L., & Falcão, T. P. (2018). A systematic literature review on teaching and learning introductory programming in higher education. *IEEE Transactions on Education*, *62*(2), 77-90.

Mujiarto, A. D., Komaro, M., Mohamed, M. A., & Rahayu, D. S. (2019). Colored object detection using 5 dof robot arm based adaptive neuro-fuzzy method. *Indonesian Journal of Electrical Engineering and Computer Science*, *13*(1), 293-299.

Mohd Shaari Azyze, N. L. A., Md Isa, I. S., & Kamaruzaman, N. S. (2021). Development Of Real-Time Lora-Based Air Pollution Monitoring System. *Asian Research Publishing Network (ARPN), 16(9)*

Pandey, A., Kashyap, A. K., Parhi, D. R., & Patle, B. K. (2019). Autonomous mobile robot navigation between static and dynamic obstacles using multiple ANFIS architecture. *World Journal of Engineering*.

Pajpach, M., Haffner, O., Kučera, E., & Drahoš, P. (2022). Low-cost education kit for teaching basic skills for industry 4.0 using deep-learning in quality control tasks. *Electronics*, *11*(2), 230.

Roumen, G. J., & Fernaeus, Y. (2021). Envisioning Arduino Action: A collaborative tool for physical computing in educational settings. *International Journal of Child-Computer Interaction*, *29*, 100277.

Sarhan, Q. I. (2020). Systematic survey on smart home safety and security systems using the Arduino platform. *IEEE Access*, *8*, 128362-128384.

Sari, U., Çelik, H., Pektaş, H. M., & Yalçın, S. (2022). Effects of STEM-focused Arduino practical activities on problem-solving and entrepreneurship skills. *Australasian Journal of Educational Technology*, *38*(3), 140-154.

Sarı, U., Pektaş, H. M., Şen, Ö. F., & Çelik, H. (2022). Algorithmic thinking development through physical computing activities with Arduino in STEM education. *Education and Information Technologies*, *27*(5), 6669-6689.

Sanjaya, W. S. M., Sambas, A., Jannah, M., Rahayu, D. S., Mamat, M., & Mohamed, M. A. (2019). Design of 4 Dof Robot ARM Based on Adaptive Neuro-Fuzzy (ANFIS) using Vision in Detecting Color Objects. *International Journal of Recent Technology and Engineering*, *8*(2S7), 224-227.

Setyawan, T. A., Nugroho, A. S., Febyana, A., & Pramono, S. (2022). Multiple linear regression method used to control nutrient solution on hydroponic cultivation. *Journal of Engineering Science and Technology*, *17*(5), 3460-3474.

Sheikh Ahmadi, S. H., Karami, M., Gholami, M., & Mirzaei, R. (2022). Improving MPPT performance in PV systems based on integrating the incremental conductance and particle swarm optimization methods. *Iranian Journal of Science and Technology, Transactions of Electrical Engineering*, 1-13.

Songara, J. C., & Patel, J. N. (2022). Calibration and comparison of various sensors for soil moisture measurement. *Measurement*, *197*, 111301.

Sutyasadi, P., & Wicaksono, M. B. (2020). Joint control of a robotic arm using particle swarm optimization based H2/H∞ robust control on arduino. *Telecommunication Computing Electronics and Control*, *18*(2), 1021-1029.

Suresh, P., Aswathy, R. H., Arumugam, S., Albraikan, A. A., Al-Wesabi, F. N., Hilal, A. M., & Alamgeer, M. (2022). IoT with Evolutionary Algorithm Based Deep Learning for Smart Irrigation System. *Computers, Materials & Continua*, Vol. 71, No. 1, pp. 1713-1728).

Tedla, T. B., Bovas, J. J. L., Berhane, Y., Davydkin, M. N., & James, P. S. (2019). Automated granary monitoring and controlling system suitable for the sub-Saharan region. *International journal of scientific & technology research*, *8*(12), 1943-1951.

Tupac-Yupanqui, M., Vidal-Silva, C., Pavesi-Farriol, L., Ortiz, A. S., Cardenas-Cobo, J., & Pereira, F. (2022). Exploiting Arduino features to develop programming competencies. *IEEE Access*, *10*, 20602-20615.

Ueyama, Y., Sago, T., Kurihara, T., & Harada, M. (2022). An Inexpensive Autonomous Mobile Robot for Undergraduate Education: Integration of Arduino and Hokuyo Laser Range Finders. *IEEE Access*, *10*, 79029-79040.

Vidal, J., Bravo, D. A., & Rengifo, C. F. (2022). Teaching Physical Sciences Using Arduino Physics Lab at the Universidad Del Cauca. *IEEE Revista Iberoamericana de Tecnologias del Aprendizaje*, *17*(3), 223-229.