

Bridging IoT Education Through Activities: A Game-Oriented Approach with Real-time Data Visualization

Nurzaman Ahmed¹ ²Flavio Esposito ³Nadia Shakoor

^{1,3}Donald Danforth Plant Science Center ²Computer Science, Saint Louis University
St. Louis, MO 63132

Email: {¹nahmed, ³nshakoor}@danforthcenter.org

² first.last@slu.edu

Abstract—The rapid evolution of the Internet of Things (IoT) has underscored the importance of comprehensive educational strategies to impart IoT concepts and applications to a diverse audience. Given IoT’s pervasive impact, there is hence a pressing need for effective education in this area. Currently, there is a significant gap between existing educational strategies for IoT and the dynamic, engaging approaches needed to captivate a diverse audience, particularly young learners. The challenge lies in developing a methodology that not only educates but also motivates students e.g., from Grade 2 to Grade 12. To address this need, we developed an innovative, activity-based educational framework, integrating interactive and immersive learning methods, aimed at simplifying complex IoT concepts with smart agricultural application in mind for early learners. We outline this novel pedagogical approach, detailing how specific IoT components are taught through targeted activities. The paper should serve as a guide for educators to implement this framework and encourage readers to recognize the importance of adopting new teaching strategies for IoT. Through the implementation of this framework, exemplified in a case study of a plant care game, we have observed an increased engagement and understanding of IoT concepts among our target students. These findings indicate the effectiveness of our approach in real-world educational settings.

Index Terms—Internet of Things (IoT), IoT Education, Smart Agriculture, STEM Education

I. INTRODUCTION

The introduction of the Internet of Things (IoT) has revolutionized various industries, prompting the need for comprehensive education on its concepts and applications [1, 2]. However, the current educational framework primarily caters to undergraduate and advanced-level students, creating a noticeable gap in elementary to high school levels. This gap underscores the necessity of developing accessible and engaging educational tools to introduce IoT principles to a wider audience.

Recently, the extensive domain of IoT has expanded to encompass diverse sectors, ranging from smart agriculture, smart homes, smart cities, to wearable electronics. This broadened reach has been facilitated by the interconnectedness of a multitude of daily life objects [3, 4]. As IoT incorporates various complex concepts of computer science, the development of IoT skills requires a foundation in software development, hardware design, communication technologies, computer networking, cloud computing, and web applications [5, 6]. Expecting students to possess prior knowledge in all these areas before delving into IoT training can be daunting

for some. To address this, a wealth of educational materials, hands-on manuals, technologies, and tools are available for implementing IoT projects, fostering specialized IoT learning tailored to specific domains or applications. With the growing integration of IoT systems in various industries, there is a pressing need for a comprehensive and holistic design of IoT courses, emphasizing the importance of introducing IoT education at the school level. The scarcity of IoT education among K-12 and below students is a significant concern, underscoring the necessity of nurturing a foundational understanding of IoT principles early on, equipping the future workforce with essential technological skills.

To address the challenges in IoT education, including the complexities arising from the integration of multiple independent domains, we firmly believe that fostering student engagement through interactive and immersive learning approaches can render IoT education more accessible and effective. Incorporating game-based or activity-based learning methods not only simplifies intricate technological concepts but also encourages critical thinking, problem-solving, and collaborative skills development among students, making the learning experience both engaging and enriching.

The contributions of this paper are two-fold. Firstly, it introduces a game or activity-based method for IoT education, emphasizing an interactive and practical learning approach. Secondly, it demonstrates an IoT education system integrated into plant care. This pioneering approach utilizes a gamified system that not only enables students to grasp IoT principles but also provides real-time data visualization, fostering a hands-on experience in a familiar and engaging context. The effectiveness of this methodology has been showcased through various outreach activities coordinated by the Donald Danforth Plant Science Center and Saint Louis University located in Saint Louis, MO, underscoring its significant role in nurturing early IoT education. Moreover, as part of these demonstrations, a user-friendly, game-based or activity-based IoT framework has been developed, which can be accessed via the following GitHub link¹.

The rest of this paper is organized as follows: Section II outlines the related work, Section III discusses the proposed IoT education methodology, Section IV presents the results and discussion, and finally, Section V concludes the paper.

¹https://github.com/Shakoor-Lab-Organization/learn_iot

II. RELATED WORK

The literature related to IoT education has witnessed a surge in recent years, with various approaches and methodologies being explored to enhance the learning experience. Several studies have emphasized the significance of project-based, hands-on-based, and application-based learning in IoT education, enabling students to grasp complex concepts more effectively.

Project-based learning methodologies, exemplified by the practical prototyping of IoT devices within a problem-based context, have been advocated in various studies. For instance, in [7], a comprehensive course outline is provided for orchestrating IoT prototyping learning experiences, accompanied by a general assessment framework for university student. Erickson *et al.* [8] introduced a course that offered a comprehensive introduction to IoT topics, software, and hardware, utilizing hands-on projects and affordable hardware kits. Similarly, multiple project-based courses have been tailored to diverse student cohorts, as evidenced in studies like [9] and [10], wherein new course plans were devised to accommodate students with varying technical proficiencies within the same class. Additionally, collaborative student projects, as detailed in [11], have demonstrated the efficacy of fostering teamwork and multidisciplinary skill development. Ferreira *et al.* [12] proposed a teaching methodology grounded in the project-based learning approach, employing a six-layer IoT Open Reference Model that comprehensively covers all aspects of an IoT solution, from sensors to the end-user interface. However, these approaches have been observed to be most suitable for specific subsets of students with pre-existing technical proficiency.

Hands-on teaching methodologies have demonstrated promise in facilitating a deeper understanding of IoT components. For instance, students have successfully developed Wi-Fi-enabled microcontrollers, temperature sensors, and heart rate sensors, as evidenced in [13]. Additionally, laboratory hands-on experiences have proven effective in imparting knowledge about IoT, cloud computing, and blockchain applications to STEM students, as highlighted in [14]. Furthermore, students have gained valuable hands-on experience with embedded systems and IoT during the early stages of their education, exemplified in [15]. Notably, however, most of these educational initiatives have been primarily designed for graduate degree students.

Seng *et al.* [16] incorporated a diverse range of end-consumer quality devices in university-level IoT courses, emphasizing the significance of focusing on both design and validation aspects. They stress the importance of aligning educational approaches with the stringent quality controls and regulations typical of IoT consumer products. Similarly, Khanafer *et al.* [17] proposed an application-driven structure for IoT courses, wherein students initially familiarize themselves with real-world applications before employing various IoT platform components, including sensors, actuators, connectivity technologies, web interfaces, and cloud computing, to implement

these applications. Drawing upon existing literature, we aim to extrapolate insights to propose an IoT education framework tailored for Grade 2 to Grade 12 students.

Efforts have been dedicated to developing customized educational tools and platforms tailored to the unique learning needs of early educators, to foster a strong foundation in IoT principles from an early age. Reviewing the literature highlights the significant potential of a project, an application or a hands-on approach in enriching the IoT learning experience. Building on this, we advocate for increased student engagement through activity or game-based approaches, especially designed for early learners. This paper seeks to enrich this knowledge base by introducing a comprehensive educational framework along with a plant care example for IoT learning, emphasizing the integration of a gamified approach to foster effective and engaging educational experiences.

III. ACTIVITY-AWARE IOT EDUCATION

A. Assumptions

Fundamentals of Computer Science:

In crafting our activities, we assumed prior exposure to basic computer hardware and software components [18, 19]. For example, younger students (Kindergarten to Grade 2) are expected to grasp fundamental concepts such as identifying computer components and using basic software. Older elementary students (Grade 3 to 5) should progress to understanding data input, storage, processing, and output, along with essential knowledge in digital citizenship and privacy. Meanwhile, middle school students (Grade 6 to 8) are assumed to have a more comprehensive understanding of computer applications and hardware, troubleshooting strategies, network technology, and digital responsibility, building upon their earlier foundational knowledge.

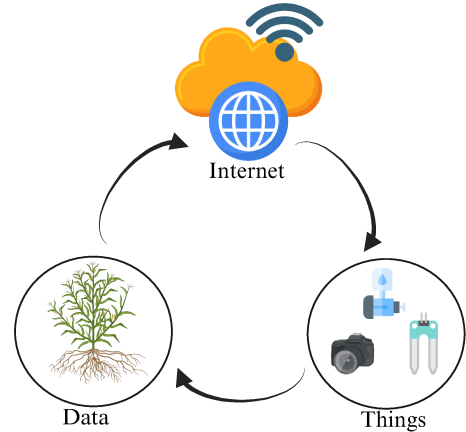


Fig. 1. Core elements of an IoT ecosystem: Internet, Data, and a set of connected things, in this case, related to smart agriculture.

B. The Problem Statement

In the context of the IoT, the Internet serves as the network connecting various computing devices, enabling seamless

communication and data transfer. However, the essence of IoT lies in its ability to interconnect “things” - everyday objects that surround us. These objects, equipped with sensors and connectivity, can collect and exchange data, contributing to a networked environment that enhances automation, efficiency, and data-driven insights.

Our IoT ecosystem assumes the interaction between three fundamental components: Internet connectivity, a few devices with an Internet interface, and Data (Fig. 1). This intersection integrates diverse technologies. Within this framework, everyday objects, or ‘Things,’ are equipped with sensors and actuators, enabling them to sense, act upon, and monitor their surrounding environment. Connectivity solutions, such as Wi-Fi networks, facilitate the transfer of data to and from the Internet, with the option of storing data in the Cloud for hosting various application services (e.g., Smart Agriculture). The architecture of this IoT system, depicted in Fig. 2, is structured into three key layers: Perception, Networking, and Application [20,21]. The Perception layer is composed of sensors, actuators, and cameras, which are collectively known as ‘things’ for sensing and interacting with the environment. These ‘things’ are connected to communication devices, forming the Networking layer, which enables data transmission. The Application layer, on the other hand, implements various IoT applications, utilizing the data gathered from the Perception layer. The sensors transmit data (e.g., soil moisture data) to the Cloud through an Internet gateway. Subsequently, the data is analyzed within the Cloud, and if necessary, actions can be initiated by sending commands to the actuators (e.g., starting a water pump) for specific tasks. Furthermore, the data stored in the Cloud can be leveraged to develop real-time applications such as web-based soil moisture visualization tools.

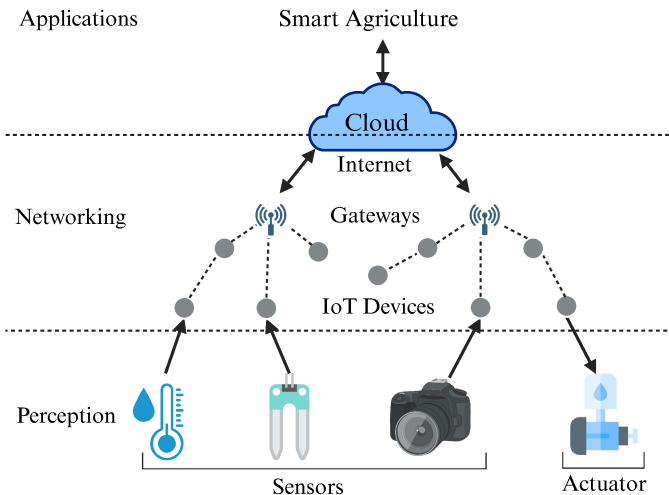


Fig. 2. IoT Architecture

Understanding the fundamental concepts of IoT architecture can be challenging for students, often leading to a multitude of questions regarding the roles and functionalities of various

components such as sensors, actuators, the cloud, connectivity, gateways, and applications within the IoT ecosystem. To address these challenges, our methodology involves the development of engaging learning activities and the strategic mapping of these activities with different components of IoT.

C. Developing Learning Activities

We propose an activity-oriented IoT education system to enhance student engagement. For example, an interactive virtual plant simulation could be designed as a captivating game-like activity through a set of buttons to start a water pump or a dryer. Players would be tasked with earning points by carefully managing the virtual plant’s moisture levels, ensuring it remains within the optimal range for growth. As players progress through increasingly challenging levels, they would face dynamically changing environmental conditions, necessitating quick and strategic decision-making to maintain the plant’s health and vitality. To streamline the learning process, educators can simulate the plant’s growth or utilize various physical components to enhance the interactivity of the game. Ultimately, increasing the number of gameplay activities enhances the robustness of IoT education.

Table I maps various IoT components for an example smart agriculture gameplay. For instance, the action of restarting the game by clicking a button (the gameplay element) necessitates the involvement of connectivity components such as the gateway and network infrastructure (the IoT components). These elements enable the communication and data transmission required to refresh the game and allow players to start again. Through this engaging game, students develop a growing curiosity about each of these components, spurring their desire to learn more about their functionalities and applications.

D. Activity Course Structure

We propose an activity-oriented activity structure to enhance student engagement and understanding. The student’s engagement and understanding of the game or activity can be measured by analyzing their scores and observing if the scores consistently increase. The gameplay should be implemented and discussed in sequence, as presented in Table I. The activities involving IoT components can be structured as follows:

1. **Sensors:** This component serves as the foundation for data collection in IoT systems. Students can explore various types of sensors and their applications [22], understanding their role in collecting data from the environment.

2. **Connectivity:** In this segment, students delve into the intricacies of connectivity and explore different existing solutions. Understanding the various communication protocols and network architectures [23] forms a significant aspect of this module, providing insights into the means through which IoT devices interact and share data.

3. **Actuator:** Students are introduced to the functionalities of actuators in the IoT context. Exploring how these components enable devices to take actions based on the received data

TABLE I
ASSOCIATING IOT COMPONENTS TO AN EXAMPLE SMART AGRICULTURE GAMEPLAY

Gameplay or Activity Elements	IoT Components
Moisture Level Monitoring: The game keeps track of how much water the plant has. It shows this on the screen, so players know when the plant needs water.	Sensor (Soil Moisture Sensor), Connectivity
Watering the Plant: Players can water the plant by clicking a button. If the plant needs water (moisture level below 70), players earn points. If not, they lose points.	Connectivity , Actuator (Water Pump)
Game Goals: The game sets goals for the player. These goals are about keeping the plant's moisture level within specific ranges. When players achieve a goal, they earn points and move to a higher level.	Application Logic and Cloud Data Storage
Points and Level: Players can see their earned points and current level on the screen. Points increase as they achieve goals.	Data Visualization (Application Interface)
Restarting the Game: If players want to play again, they can restart the game by clicking a button. This refreshes the game.	Connectivity (Gateway and Network Infrastructure)

fosters an in-depth understanding of the practical application of IoT principles [24].

4. *Application Logic:* This module focuses on the logic and algorithms that govern the decision-making processes within an IoT system. Students gain insights into the critical thinking and problem-solving skills required to design effective IoT applications.

5. *Cloud Storage:* Understanding the importance of cloud storage in IoT systems is crucial for students. They learn about data storage, retrieval, and analysis, emphasizing the role of the cloud in handling vast amounts of data generated by IoT devices [25, 26].

6. *Gateway:* The gateway section focuses on the role of gateways in IoT, elucidating their function as intermediaries between various devices and the internet, facilitating seamless data transfer and communication.

7. *Visualization:* This module highlights the significance of data visualization in IoT, emphasizing the methods and tools used to represent complex data sets in a user-friendly and comprehensible format.

This structured course enables students to develop a comprehensive understanding of the fundamental components of IoT and their interplay within the broader IoT ecosystem. Each component can be allocated as a dedicated chapter within the course, with the duration tailored to the specific class size and structure.

IV. EVALUATION AND RESULTS

We employed an iterative development process to create a game-based approach for plant care, incorporating a sufficient number of activities that engage students with key IoT components.

A. Prototype Development

Fig. 3 illustrates the deployed prototype for evaluating the proposed activity. Our setup includes two NodeMCU² units, utilized for the sensor and actuator modules. These battery-operated NodeMCU devices are equipped with General Purpose Input/Output (GPIO) ports for connecting external sensors, such as Soil Moisture Sensors, and actuators like

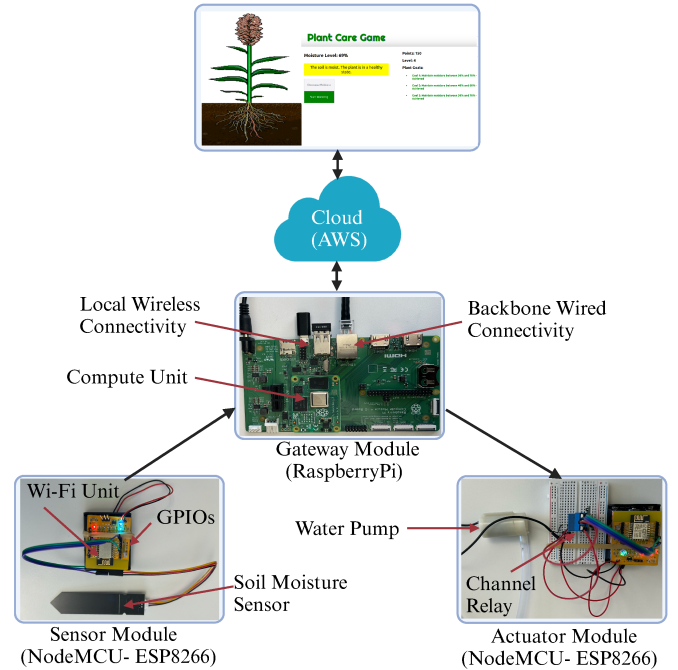


Fig. 3. Deployed prototype for the proposed activity

Water Pumps. They leverage the ESP8266-based Wi-Fi module³ for transmitting and receiving data to and from the cloud. Additionally, the channel relay unit within the actuator module plays a pivotal role in regulating the water pump operation, as it facilitates the control of the pump by appropriately switching between different voltage levels as needed. A Raspberry Pi-based gateway⁴ serves as the communication hub, linking the sensors and actuators to the Internet backbone. It achieves this through a dual-interface system: utilizing Wi-Fi for wireless connections with the sensors and actuators, and Ethernet for a wired connection to the Internet backbone. For the backend, we developed a cloud module using Amazon Web Services (AWS)⁵ to host the game/activity logic. This cloud-based system also supports a visual/control interface, which displays

³<https://www.espressif.com/en/products/socs/esp8266>

⁴<https://www.raspberrypi.com>

⁵<https://aws.amazon.com>

²https://www.nodemcu.com/index_en.html

the plant's growth and includes control buttons, levels, and a scoring system for competition. This interface allows for real-time interaction and feedback, making the activity both engaging and educational.

B. Activity Evaluation

This implementation was showcased at multiple events, hosted by the Donald Danforth Plant Science Center and Saint Louis University in St. Louis, Missouri, USA. At these events, we initiated discussions with simple questions: What are the key factors to consider when caring for plants? How does water intake impact a plant's growth and health? What are common challenges in plant maintenance? How can technology automate plant care? Do you know what IoT is? What role can IoT play in improving plant care and monitoring? While these questions were not part of the main activity, this initial engagement effectively sparked interest and prepared the participants. It helped them understand the context and relevance of IoT in practical applications, thereby setting the stage for a more meaningful and insightful learning experience.

C. Outreach Activities at Danforth Center (Audience: Mixed)

The Danforth Center hosts an annual outreach activity organized by the Education Research and Outreach Lab⁶. Last year, around 400 visitors participated in an event known as PlanTech Jam⁷. In this mixed audience, the concept of IoT was effectively conveyed through the game, even to non-technological individuals. Even children as young as 2-3 years old showed keen interest in playing the game and were curious to learn about the effects of watering on the plant pots. Despite the limited time, the students displayed a strong eagerness to learn more about IoT.

D. Outreach Activities at Saint Louis University (Audience: Grade 2)

We demonstrated the same game to Grade 2 students at Saint Louis University's iSCORE campaign⁸. In a group of approximately 10 students, we observed that the students quickly became familiar with the game. They enjoyed interacting with the buttons, watering the plant, and checking their scores. The physical presence of sensors, actuators, processing devices, and visualizations helped the students relate these components to their basic understanding of IoT.

E. Outreach Activities at Saint Louis University (Audience: Grade 4)

During another iSCORE camp session, we conducted an engaging demonstration of the game for a group of ten enthusiastic Grade 4 students. Already well-versed in plant care requirements, the students eagerly observed the real-time response of plant growth to varying soil moisture levels and actively controlled the water pump using the interactive

buttons. The interactive demonstration piqued their curiosity, prompting numerous inquiries about the underlying mechanisms. With their existing familiarity with coding, the students quickly grasped the intricacies of application logic and data flow within the IoT system.

F. Discussion and Future Implications

Interpretation of the Results and their Implications for IoT Education: The comprehensive evaluation of the activity-based IoT education approach yields promising results that highlight its suitability and effectiveness in diverse educational settings. By fostering active student participation and providing an immersive learning experience, this approach has the potential to bridge the gap in IoT education. Analyzing the results in the context of curriculum development and pedagogical strategies reveals its transformative potential in enhancing student engagement and understanding of complex technological concepts. The successful implementation of activity-based IoT learning approaches not only addresses educational disparities but also contributes to the cultivation of a technologically proficient and critically aware student populace, capable of navigating the intricacies of the evolving IoT landscape.

Future Implications and Considerations: Moving forward, careful consideration must be given to various factors such as multiple IoT applications, different audience demographics, varying class sizes, diverse populations, and the incorporation of iterative feedback. As we look to the future of activity-based IoT education, it's crucial to develop a robust and flexible framework that effectively adapts to the varying needs across different educational settings. This framework should specifically cater to the diverse learning requirements of students in Grades 2 through 12, modeling activities to align with their cognitive and skill levels. Moreover, conducting multiple iterations of the activity-based approach in various educational settings can provide valuable insights into the customization and optimization of the methodology for different learning environments. These future implications aim to create an inclusive and comprehensive IoT education model that caters to the diverse learning needs and requirements of students across different educational institutions.

Limitations and Challenges: The implementation of activity-based IoT learning approaches, while transformative, encounters several challenges that need careful consideration. These include technological constraints, such as ensuring access to necessary hardware, software, and reliable Internet connectivity, which are essential for a diverse range of student skill levels. Integrating these IoT activities into existing curricula poses another challenge, requiring alignment with educational standards and a balance between the curriculum's learning objectives and the technological complexity of IoT. Furthermore, the rapid evolution of IoT technologies demands a dynamic and adaptable curriculum that stays abreast of the latest advancements and industry trends. Addressing these challenges, particularly ensuring consistent and high-quality Internet access in areas with limited infrastructure, is critical

⁶<https://www.danforthcenter.org/our-work/education-outreach/>

⁷<https://www.danforthcenter.org/event/planttech-jam-2023/>

⁸<https://www.slu.edu/education/institutes/iscore/>

for the sustained effectiveness and relevance of activity-based IoT education in modern educational contexts.

V. CONCLUSION

This paper presented an activity-based IoT education approach - a paradigm that fosters engaging and immersive learning experiences for students. By leveraging gamification and interactive methodologies, this approach effectively bridges the gap in IoT education, empowering students with the necessary skills and knowledge to navigate the complexities of the digital landscape. The successful implementation of this approach not only cultivates a technologically proficient student populace but also instills critical thinking and problem-solving abilities vital for the evolving IoT domain. Despite the challenges posed by technological constraints and curriculum integration, the continual refinement and adaptation of this approach holds the key to unlocking a comprehensive and inclusive IoT education framework. As the realm of IoT continues to evolve, the significance of innovative educational strategies remains paramount in preparing students for the challenges and opportunities of the digital future.

ACKNOWLEDGMENTS

The authors wish to extend their sincere appreciation to Sandra Arango-Caro, Senior Education Researcher and Program Manager at the Donald Danforth Plant Science Center, for providing critical feedback to this paper.

REFERENCES

- [1] M. S. Ali, M. Vecchio, M. Pincheira, K. Dolui, F. Antonelli, and M. H. Rehmani, "Applications of blockchains in the internet of things: A comprehensive survey," *IEEE Communications Surveys & Tutorials*, vol. 21, no. 2, pp. 1676–1717, 2018.
- [2] N. Ahmad, P. Laplante, and J. F. DeFranco, "Life, iot, and the pursuit of happiness," *IT Professional*, vol. 22, no. 6, pp. 4–7, 2020.
- [3] O. Vermesan and P. Friess, *Digitising the Industry Internet of Things Connecting the Physical, Digital and Virtual Worlds*. CRC Press, 2022.
- [4] O. Vermesan and P. Friess, *Internet of things: converging technologies for smart environments and integrated ecosystems*. River publishers, 2013.
- [5] M. Díaz, C. Martín, and B. Rubio, "State-of-the-art, challenges, and open issues in the integration of internet of things and cloud computing," *Journal of Network and Computer applications*, vol. 67, pp. 99–117, 2016.
- [6] A. Taivalsaari and T. Mikkonen, "A roadmap to the programmable world: software challenges in the iot era," *IEEE software*, vol. 34, no. 1, pp. 72–80, 2017.
- [7] H. Maenpää, S. Varjonen, A. Hellas, S. Tarkoma, and T. Mannisto, "Assessing iot projects in university education - a framework for problem-based learning," in *2017 IEEE/ACM 39th International Conference on Software Engineering: Software Engineering Education and Training Track (ICSE-SEET)*, pp. 37–46, 2017.
- [8] V. L. Erickson, P. Varshney, and L. Ertaul, "A project-based approach to teaching iot," in *Advances in Software Engineering, Education, and e-Learning: Proceedings from FECS'20, FCS'20, SERP'20, and EEE'20*, pp. 195–216, Springer, 2021.
- [9] H. Mäenpää, S. Tarkoma, S. Varjonen, and A. Vihavainen, "Blending problem-and project-based learning in internet of things education: Case greenhouse maintenance," in *Proceedings of the 46th ACM technical symposium on computer science education*, pp. 398–403, 2015.
- [10] P. Netinant, P. Narad, and M. Rukhiran, "A case study of project-based learning on internet of things course," in *Proceedings of the 7th International Conference on Frontiers of Educational Technologies*, pp. 126–131, 2021.
- [11] S. Trilles, A. Monfort-Muriach, Á. Gómez-Cambronero, and C. Granell, "Sucre4stem: collaborative projects based on iot devices for students in secondary and pre-university education," *IEEE Revista Iberoamericana de Tecnologías del Aprendizaje*, vol. 17, no. 2, pp. 150–159, 2022.
- [12] L. C. B. C. Ferreira, O. C. Branquinho, P. R. Chaves, P. Cardieri, F. Fruett, and M. D. Yacoub, "A pbl-based methodology for iot teaching," *IEEE Communications Magazine*, vol. 57, no. 11, pp. 20–26, 2019.
- [13] S. A. Frimpong, A. O. Salau, A. Quansah, I. Hanson, R. Abubakar, and V. Yeboah, "Innovative iot-based wristlet for early covid-19 detection and monitoring among students," *Mathematical Modelling of Engineering Problems*, vol. 9, no. 6, 2022.
- [14] A. R. Rao and R. Dave, "Developing hands-on laboratory exercises for teaching stem students the internet-of-things, cloud computing and blockchain applications," in *2019 IEEE Integrated STEM Education Conference (ISEC)*, pp. 191–198, IEEE, 2019.
- [15] J. P. Jones, "A hands-on introduction to embedded systems & iot," in *2020 ASEE Virtual Annual Conference Content Access*, 2020.
- [16] L. G. Seng, K. L. K. Wei, and S. J. Narciso, "Effective industry ready iot applied courseware-teaching iot design and validation," in *2020 IEEE Global Engineering Education Conference (EDUCON)*, pp. 1579–1583, IEEE, 2020.
- [17] M. Khanafer and T. M. Jois, "Towards application-driven iot education," in *2023 IEEE Global Engineering Education Conference (EDUCON)*, pp. 1–7, IEEE, 2023.
- [18] ed.gov, "Guiding principles for use of technology with early learners." <https://tech.ed.gov/earlylearning/principles/>, 2024. Accessed: 2024-01-18.
- [19] Learning.com, "What are computer fundamentals & why are they important?." <https://www.learning.com/blog/why-do-students-need-to-study-computer-fundamentals-programming/>, 2024. Accessed: 2024-01-18.
- [20] A. Al-Fuqaha, M. Guizani, M. Mohammadi, M. Aledhari, and M. Ayyash, "Internet of things: A survey on enabling technologies, protocols, and applications," *IEEE communications surveys & tutorials*, vol. 17, no. 4, pp. 2347–2376, 2015.
- [21] Z. Yang, Y. Yue, Y. Yang, Y. Peng, X. Wang, and W. Liu, "Study and application on the architecture and key technologies for iot," in *2011 International Conference on Multimedia Technology*, pp. 747–751, IEEE, 2011.
- [22] F. K. Shaikh, S. Karim, S. Zeadally, and J. Nebhen, "Recent trends in internet-of-things-enabled sensor technologies for smart agriculture," *IEEE Internet of Things Journal*, vol. 9, no. 23, pp. 23583–23598, 2022.
- [23] F. Javed, M. K. Afzal, M. Sharif, and B.-S. Kim, "Internet of things (iot) operating systems support, networking technologies, applications, and challenges: A comparative review," *IEEE Communications Surveys & Tutorials*, vol. 20, no. 3, pp. 2062–2100, 2018.
- [24] A. Rayes and S. Salam, "The things in iot: Sensors and actuators," in *Internet of Things From Hype to Reality: The Road to Digitization*, pp. 63–82, Springer, 2022.
- [25] P. P. Ray, "A survey of iot cloud platforms," *Future Computing and Informatics Journal*, vol. 1, no. 1-2, pp. 35–46, 2016.
- [26] A. Khatib, A. Abdelgawad, and K. Yelmarthi, "Design and implementation of a cloud-based iot scheme for precision agriculture," in *2016 28th International Conference on Microelectronics (ICM)*, pp. 201–204, IEEE, 2016.