Operational Research in Engineering Sciences: Theory and Applications
Vol. 6, Issue 1, 2023, pp. 668-687
ISSN: 2620-1607
eISSN: 2620-1747
DOI: https://doi.org/10.31181/oresta/0601132

NEW AGE ROBOTICS: IMPLICATIONS FOR A BLOCKCHAIN-INTEGRATED PROTOTYPE FOR EDUCATION

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Received: 17 January 2023
Accepted: 26 March 2023
First Online: 15 April 2023

Research Paper

Abstract: *In the 21st century, the rapid expansion of automated robots and intelligent devices in industries such as manufacturing, production, healthcare, and education ushered in the era of digital informatics. However, the emergence of a new era of robotics has presented significant security challenges in the supply chain of manufacturers, users, and data exchange between these smart devices, making them attractive targets for cybercriminals. This paper proposes the development of a new-age robotics prototype and a conceptual three-level framework for robotics prototypes by integrating blockchain technology with the robot order, ownership, and robot-to-robot communication processes. The objective was to provide a model for the safe development and use of robots with secure access to internal data with educational implications. The researchers adapted a prefabricated robot prototype for the ESP32 family of microcontroller boards and Raspberry Pi Pico as the receiver to accomplish this. Due to the large number of pins, the ESP32 board was used for the values from the primary sensors, while the Raspberry Pi Pico board was used for components that required precision and stable operation. Using an encryption mechanism with a hash function in conjunction with uploading the command set from the factory to the robot, the robotics prototype of the twenty-first century was able to secure instructions and data effectively. This also encrypted the owner's command set, including encrypted robot-to-robot communication, and divided the operation into three parts, making it simple to update the robot with new information. This mechanism could be combined with a language for creating Internet of Things (IoT) devices, such as MicroPython. The robotics prototype was implemented in education through the testing and evaluation a pilot prototype by students, who reported high levels of satisfaction, improved academic performance, and acquired artificial intelligence (AI) skills. Lastly, the robotics prototype could serve as a*

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blueprint for future innovation-generating research.

Keywords: *Robotics; blockchain; prototype; artificial intelligent; supply chain, industry 4.0, cybercriminals; educational.*

1. Introduction

Technology and innovation advancements have ushered in a new digital transformation era, which has altered how people live and work and increased productivity in sectors including business, Industry 4.0, and education (Suanpang et al., 2022a; Suanpang et al., 2022b). The robot, which has evolved from human-like mechanical structures to virtual artificial intelligence (AI) technology, is the most widely used technology in this disruptive world (Li et al., 2019). Numerous technologies, including AI, sensors, automation, speech recognition, control, visualization, and data analysis, have been incorporated into the development of robots (ibid). Robots can be classified into different types based on their applications: industrial, service, military, space, surgical, and micro (Li et al., 2019; Suanpang et al., 2022c). As technology advances, robotic automation systems and unmanned vehicles will be continuously developed to increase their efficiency, accuracy, and cost-effectiveness, as evidenced by vacuuming robots, patient-monitoring robots, food-serving robots, and smart electric vehicles from a variety of companies with a growing user base (Li et al., 2019; Suanpang et al., 2022d). Robots are increasingly being recognized as valuable tools for education worldwide (Alnajjar et al., 2021; Chou et al., 2023). Robotics education is a prevalent teaching method in science, technology, engineering, and mathematics (STEM) for students from K-12 to university levels (Chen et al., 2022; Suanpang & Jamjuntr, 2021). Robots in education are also emerging, consequently offering new opportunities for curriculum development, learner motivation, and skills and competency development (Módné Takács, Pogátsnik, & Kersánszki, 2021). Robots in education have numerous advantages when implemented in innovative educational methods. Furthermore, studies have shown that robots offer a functional and enjoyable environment that responds to the curiosity of the students (Anwar et al., 2019; Li et al., 2019; Ueyama et al., 2022). Additionally, educational robots provide a learning environment that encourages student interest and engagement through physical and user interfaces (Chou et al., 2023; Li et al., 2019; Suanpang, Pothipasa, & Netwrong, 2021). Several studies about the use of educational robots in schools (Li et al., 2019; Suanpang et al., 2022b; Suanpang et al., 2021) have found that (1) robots improve the level of engagement and motivation, as they provide a novel and interactive learning experience, (2) robots enhance the learning outcomes, especially in areas of programming, engineering, and STEP education, (3) robots increase accessibility for disabled students, (4) robots improve the learning interactions between students and teachers by providing shared learning experiences, and (5) robots are flexible and adaptable, thus allowing customization to fit the learning environment.

However, robots have several barriers that must be addressed to maximize their effectiveness. These include (1) technical difficulties due to the complexity of programming and operating robots, which requires specialized knowledge and skills that may not be readily available to all educators, (2) the expense of purchasing and maintaining robots, (3) the limited functionality of robots compared to humans, (4) ethical concerns surrounding privacy, data security, and the impact on human employment, and (5) the lack of standardization (Chou et al., 2023; Li et al., 2019).

Blockchain technology has recently transformed numerous industries, including the robotics sector (Alsamhi et al., 2021; Suanpang et al., 2021). Several industries, such as finance, supply chain, healthcare, and education, could utilize blockchain because it decentralizes data to other parties in network systems (Afari & Khine, 2017; Souza et al., 2018; Zhang et al., 2021). With the advent of blockchain, robot operations have become more efficient, secure, and transparent. The decentralized and immutable nature of blockchain would enable robots to perform tasks without relying on a central authority or human intervention, creating a plethora of opportunities for robots in various fields, such as manufacturing, healthcare, logistics, and education (Afari & Khine, 2017; Almendingen et al., 2021; Zhong & Xia, 2020). One significant advantage of using blockchain in robots would be increased data transmission and storage security. Robots can store sensitive data on the blockchain, such as a patient's information or confidential trade matters, ensuring that the data is secure and only accessible by authorized parties. This would make robots more trustworthy and reliable in their operations, improving productivity and efficiency (Souza et al., 2018; Zhong & Xia, 2020). Additionally, blockchain could facilitate peer-to-peer transactions, allowing robots to perform tasks and interact with other robots, humans, and machines without intermediaries. In addition, smart contracts, self-executing contracts on the blockchain, could be programmed to execute transactions automatically based on predefined conditions. This would allow robots to perform complex tasks, such as supply chain management, with minimal human intervention (Aithal, Aithal, & Dias, 2021; Souza et al., 2018).

However, research on integrating blockchain technology with robots is still in its infancy, and more studies are required to fully comprehend the benefits of this integration for enhancing work efficiency. In addition, implementing this technology would be complicated by limited resources, a lack of technical expertise, and cultural resistance (Alsamhi et al., 2021; Souza et al., 2018). As a result, the emergence of advanced robotics technologies has provided educational institutions with new opportunities to enhance the learning experience and improve student outcomes. However, implementing robotics in education would need to address concerns regarding security and privacy, particularly in an era where cybersecurity threats are becoming increasingly sophisticated.

While the use of robots in education in Thailand, a developing country, is still in its infancy, there is a growing interest in their potential to improve teaching and learning in STEM and other fields, including university teaching, language instruction, science education, and distance learning (Li et al., 2019; Souza et al., 2018; Spolaôr & Benitti, 2017). Upon examining the context of using robots in education in Thailand, it was discovered that integrating robotics into teaching programs was still in its emerging stages. Nonetheless, some universities have taken notable steps toward integrating robotics into their teaching programs in higher education (Bangkok Post, 2021). Simultaneously, other universities in the country, such as Sisaket Rajabhat University in the Northeastern region of Thailand, have begun to incorporate the development of a new type of robot into their curriculum. The province has actively promoted robotics in education, particularly in science and technology classes. Several schools in the province of Sisaket have already implemented robots into their classrooms, allowing students to gain practical experience in coding, programming, and problem-solving. However, in Sisaket province, the use of robot technology in secondary and higher education is still limited due to the lack of a flexible, easy-to-modify, and age-appropriate robot kit that is readily available. Hence, it would be important for universities in Thailand to carefully consider these potential problems and limitations before incorporating robots into their curricula. By doing so, they could maximize the benefits of using robots in education while minimizing any potential negative impacts. Universities should also consider investing in technical expertise, research, and development to help address some of these challenges and overcome potential obstacles to the implementation of robots in education (Miller & Nourbakhsh, 2016; Engelseth, et al., 2021)

Concerning the problems and challenges of designing and developing the implications for new-age robotics for education, it was discovered that these supported basic operations, such as moving forward, turning left, and turning right. However, it was not easy to adjust the instruction set, and it was not designed to maintain appropriate robotic assembly data, which should be advanced in transferring robotics knowledge to young people. Moreover, the domestic use of robots is increasing, making data within robots and networks for robots and automation a new cybercriminal target(Conti, et al., 2017; Rossi, et al.,2020; Yang, et al.,2018; Crowe, 2018). Table 1 illustrates the problems of traditional robots and the challenges of developing new-age robots.

Table 1: Problems of traditional robots and the challenges of developing new-age robots.

Problems	Challenges
1. The operation of the robot uses a set of instructions from the manufacturer's factory.	1. Developers and users can add commands suitable for their work.
2. The design does not consider the security of the data stored in the robot.	2. Remembering the data security of the robot and the user.
3. Difficult to modify the instruction set.	3. Easy to change and modify the instruction set.
4. Developed under closed technology.	4. Developed using open technology that allows developers to build on their capabilities.

This paper aimed to design, develop, and use a new-age robotics prototype that would integrate the implications of blockchain technology for a case study on education in Thailand. This paper utilized a safe and secure robot by applying blockchain technology to the system, which divided access to the robot's data and commands into three levels via the uploading and writing commands and data. In the blockchain, the MicroPython programming language was encrypted using hash functions. Using web browsers, the HTTP and HTTPS protocols enabled communication between users at each level.

2. Related Work

The research team researched the following issues to obtain a prototype of a new-age robotic design.

2.1 Robotics

The robot is an innovation that originated in 1928 with the humanoid robot (Chiazzese et al., 2019). Since then, the term "robot" has been extended to include mechanical or virtual AI collections (Chiazzese et al., 2019; Li et al., 2019). A robot's physical components comprise numerous high technologies, such as AI, sensors, automation, speech recognition, control, visualization, and data analysis. AI is the core technology that enables robots to make intelligent judgments and decisions and interact with humans. Robots can be categorized into various types, including industrial robots, military robots, space robots, service robots, mimetic robots, surgical robots, underwater robots, and micro-robots (Kanda & Ishiguro, 2013) (Chiazzese et al., 2019; Li et al., 2019). The use of robots is expanding from industrial research and applications to education. In particular, classrooms use robots as effective tools to enhance students' practical thinking and innovative abilities and assist in teaching and educational activities. Table 2 illustrates the applications of robots in education (Li et al., 2019).

Table 2: Robots in education (Li et al., 2019)

Type of Robot	Definition	Feature
Subject Instruction	Teaching skills and knowledge are based on the subject in the curriculum.	The robot's design is based on the curriculum.
Assisted Instruction	Robots are used as the teacher to assist in teaching and learning.	Robots are used as a tool for improving the learning environment.
Managed Instruction	Robots are used for conducting and managing education activities.	Robots are used as learning resources by teachers.
Represented Routine	Robots are used for teaching and learning as routine work.	Robots can reduce the teaching workload related to routine work for the teacher.
Directed Instruction	Robots are used for implementing instruction activities.	Robots can help in teaching and doing automated work in the classroom.

From Table 2, the classification of a robot for education is as follows (Li et al., 2019): (1) Subject instruction: The design is based on the curriculum and requires master knowledge of the professional systems. (2) Assisted instruction is the most common robot to assist the teacher in teaching and learning. (3) Managed Instruction: A robot is used for conducting and managing learning activities. (4) Represented Routine: A robot is used for teaching and learning as routine work.(5) Directed Instruction: A robot implements instruction activities.

2.2 The Application of Robots in Education

Since the late 1990s, a growing trend of integrating robotics into education has been growing. Initially, educational robots were designed to teach coding and programming to students, but their scope has since expanded to cover various subjects and levels of education, including primary, secondary, and tertiary education. One significant advantage of using robots in education is the potential for personalized learning. Robots can adapt to individual learning styles, provide tailored feedback, and support each student. Kanda and Ishiguro (2013) conducted a study where a humanoid robot was used to teach mathematics to elementary school students. The robot adjusted to each student's level of understanding and provided appropriate feedback, resulting in improved learning outcomes.

Furthermore, robots can provide students with hands-on experience, allowing them to explore complex concepts and develop practical skills. Likewise, Belpaeme et al. (2018) conducted a study using a robot to teach students about renewable energy. The robot acted as a virtual laboratory enabling students to conduct experiments and explore different scenarios in a safe and controlled environment. Additionally, robots can engage students in ways that traditional teaching methods may not be able to achieve. According to Mubin et al. (2013), a robot teacher was more engaging and motivating than a human teacher, which resulted in increased student participation and improved learning outcomes.

2.3 Robots Designed for Supporting Education

Depending on their intended application and intended audience, the design of educational robots may vary. Figure 1 illustrates common design characteristics (Huang et al., 2021):

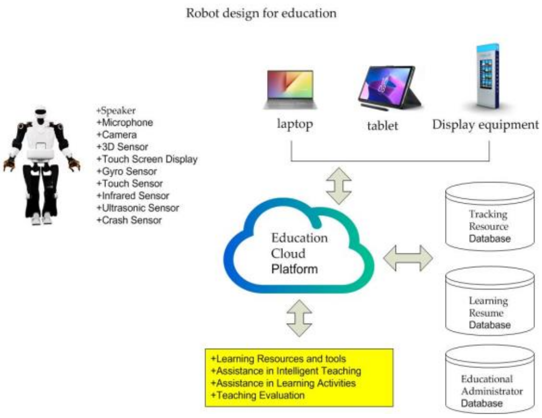

Figure 1. Robots designed for education (Huang et al., 2021; Li et al., 2019).

Physical appearance: The robot's appearance could impact students' engagement and perception of the technology. For example, a humanoid robot could be more relatable and approachable to students than a non-humanoid robot.

Sensors and actuators: The robot's sensors and actuators could dictate its tasks. For instance, a robot teaching music could have sensors that detect and respond to sound.

Programming and control: The robot's programming and control system could determine students' interaction and customization options. For instance, a robot designed for teaching coding could have an interface for visual programming that would make it simple for students to create and modify code (Huang et al., 2021).

The design characteristics of educational robots may have a substantial impact on learning outcomes. According to research, robots with personalized and adaptable capabilities could enhance student engagement and learning outcomes. For example, Huang et al. (2021) discovered that a robot that could adapt to each student's learning style and pace produced better learning outcomes than a robot with a fixed curriculum.

Similarly, Zhang et al. (2018) discovered that an emotional recognition-capable robot improved students' emotional regulation and learning outcomes. In addition, the design features of educational robots may influence the growth of soft skills, such as collaboration and communication. Additionally, Tian and Oviatt (2021) discovered that a robot to facilitate group problem-solving activities enhanced students' collaborative and problem-solving skills.

2.4 Data Security in a Robotic System

Ensuring data security in robotic systems, automation, unmanned vehicles, and robot-to-robot communication is a difficult task that requires increasing the autonomy of these systems. As industries transition to Industry 4.0, conventional factories will become smart factories with interconnected machines and human and robot collaboration. These new technologies would enable flexible production and higher levels of automation, but they would also increase the need for system safety and security. Given the potential for harm to humans in collaborative scenarios involving robots, it would be prudent to increase understanding of cybersecurity and its relationship to system security (Zhong & Xia, 2020).

In addition, Hollerer et al. (2021) provided a safety evaluation for a particular collaborative robot by identifying potential attack surfaces and vulnerabilities that could compromise the operators' security. Franka Emika Panda's defined attack surfaces were subjected to a penetration test based on the Open-Source Security Testing Methodology (OSSTM) and the Open Worldwide Application Security Project (OWASP) testing guide. Several vulnerabilities that could potentially compromise the operator's security were discovered. Consequently, countermeasures were implemented for each finding to prevent potential cyber-attacks (Figure 2).

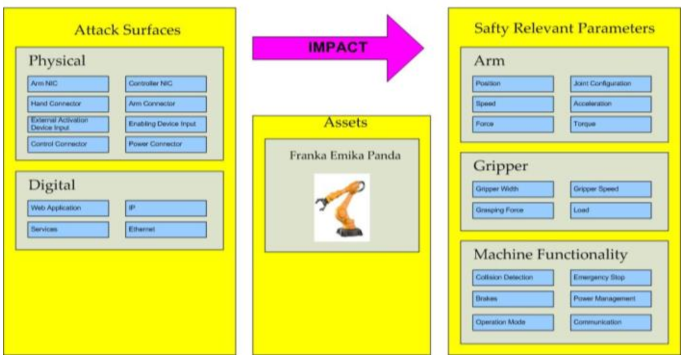

Figure 2. An overview of the different types of attacks and effects in the example of Franka Emika Panda (Hollerer et al., 2021).

2.5 MicroPython for the Development of Robots

MicroPython is a microcontroller-optimized, lightweight version of the Python programming language, making it an ideal language for developing educational robots (Kolberg, Reich, & Levin, 2014). Moreover, there are several benefits associated with using MicroPython in developing educational robots, including its simple syntax, fast development cycle, high-level programming interface, and large community of developers who provide support and resources (Kolberg et al., 2014; Tsui et al., 2009). MicroPython has been used in various educational robots, such as robotic kits, sensor-based robots, and control systems, allowing students to learn about control theory and systems design.

Likewise, Villoro et al. (2021) aimed to find a language that could be used for computers and Internet-of-Things (IoT) devices. According to their literature review, Python and MicroPython satisfied their requirements. Consequently, they presented TDR-Wi-Fi, a wireless, portable, and inexpensive interface, to detect by connecting a TDR cable tester to a TDR-Wi-Fi smartphone containing a microprocessor equipped with a Wi-Fi microcontroller (M5Stack unit) and connecting it to the TDR device via an RS232-TTL adapter. The M5stack firmware was written in the programming language MicroPython and acted as a server between the user and the TDR device via a web page accessible via the web browser on a smartphone. The system was successfully demonstrated in laboratory and field tests, enabling water content measurement on roads with steep slopes. TDR-Wi-Fi is practical and effective in remote locations.

2.6 Raspberry Pi 3B for the Development of Robots

Raspberry Pi 3B is a powerful single-board computer that can be used for various applications, including robot development (Figure 3).

Figure 3. Raspberry Pi 3B.

Raspberry Pi is a popular, low-cost computer often used in various applications, including robotics. The latest version, Raspberry Pi 3B, has a 1.2 GHz 64-bit quad-core ARM Cortex-A53 CPU, 1GB RAM, Bluetooth, and Wi-Fi connectivity, making it an ideal platform for developing robots. Researchers have utilized Raspberry Pi in various robotic development projects. For instance, Ali, et al., (2019) used a telepresence robot controlled remotely via a web interface and developed using Raspberry Pi. The robot was fitted with a camera and a microphone, which enabled it to stream live video and audio to the operator.

Additionally, Rzayev and Aghaei (2022) utilized Raspberry Pi to develop a robotic arm controlled by a mobile application. The robotic arm was capable of accurately picking up and placing objects. Apart from research purposes, Raspberry Pi has also been widely used in education, with many educational robotics kits, such as the GoPiGo and the BrickPi, based on it. These kits have provided an easy-to-use platform for students to learn about robotics and programming. In summary, Raspberry Pi's small size, low power consumption, and connectivity options make it a versatile and affordable platform for research and education in robotics.

2.7. Blockchain Integration for the Development of Robots

Integrating blockchain technology into educational robots could provide a secure and transparent method for storing and sharing data, thereby addressing the issues of data security and transparency (Rzayev & Aghaei, 2022). Following are the benefits of integrating blockchain technology into educational robots: First, it would provide a secure and protected method of data storage that would protect sensitive student data from cyberattacks and unauthorized access. Second, the decentralized nature of blockchain technology would encourage data-sharing transparency, thereby fostering trust between educators and students. Thirdly, using smart contracts on a blockchain could automate certain tasks and processes, such as grading and record-keeping, thereby improving efficiency and reducing educators' workload. By providing an immutable record of academic achievements and credentials, blockchain technology could ensure accountability within the educational system.

Moreover, Aithal et al. (2021) discussed the main requirements and technical challenges faced by robots and explored the potential of blockchain technology for solving these issues. The article provided a tutorial overview of blockchain technology and its role in various use cases for robotics. It also highlighted the technical challenges that must be addressed to exploit blockchain's potential for robotics fully. Additionally, the scope of robotics has expanded in recent years, and blockchain technology has been identified as a promising solution for addressing issues such as identifying malicious nodes, malfunctions/errors in automated processes, failure to comply with agreed privacy norms and rules, security attacks, and lack of transparency in monitoring and auditing performance. With features like decentralization, irreplaceability, low operating costs, strict access control, and reliable operation, blockchain technology could significantly improve new applications and use cases powered by robots (Gräther et al., 2018; Grech & Camilleri, 2017).

3. Materials and Methods

The researchers followed the steps below to obtain a prototype of a next-generation robotic system that adds blockchain modules to enhance user security.

3.1. Concept of a Robotics Design

To create a flexible and adaptable system, researchers divided the new robot system's functionality into three tiers (Figure 4). The first tier included the robot's manufacturer, the second tier included the robot's owner, and the third tier facilitated communication between the robots. Figure 4 illustrates the system architecture of an educational robot incorporating blockchain technology. This included:

3.1 Hardware and software design

The research extensively used the ESP32 microcontroller board, the Raspberry Pi 3B, and the Raspberry Pi Pico as the central processing, communication, and sensor interface units, respectively. This research made use of MicroPython and TensorFlow Lite as its software. MicroPython was utilized on the ESP32 board and Raspberry Pi Pico, whereas TensorFlow Lite was used on the Raspberry Pi 3B.

3.2 Physical robot design

The physical design of the robot was separated into the head, torso, arms, and legs, with each movement being executed by a MicroPython microcontroller board.

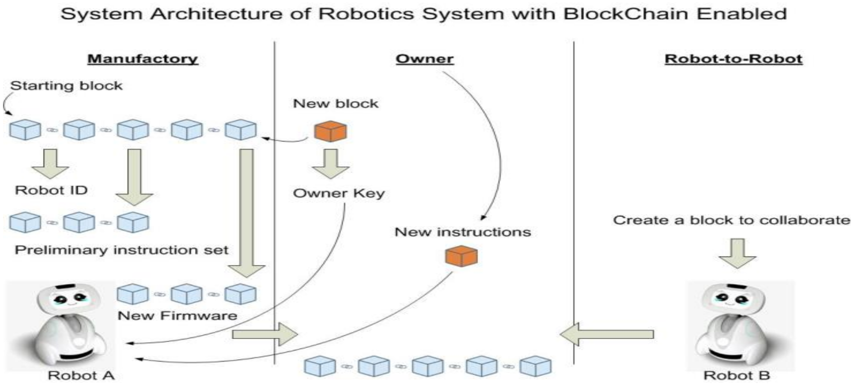

Figure 4. Systems architecture of an educational robot that integrated blockchain technology.

3.3 Development of a Robot

Researchers designed a three-tier architecture for the robot's operations to create a robot that could receive instructions and firmware updates from any Internet-connected location worldwide. The structure was composed of:

(1) *Manufacturer tier:* This uploaded a basic set of instructions to the robot, as well as firmware when bugs were discovered in factory-made robots or when the basic commands needed to be modified to meet the user group's needs. By ensuring data security at the factory level, robot ownership and data exchange between robots were protected. For the manufacturer-level command set, the process began with examining the robot's peripherals, such as its head, arms, legs, and various sensors. This component would function similarly to the BIOS on a computer motherboard. However, receiving the command from the factory over the Internet to the robot was accomplished via a module that acted as an HTTP server and supported uploading the command files and firmware from the factory's operator to the robot before instructing it to reboot itself to load the most recent boot.py command set.

(2) *User tier:* For the user's instruction set, the user could write block-based coding instructions and export them to the MicroPython language before uploading the code via a web form to the robot's address. From generating the blocks of code to uploading the instructions to the robot, the process would be recorded as a block in the blockchain system to ensure ownership.

(3) *Robot-to-robot tier:* Before exchanging data, both robots must verify the hash representing the robot owner's number, instructions, and job status. Before exchanging data, additional robots would perform additional or subsequent tasks to those completed by the initial robot.

3.4 Implications and Evaluation of Robots in Education

3.5 Implications of a Robotic Prototype in Education

The robot was implicated and used for teaching and learning in the pilot project (Figure 5).

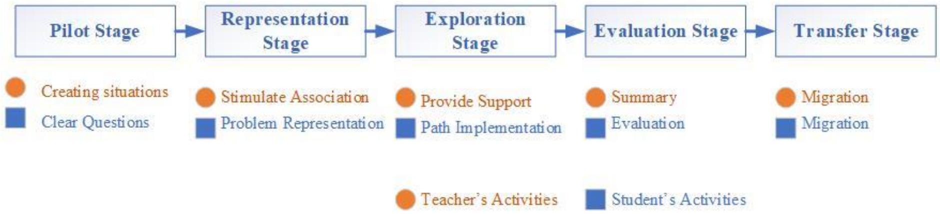

Figure 5. Robots in teaching and learning in the pilot project (Budiharto, Cahyani, & Rumondor, 2017).

As depicted in Figure 5, the teaching process consists of five stages: the pilot stage, the presentation stage, the exploration stage, the evaluation stage, and the transfer stage (Budiharto et al., 2017). Each phase included specific teacher and student activities. The teacher's activities included creating a project-related situation, guiding students to develop a general understanding of the robot-building project, providing learning support, and concluding with a summary and additional ideas for students. Under the teacher's guidance, the students were expected to identify the problem, represent it, implement a solution, and present and evaluate it in groups.

3.6 Evaluation of the Robot

As the prototype to be tested at Sisaket Rajabhat University, Sisaket Province, Thailand, this implication was enabled by the design of a new-age robotics prototype with blockchain. This location was chosen for the experiment because it was a university that had developed a comprehensive robotics system to aid teaching and learning at all levels of education, from elementary school to university. Students were allowed to develop various robotic innovations, including robots for reducing production time in small factories and for agriculture, among others. To evaluate the performance of these robots, the research team chose to conduct experiments with a group of 30 students using these robots.

1) *Research design*: The data were collected and analyzed using a combination of methods. Students' pre-and post-test scores were used alongside surveys to collect quantitative data.
2) *Participants*: The study included a teacher and 30 students from different levels of education who had used robots for conducting a project.
3) The questionnaire to evaluate the robot comprised three sections. The first section had five closed questions (gender, age, etc.) related to the sample demographics.

The second section of the questionnaire about evaluating the system consisted of 10 questions (functionality, design, system simplicity, and learning activity). The third satisfaction section had three closed questions (satisfaction and overall). The questions used a five-point Likert scale ranging from 5 = strongly agree, 4 = agree, 3 = moderate, 2 = disagree, and 1 = strongly disagree. The data were analyzed using SPSS for descriptive statistics.

4) *Data analysis*: The quantitative data were analyzed using descriptive and inferential statistics, whereas the qualitative data were analyzed using thematic analysis.

4. Results

4.1 New Age Robotic Prototype Enabled with Blockchain

The research had two main components: a hardware prototype of the robot, a set of commands, and a user interface that could be accessed through a web browser and connected to the robot. The prototype (Figure 6) was based on a small robot chassis initially designed for the Arduino UNO board. However, the prototype was modified by incorporating an ESP32 board and a more advanced and precise Raspberry Pi Pico board.

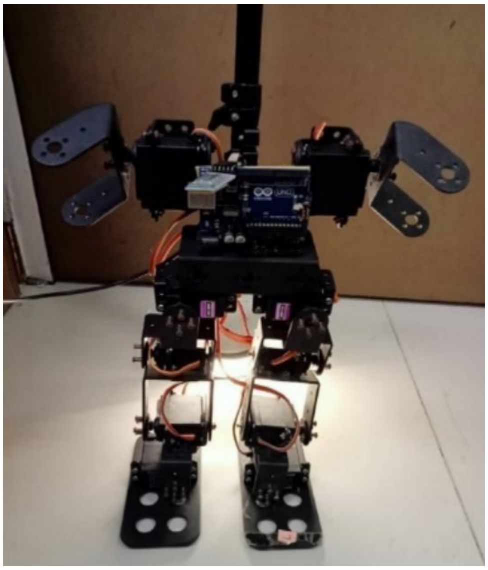

Figure 6. A prototype of a robot that incorporated blockchain technology.

The robot management system with a user interface was developed and divided into three views (Figure 7). The manufacturer's view allowed a set of instructions to be uploaded to the robot through a web browser. The latest firmware version, which included movements, decisions, processing times, and subsequent actions, could be uploaded to the target robot via a web browser within the robot itself. The robot's engine contained a web server-like component that supported uploading data using the POST method working in conjunction with creating a blockchain hash function to support updating new instructions.

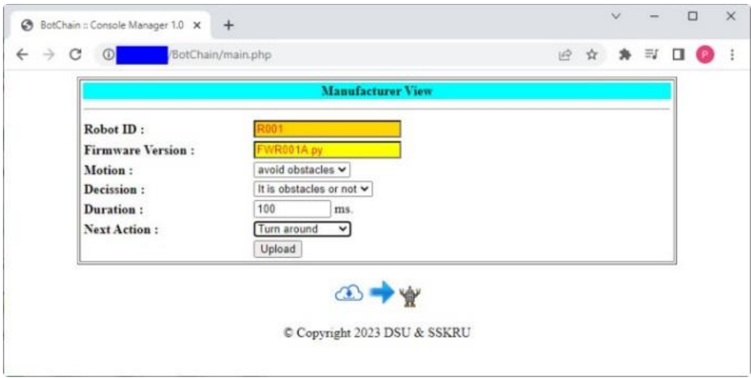

Figure 7. In the manufacturer's view, uploading instructions to the robot could be done through a web browser.

Figure 8 demonstrates the latest firmware for the robot, including the version, movements, decisions, processing times, and subsequent actions uploaded to the target robot via a web browser, i.e., inside the robot. The engine itself had a web server-like component that supported uploading data using the POST method, which worked in conjunction with creating the blockchain hash function to support updating new instructions. The image shows that each version of the firmware was written in a MicroPython instruction set that could be placed on both Raspberry Pi and ESP32 microcontrollers and instructing robots that used both microcontroller families. This rebooted itself to bring the new capabilities in the instruction set uploaded to the robot to be used immediately. The new firmware was uploaded from the factory to the target robot in roughly one second (Figure 8). The online uploading of the manufacturer's firmware to the robot was a previously unreported innovation. This was because robots from other developers were typically delivered to the manufacturing plant without a data cable connecting the robot to the burn firmware machine.

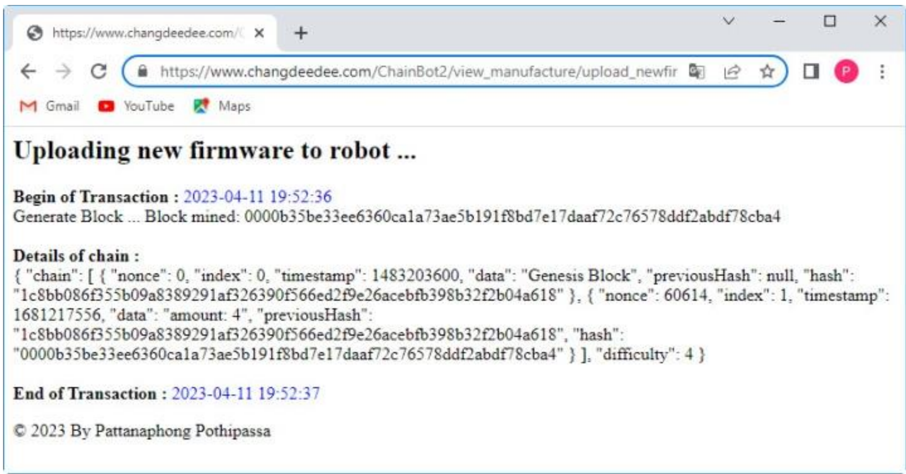

Figure 8. The creation of a block every time new firmware was uploaded to the robot.

Figure 8 shows the efficiency of generating a new blockchain every time new firmware was uploaded to the robot. This took an average of one second since the firmware was a MicroPython instruction set; therefore, it was very small because there was no need to include other libraries. For the owner of the robot, they could match their electronic combination lock to the robot to show their ownership. The movements and decisions corresponding to their tasks could be assigned to the robot through a web browser program, just like a robot factory worker.

TABLE 3: Comparison of traditional robots and a new age of robots.

Assessment Issues	Traditional Robot	New Age Robot
Instruction set update	By factory	Both the factory and owner
Command set connection	Via a data cable	Both the data cable and Internet
Data encryption support	No	Yes
Support the communication between robots.	No	Yes

The performance of the new-age robot was more efficient than that of the traditional robot in terms of the instruction set update, which both the factory and the owner could run, while the command set connection could be run by both the data cable and the Internet, which supported data encryption and communication between the robots, as shown in Table 2.

Figure 9. The development of robotic hardware by Computer Technology and Digital students, Faculty of Liberal Arts and Sciences, Sisaket Rajabhat University, Thailand.

4.2 Evaluation of a New Age Robotic Prototype

4.3 User's evaluation

In this study, 30 students from the Faculty of Science and Arts at Sisaket Rajabhat University were used to test a prototype robot. The students were given a pre-test before using the robot to support their learning of innovation development, information systems, and IoT. Students had the opportunity to learn about robot development and programming to control the robot during the four-week experimental period. Following the study's conclusion, a post-test was administered to assess the intervention's efficacy and the robot's performance. For evaluating the robot's performance based on the designed activity set, Table 3 is provided, which considers relevant research guidelines (Chou et al., 2023; Suanpang et al., 2022d).

Table 4 Evaluating the performance of the robot.

The Robot's Performance	Mean	Standard Deviation (SD)
Ease of control and use.	4.10	0.40
The robot helps students achieve the learning objectives.	4.10	0.31
The robot is suitable for the teaching style.	3.77	0.43
The robot's format attracts the learners' attention.	4.70	0.47
Robots help provide concrete examples, thus making the content easier to understand.	3.97	0.56
Robots provide interaction.	4.40	0.56
Real-time hardware failure resistance.	3.70	0.53
System simplicity.	3.63	0.56
Flexibility.	3.70	0.53
Overall.	4.17	0.38
Total	**4.02**	**0.47**

The results of the robot evaluation shown in Table 3 indicated that the robot's format attracted the learners' attention, which was the highest score ($\bar{X}$=4.70; SD=0.47). Secondly, the robot provided high interaction ($\bar{X}$=4.40; SD=0.56), and finally, the overall satisfaction with the system was highly rated ($\bar{X}$=4.17, SD=0.38), respectively.

4.4 Evaluation of the academic performance

Table 5. Evaluating academic performance.

Academic Performance	Mean	Standard	Mean Deviation	Standard Deviation (SD)	t	p
Pretest	4.00	1.31	-4.567	1.331	-18.794	.001
Post-test	8.57	0.94				

Table 5 shows the users' academic performance evaluation by comparing their pre-test and post-test test scores. The result of the academic performance of the students before using a new-age robot showed an average value of 4.00. However, after the post-test, the average value increased to 8.57. Using the Paired Samples T-Test, the statistical analysis revealed a significant correlation between the pre-test and post-test scores. This indicated that the evaluation of the robot's performance after the test was highly effective according to the predetermined criteria.

5. Discussions and Conclusion

As potential targets for cybercriminals, this study highlighted the need to address security concerns in the supply chain and data exchange between these devices. To address these issues, the paper proposes the creation of a new-age robotics prototype and presents a three-level conceptual framework. This framework incorporated blockchain technology into the robot ordering, ownership, and communication processes. The study involved the creation of a robot hardware prototype, a set of commands, and a user interface that could be accessed through a web browser and connected to the robot. The hardware prototype of the robot was based on a small robot chassis to which an ESP32 board and a more advanced and precise Raspberry Pi Pico board had been added. The study evaluated the robot's performance based on a predetermined activity set.

The study results showed that the robot management system based on blockchain technology could efficiently upload new firmware to the robot within one second. This was a breakthrough as other robots from different developers usually required delivery to the manufacturing plant before connecting the robot to the burn Firmware machine with a data cable. Consequently, blockchain technology ensures secure and reliable communication between the manufacturer, owner, and the robot (Chen et al., 2021; Conti et al., 2017; Nataraj, Al-Turjman & Adom, 2020; Ghaffari, Valls & Dissanayake, 2018). The three views of the robot management system with a user interface - the manufacturer's view, the owner's view, and the robot's view - allowed the robot to receive instructions from the manufacturer via a web browser. The latest firmware version could be uploaded to the target robot via an internal web browser. The robot's engine contained a component resembling a web server that supported uploading data using the POST method and creating a blockchain hash function to support updating new instructions (Villoro et al., 2021). (Bhadani, Sprinkle & Bunting, 2018 ; Omar & Cobanoglu, 2021).

Regarding practical implementation, the research team tested a pilot prototype of the robot in an educational setting. The prototype was evaluated by the students, who reported high levels of satisfaction and the development of their AI skills through their interactions with the robot. This successful implementation highlighted the potential of the robotics prototype to revolutionize education.

In the future, the researchers intend to conduct further research and development and upload the robot commands that have been developed, encompassing both collaborative and group robots. This would include the design of commands that could automatically divide the robot's tasks.

In conclusion, the paper proposed a new-age robotics prototype integrated with blockchain technology, which offered a secure solution for developing and applying robots in various industries with a specific focus on education. The prototype's encryption mechanism and the positive feedback from the students indicated its potential as a blueprint for future research and innovation in robotics.

Disclosure Statement: No potential conflict of interest was reported by the author(s).

Funding

This work was supported in part by the Suan Dusit University under the Ministry of Higher Education, Science, Research and Innovation, Thailand, grant number FF66-4-006 "Innovative of gastronomy and Agrotourism tourism platform of Suphanburi using identity and culture integrated with the expertise of the university to drive the

economic foundation to support next normal in post-Covid-19".

Acknowledgment

The researchers thank Professor Dr Chidchanok Lursinsap for supervising and advising the research team during the project's development. Additionally, we would like to express our gratitude to Suan Dusit University, Chulalongkorn University, and Sisaket Rajabhat University for providing research support and establishing a network of researchers in the region where the study was conducted. We would also like to extend our appreciation to the participating students.

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