PREPARING STUDENTS FOR STEM PRODUCT DEVELOPMENT: AUTOMATED WATERING SYSTEM

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ABSTRACT

In this project, an automated water dispenser system was designed and tested using the Arduino platform and modern sensor technologies. The research addresses the growing relevance of automation in everyday life, particularly in managing water usage efficiently while reducing human labor and energy consumption. The system automatically detects the presence of a cup, pours water, monitors the reservoir level, and provides an audio alert when full. Using engineering modeling, prototyping, and experimental testing, students created a working prototype and optimized the control algorithm for accuracy and energy efficiency. The results demonstrated that the device significantly improves safety, time management, and resource conservation. Thus, the project not only enhances the quality of STEM education but also fosters students' creativity, collaboration, and problem-solving skills through real-world engineering applications.

Keywords: STEM education, STEM product, automated system, water pump, energy efficiency, sensor, Arduino, industrial application, innovative technology.

INTRODUCTION

In today's industrial society, the demand for energy efficiency and automated devices is growing rapidly. Many industrial and domestic processes still require constant human involvement, leading to unnecessary waste of time and resources. This situation calls for the widespread adoption of automation technologies, including sensor- and microcontroller-based systems. Automated water dispensing systems are among the modern solutions in this field, providing precise water level control, optimized energy consumption, and reduced operational costs [1].

Industrial automation paradigms such as Industry 4.0 and the Industrial Internet of Things (IIoT) are increasingly focused on applying automated systems in water treatment and distribution facilities to optimize energy usage and reduce costs [2]. Such approaches help address traditional challenges in water management, including tank overflow, pipeline leaks, and idle pump operation, which have long

complicated urban water resource management [3]. The use of smart water systems and digital twins can significantly reduce both water losses in distribution networks and overall energy consumption [4].

Automated water dispensing systems play an important role not only in improving energy efficiency but also in ensuring sanitary and hygienic safety. During the pandemic, the effectiveness of contactless service devices became evident, as they helped reduce the risk of spreading viral infections [5]. These systems operate without direct human intervention, providing touch-free service and contributing to compliance with hygiene standards.

Energy consumption efficiency remains one of the key directions in the development of automated systems. To reduce dependence on conventional power sources, the use of renewable energy, including solar energy, has become increasingly relevant [6]. Studies have proven that automated cooling and heating systems powered by solar energy enhance overall energy efficiency—an approach that can also be applied to automated water dispensers [7]. Solar panels not only supply energy to the system but also ensure its autonomous and sustainable operation [8].

Monitoring and efficient use of water quality is a critical factor in industrial processes. Automated systems significantly improve the ability to monitor and manage water purity and quality. For instance, quality control systems in the dairy industry have proven effective in ensuring the safety and consistency of raw materials [9]. Applying similar principles in automated water dispensing systems can enhance water safety and enable reliable water distribution in industrial facilities and public spaces.

Furthermore, the use of micro-thermoelectric devices can increase the overall efficiency and functionality of water dispensing systems. These devices help maintain a stable temperature, delivering water at the desired level. Such technologies improve system reliability and ensure user-oriented, adaptive performance [10].

To ensure stable and efficient operation of automated water dispensing systems, maintaining the performance of energy sources is also crucial. Studies have shown that solar panel cleaning and cooling technologies can enhance their efficiency [11]. Integrating these technologies into automated water dispensing systems can ensure their autonomy and support long-term, uninterrupted operation.

The purpose of this research is to explore ways to improve the energy efficiency of automated water dispensing systems and to analyze their potential applications in industrial and public environments. By optimizing such systems, it becomes possible to achieve efficient water management, reduced energy consumption, and compliance with sanitary standards. Moreover, the widespread adoption of such devices in industrial and domestic settings aligns with the principles of sustainable development.

RESEARCH METHOD

In this study, a comprehensive approach was employed, combining methods such as engineering modeling, prototyping, experimental research, sensor calibration, and algorithm optimization. These techniques played a crucial role in enhancing the system's reliability, accuracy, and energy efficiency. The essence and application of each method are described below.

Engineering Modeling

At the design stage, the engineering modeling method was used to analyze the structural elements of the system and their interactions in advance. This approach allowed for the optimization of component dimensions and parameters, ensuring mechanical and electrical compatibility. In addition, the hydrodynamic characteristics of the water dispensing system—such as liquid flow rate, pressure, and volume—were simulated, helping to refine the system's technical specifications and select the most efficient design solutions.

Prototyping (Model Construction)

The initial physical prototype of the system was created through prototyping. At this stage, sensors, motors, relays, tubes, and control modules were integrated to assemble a functional mock-up and test its operability. Various design options were evaluated to improve the device's ergonomics and user convenience. Identified shortcomings during the prototyping phase were addressed through design adjustments, leading to an improved version of the system.

Experimental Research

The system's performance and efficiency were verified experimentally. During this phase, its continuous operating time was determined, and the long-term reliability of components was assessed. Power consumption was measured using a 9V battery and alternative power sources. The system was tested in different environments such as homes, offices, and industrial spaces to evaluate sensor sensitivity and water flow rate.

RESEARCH FINDINGS

An automated water dispensing system is a device based on sensors and the Arduino platform that automatically detects the water level and dispenses an accurate amount of water into a cup. Such a system reduces human involvement, saves time, promotes efficient resource use, and enhances hygienic safety. The main functions of the system include cup detection, water dispensing, water level monitoring, sound notification when full, and power saving. This device is suitable for use in domestic, public, and industrial environments and meets modern technological standards (Fig 1.).

Figure 1. 3D-printed structure of the automated water dispenser

The main feature of the automated water dispensing system is its energy efficiency. The system conserves electrical energy through the use of low-power components, optimized algorithms, and alternative energy sources such as solar panels. Enhancing sensor sensitivity, reducing motor operating time, and implementing a power-saving mode enable the device to operate continuously for

extended periods. As a result, the energy consumption per cycle remains at 0.03 Wh, allowing a 9 V battery to function for up to 48 hours.

Energy efficiency practices and methods

The results of engineering modeling made it possible to identify the main structural characteristics of the automated water dispenser system and ensure the compatibility of its components. The calculations and simulations conducted refined the operating parameters of the device and increased its efficiency. As a result of liquid flow modeling, the water dispensing time was optimized to 3–5 seconds. Moreover, the motor was able to maintain a steady pressure within the 9–12 V power range, and the control signal delay between the sensor and the motor was reduced to only 50 milliseconds. These parameters ensured reliable and fast system operation, energy savings, and user convenience.

The prototyping phase provided an opportunity to test the practical functionality of the automated water dispensing system and evaluate the effectiveness of its technical solutions. Through the first prototype, the accuracy of cup detection reached 95%, demonstrating the system's reliability. The connection and disconnection mechanisms between the motor and relay operated precisely and consistently, ensuring the uninterrupted performance of the main functions. Consequently, the complete automation of the water dispensing process was successfully achieved without any direct user intervention. These results confirmed that the device meets modern technological standards and is suitable for both household and industrial use (Fig 2.).

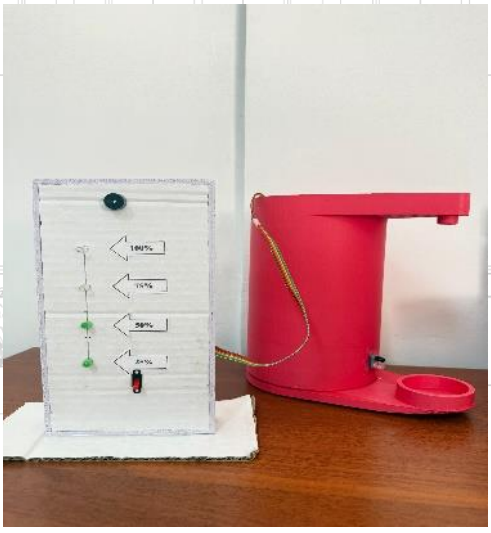

Figure 2. Experimental prototype of the automated water dispensing system

Thus, the results of our study on the automated water dispensing system not only support the main ideas presented in the reviewed scientific works but also further specify their practical application in domestic and industrial contexts. The findings demonstrate that this device can be adapted for solar-powered operation and enhanced through the integration of IoT technologies, thereby expanding its functionality. As a result, such automated systems that combine sensor technologies with energy efficiency can make a significant contribution to resource conservation, hygienic safety, and the implementation of sustainable development principles in industrial and public environments.

CONCLUSION

Involving students in the project of developing an automated water dispensing system proved highly effective in enhancing their engineering and research skills. Throughout the project, students learned to work with the Arduino platform, install and calibrate sensors, build prototypes, and conduct testing. This experience not only improved their technical literacy but also fostered essential soft skills such as logical and critical thinking, creative problem-solving, and teamwork. Moreover, the STEM-based, problem-oriented approach enabled students to connect theoretical knowledge with practical application and to develop innovative thinking. As a result, the participants demonstrated increased research activity, stronger motivation, and a deeper interest in using modern technologies in real-world contexts.

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REFERENCES

1. Nicolae, A., Korodi, A., & Silea, I. (2021). Complete automation of an energy consumption reduction strategy from a water treatment and distribution facility, inside an industrial Internet of Things-compliant proactive historian application. Sensors, 21(7), 2569. https://doi.org/10.3390/s21072569

2. Nagasa, M. M., & Johnson, P. (2025). Industrial Internet of Things for a wirelessly controlled water distribution network. Sensors, 25(8), 2348. https://doi.org/10.3390/s25082348

3. Fritz, R. T., Gimenes, J. de C., & Filho, A. C. de P. (2020). Um estudo da automação para redução de perdas na rede de distribuição de água. Brazilian Journal of Development, 6(8), 56408. https://doi.org/10.34117/bjdv6n8-161

4. Ramos, H. M., Kuriqi, A., Besharat, M., Creaco, E., Tasca, E., Coronado-Hernández, Ó. E., Pienika, R., & Iglesias-Rey, P. L. (2023). Smart water grids and digital twin for the management of system efficiency in water distribution networks. Water, 15(6), 1129. https://doi.org/10.3390/w15061129

5. Raja Sekhar, G. C., Kalyan, D., Ramkumar, R., & Lakshmi, M. (2023). Automated water dispenser – A hygiene solution for pandemic. In IoT and analytics in renewable energy systems (Volume 2): AI, ML and IoT deployment in sustainable smart cities (pp. 289–298). CRC Press. https://doi.org/10.1201/9781003374121-24

6. Nayak, M., Manjunath, H. N., & Madhusudhan, M. (2020). Performance studies on automated solar powered air cooler/air heater. International Journal of Scientific and Technology Research, 9(1), 3480–3483.

7. Nithiyananthan, K. (2017). Design and development of automated solar panel cleaner and cooler. International Journal of Electrical Engineers, 9(2), 186–197.

8. Tanwar, A., Lal, S., Kaur, R., Padmanathan, N., Dalton, E., & Razeeb, K. M. (2023). A fully automated measurement system for the characterization of micro thermoelectric devices. Applied Thermal Engineering, 224, 120111. https://doi.org/10.1016/j.applthermaleng.2023.120111

9. Vara Martinez, J. A. de la, Garcia Higuera, A., Roman Esteban, M., Romero Asensio, J., Carmona Delgado, M., Berruga, I., & Molina, A. (2018). Monitoring bulk milk quality by an integral traceability system of milk. Journal of Applied Animal Research, 46(1), 784–790.

10. Tanwar, A., Lal, S., Kaur, R., Padmanathan, N., Dalton, E., & Razeeb, K. M. (2023). A fully automated measurement system for the characterization of micro thermoelectric devices near room temperature. Applied Thermal Engineering, 224, 120111. https://doi.org/10.1016/j.applthermaleng.2023.120111

11. Nithiyananthan, K. (2017). Design and development of automated solar panel cleaner and cooler. International Journal of Electrical Engineers, 9(2), 186–197.