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Gamified and IoT-integrated Approach for Water Industry Education and Outreach

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Abstract

In recent years, an aging workforce and a shortage of new hires have raised concerns about the future of the water treatment industry. However, recent technological advances, such as developments in computer simulations and educational systems, offer promising solutions to this pressing problem. Building on these new technologies, our work presents a system that addresses the looming challenges in the fields of water resources, water pollution, and water purification. To address these issues comprehensively, we have leveraged Raspberry Pi technology to monitor critical parameters such as water temperature and pH. Additionally, we have incorporated camera functionality to transmit real-time data to a mobile app, providing users with up-to-the-minute information on water quality. The interactive and entertaining nature of the lab trivia game is not only educational but also entertaining, encouraging students to delve deeper into the complexities of water pollution and gain valuable insights into the water purification process.

Keywords

Water Industry, Education, Gamified Learning

Introduction

Recently, The water treatment industry has been facing two pressing issues [1]: the aging workforce and difficulties in recruiting new employees [2]. This has raised serious concerns about the industry's future as challenges in areas such as water resources, water pollution, and water purification are rapidly increasing [3]. However, we have proposed an inspiring solution known as the WaterMobile system. This system not only serves an educational purpose but also incorporates an element of entertainment. By adopting a gamified approach, we assist students in better understanding and engaging in water treatment work, thus nurturing a new generation of water treatment professionals. This gamified nature of mobile phones [4] not only makes learning more engaging but also ignites students' interest in participation, aiding outreach efforts and attracting potential new professionals to the field. The user-friendliness and appeal of the WaterMobile system make it a pathway to guide more individuals into the water treatment industry. Additionally, in light of the disruption caused by the COVID-19 pandemic to regular laboratory courses [5], we have also introduced virtual simulation laboratories [6] and Raspberry Pi technology, allowing students to remotely participate in practical operations and experiments without the need to be

physically present on-site. This provides valuable hands-on experience to students without the constraints of limited laboratory equipment, thus promoting and enhancing the accessibility of water treatment education.

Project Approach and System Desing

WaterMobile is an innovative mobile learning environment designed to provide school classrooms with demonstrations of practical activities related to water resources. It covers activities on hydraulics (pumps and pipes), water treatment (removing pollutants using physical/chemical processes), water contamination, and the role of soils in buried pipes and construction materials (e.g., concrete for water/sewer lines.) WaterMobile is a low-cost and simple mobile ecosystem that is easy for school districts to adopt and implement in the classroom. Each activity connects to the science portion of the New Jersey Core Curriculum Content Standards that support science education. As such, it complements the WaterPal app by visualizing real-world experiences.
The WaterMobile application (WaterMobile) is a feature-rich tool designed to meet the needs of teachers and students in the field of water resources education and research. The application has an intuitive user interface as shown in Figure 1, the WaterMobile application is designed with two main modules: the Teacher Module and the Student Module. Below, we will provide specific introductions for both of these modules:

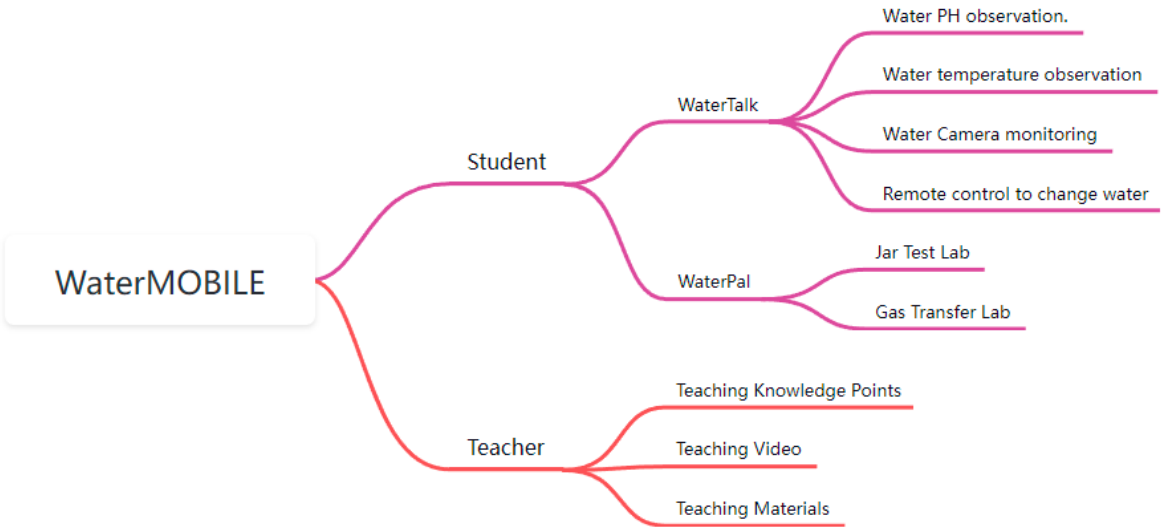

Figure 1. WaterMobile Application Design Function Diagram

The Teacher module is shown on the left side of Figure 2 and is designed for teacher access. Using the Teacher module, instructors can easily access resources and course materials to help with planning and giving lessons on relevant topics like water treatment. This module includes the following three specific functions:

1. Teaching Points of Knowledge: The WaterMobile application gives teachers easy access to all relevant educational content for water resources, water pollution, and water purification. These resources are updated in real time and help teachers to keep up to date with the latest knowledge. This allows teachers to stay up-to-date with the latest lesson content so that they can teach up-to-date knowledge to their students.

2. Instructional Videos: This section allows you to browse and share instructional videos related to water treatment. These videos are helpful in explaining complex concepts and processes.
3. Instructional Materials: Teachers can easily access a variety of instructional materials including textbooks, presentations, and lab guides. These materials help teachers to better prepare for their lessons. Teachers can easily find and access the educational tools they need to improve their teaching and learning.

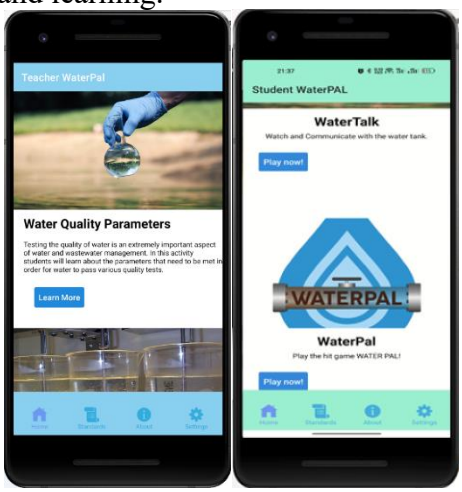

Figure 2. The interactive interface of WaterMobile, showing the teacher screen (left) and the student screen (right).

The Student Module, shown on the left side of Figure 2, is designed for student access. Using the Student Module, students can access the modules WaterPal and WaterWork to stimulate their interest in water management and other related topics. The module includes the following two specific functions:

1. WaterTalk: WaterTalk serves as a real-time, remote, hands-on lab that allows students to observe water pH and temperature in real time. Through the WaterMobile app, students can easily access information about these key water quality parameters that are critical to the health and suitability of water bodies. Students can instantly learn the status of water quality so they can better understand its suitability and impact on the environment. Additionally, students can remotely observe the status of water bodies through the app's real-time water quality camera feature and collect data for subsequent analysis. They are also able to remotely control the experimental environment, including adjusting the pH and water temperature of the experimental environment to simulate different water quality conditions and observe the effects of these changes on water quality and aquatic ecosystems. These features enable students to gain a deeper understanding of water quality and aquatic ecosystems through real-time observations and experiments, thus improving their understanding and practical skills in water resources management.

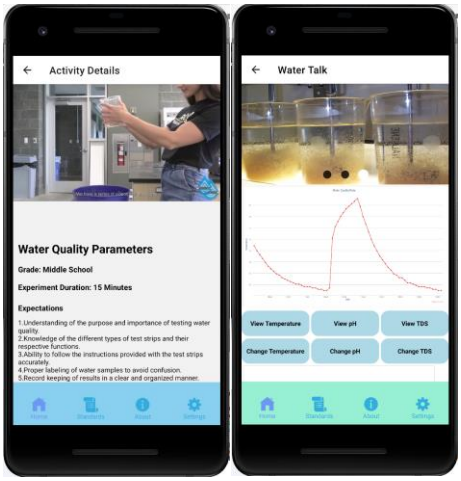

Figure 3. Additional interface of WaterMobile, showing the teacher screen (left) and the Student WaterTalk screen (right).

2. WaterPal: WaterPal is a mini-game with 2 experiments. Students will have the opportunity to choose a character as shown on the left side of Figure 4, and this character will represent them in the game. The choice of character adds to the entertainment and provides a greater sense of immersion for the students. The game has a complete video tutorial to teach students how to conduct the lab mini-games as shown on the right side of Figure 4. We'll cover both games in detail:

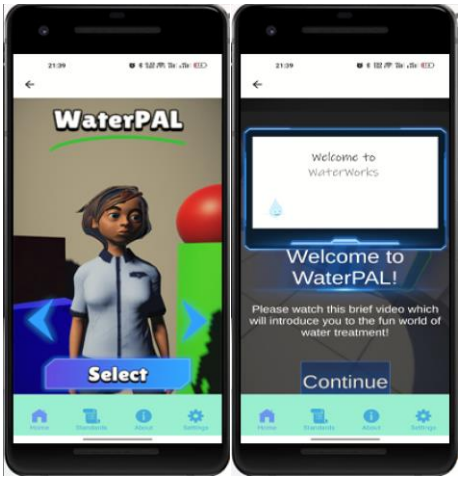

Figure 4. The mini-games in WaterMobile, showing the Character Selection screen (left) and the introduction screen (right).

a) JarTest Lab: As shown on the left in Figure 5, the Jar Test Lab in WaterPal is a fun and interactive lab module that teaches students important concepts about the water purification process in an entertaining way by simulating a jar test, which is a common lab experiment for water treatment courses. In this lab, students will have the opportunity to adjust different dosages of reagents and observe their effects on the clarity of water and the clumping of sediment. They can simulate a real water treatment process and observe how small particles gather into larger, heavier clusters that eventually precipitate solid impurities from the water. This experiment helps students understand the chemical reactions and operations involved in water purification and how to optimize water quality.

b) Gas Transfer Lab: As shown on the right side of Figure 5, the Gas Transfer Lab is a highly interactive learning environment designed to teach students key knowledge about gas

transfer and gas exchange in aqueous bodies. In this lab, students will be able to explore and gain an in-depth understanding of gas transfer processes between liquid and gas phases. The goal of this lab is to help students better understand the importance of gas transport in environmental processes and areas of application, including wastewater treatment and water purification, through hands-on exercises and simulations.

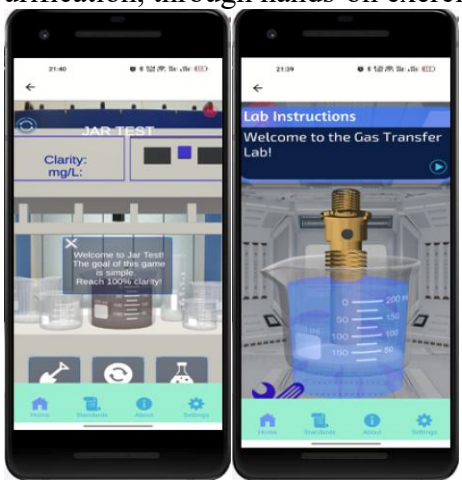

Figure 5. The mini-games in WaterMobile, showing the game Jar Test (left) and the Gas Transfer Lab(right).

WaterMobile inspires students to take a keen interest in water resources and water treatment in an interactive and entertaining way, while providing teachers with a convenient tool to facilitate teaching and research. The app works in both classroom and independent study.

CONCLUSIONS

Using an innovative approach that blends gaming elements and IoT technology in the form of the WaterMobile app, WaterTalk, and WaterPal mini-games, our water industry education and outreach program successfully addresses challenges in the areas of water resources, water pollution, and water purification. Currently, the water treatment industry faces an aging workforce and a shortage of new talent, and our program offers promising solutions for students and educators. As an innovative mobile learning environment that brings real-world water-related activities into the school classroom. It covers important topics such as hydraulics, water treatment, water pollution and the role of soil in water infrastructure. This low-cost, user-friendly ecosystem has the potential to be widely adopted by school districts, providing a rich educational experience for students. Additionally, WaterMobile is aligned with the New Jersey Core Curriculum Content Standards, ensuring that it complements traditional classroom instruction. Our program not only addresses the workforce challenges facing the water treatment industry, but also stimulates student interest in water resources and water treatment through an interactive and entertaining approach. By making learning lively and interactive, our goal is to inspire the next generation of water treatment industry professionals who will play a vital role in protecting this valuable resource.

ACKNOWLEDGEMENT

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