Design and Development of a User-Centric Mobile Application to Promote Sustainable Hydration and Reduce Single-Use Plastic Water Bottle Consumption: A Case Study of Chulalongkorn University

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Received: July 23, 2024 *Revised: June 4, 2025* *Accepted: July 4, 2025*

Abstract

This study investigates the efficacy of WaterMap, an innovative user-centric mobile application designed to reduce single-use plastic water bottle consumption at Chulalongkorn University, Thailand—a regionally significant case within Southeast Asia's broader plastic pollution crisis. Employing a User-Centered Design (UCD) approach, we developed and evaluated a system that integrates real-time information on water dispenser locations and water quality with gamification elements to promote sustainable hydration practices. Key informants for the qualitative research were selected from Chulalongkorn University students based on prior participation in environmental surveys, while 17 participants were recruited for quantitative usability testing. Our mixed-methods evaluation, combining quantitative usability metrics (e.g., satisfaction ratings on a 5-point Likert scale) with

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qualitative thematic analysis, revealed high user satisfaction and a strong perceived potential for reducing plastic waste. Users appreciated the app's ease of use and its role in promoting sustainable behaviors. Notably, 76.5% of participants expressed moderate to high trust in the app's water quality data, while 70.6% reported consistent use of reusable bottles. Areas for enhancement, such as multi-language support and improved gamification engagement, were also identified. This research contributes significantly to the growing body of literature on technological interventions for sustainability, offering valuable insights for developing similar initiatives in other educational institutions—particularly in Southeast Asian contexts facing acute plastic pollution challenges. Our findings demonstrate the potential of combining mobile technology, IoT, and gamification to foster behavioral change toward environmental sustainability in higher education settings, with implications for broader public spaces.

Keywords: Sustainable Behavior, Plastic Waste Reduction, User-Centered Design, Mobile Application Development

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การออกแบบและพัฒนาแอปพลิเคชั่นมือถือที่ยึดผู้ใช้เป็นศูนย์กลางเพื่อส่งเสริมภาวะสมดุลน้ำอย่างยั่งยืนและลดการใช้ขวดน้ำพลาสติกแบบครั้งเดียวทิ้ง : กรณีศึกษาจุฬาลงกรณ์มหาวิทยาลัย

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บทคัดย่อ

งานวิจัยนี้ศึกษาประสิทธิภาพของแผนที่น้ำ (WaterMap) นวัตกรรมแอปพลิเคชั่นมือถือที่ยึดผู้ใช้เป็นศูนย์กลาง ออกแบบมาเพื่อลดการใช้ขวดน้ำพลาสติกแบบใช้ครั้งเดียวทิ้ง บริเวณจุฬาลงกรณ์มหาวิทยาลัย ประเทศไทย ซึ่งนับเป็นกรณีศึกษาสำคัญด้านวิกฤตจากมลภาวะพลาสติกในวงกว้าง ระดับภูมิภาคเอเชียตะวันออกเฉียงใต้ ทั้งนี้การใช้ดีไซน์ที่ยึดผู้ใช้เป็นศูนย์กลาง (User-Centered Design: UCD) นั้น มีการพัฒนาและประเมินระบบที่บูรณาการข้อมูลสถานที่กดน้ำแบบทันทีประกอบกับข้อมูลคุณภาพน้ำที่นำมาจากกลไกและเทคนิคจากเกมส์ ทั้งนี้ เพื่อส่งเสริมวิธีปฏิบัติตัวเพื่อให้มีภาวะน้ำที่สมดุลอย่างยั่งยืน กลุ่มตัวอย่าง หลักของงานวิจัยเลือกจากนิสิตจุฬาลงกรณ์มหาวิทยาลัยที่ได้ตกลงเข้าร่วมทำแบบสำรวจเกี่ยวกับสิ่งแวดล้อมไว้ก่อนแล้ว โดยที่นิสิต 17 ราย เลือกมาด้วยวิธีเชิงปริมาณ คือ การทดสอบความง่ายในการใช้งาน ทั้งนี้ การประเมินวิจัยแบบผสม ประกอบด้วยวิธีเชิงปริมาณโดยการวัดค่าการทดสอบความง่ายในการใช้งาน (เช่น ระดับความพึงพอใจ 5 ระดับ) และวิธีเชิงคุณภาพโดยการวิเคราะห์สาระสำคัญ ผลการวิจัยแสดงให้เห็นว่า มีความพึงพอใจระดับสูงและมีศักยภาพแบบที่รับรู้ได้ในระดับดีสำหรับการลดขยะพลาสติก ทั้งนี้ผู้ใช้ชื่นชมว่า แอปพลิเคชั่นใช้งานง่ายและมีบทบาทในการส่งเสริมพฤติกรรมยั่งยืน โดยที่ 76.5% ของกลุ่มตัวอย่าง มีความเชื่อมั่นระดับปานกลางถึงระดับสูงต่อข้อมูลคุณภาพน้ำของแอปพลิเคชั่น ในขณะที่ 70.6%

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รายงานว่า ใช้ขวดน้ำซ้ำอีกเป็นประจำ อย่างไรก็ตาม ยังคงมีส่วนที่ต้องปรับปรุง เช่น การรองรับภาษาที่หลากหลายและปรับปรุงระบบปฏิสัมพันธ์ของกลไกและเทคนิคจากเกมส์ นอกจากนี้งานวิจัยยังส่งเสริมให้มีวรรณกรรม ใหม่เรื่องการพัฒนาเทคโนโลยีสำหรับความยั่งยืน ส่งผลให้เกิดข้อมูลความเข้าใจเชิงลึกที่มีประโยชน์ สำหรับการพัฒนานวัตกรรมใหม่ในลักษณะเดียวกันขององค์การศึกษาอื่น ๆ โดยเฉพาะอย่างยิ่งในบริบท ของทวีปเอเชียตะวันออกเฉียงใต้ ซึ่งกำลังเผชิญกับความท้าทายจากมลพิษจากขยะพลาสติกแบบฉับพลันผลงานวิจัยยังชี้ให้เห็นอีกว่า มีความเป็นไปได้ในการผสมผสานเทคโนโลยีมือถือ อินเตอร์ในทุกสิ่งและกลไกและเทคนิคจากเกมส์ เพื่อให้เกิดความเปลี่ยนแปลงทางด้านพฤติกรรมสิ่งแวดล้อมอย่างยั่งยืนในระดับอุดมศึษา ที่อาจต่อยอดไปถึงการนำไปใช้เชิงสาธารณะในวงกว้างต่อไป

คำสำคัญ : พฤติกรรมยั่งยืน การลดขยะพลาสติก ดีไซน์ที่ยึดผู้ใช้เป็นศูนย์กลาง การพัฒนาแอปลิเคชั่นมือถือ

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Introduction

The global proliferation of plastics—especially short-lived, disposable products—has become a leading driver of environmental degradation. Plastics now comprise 85% of marine litter, posing severe threats to ecosystems. Without urgent action, plastic pollution could triple by 2060 (United Nations, 2023). Each year, 400 million tonnes of plastic are produced globally, yet only 9% is recycled and 12% incinerated (UNEP, 2021). The Environmental Protection Agency [EPA] (2024) underscores the wide-reaching impacts of plastic waste, including harm to wildlife, contributions to climate change, and risks to human health. Southeast Asia is a major contributor to marine plastic pollution, producing 31 million tonnes annually. The region includes five of the top ten global polluters—a crisis worsened by increased single-use plastic consumption during the COVID-19 pandemic (Julius & Trajano, 2022; van Trotsenburg & Lim, 2022). In Thailand alone, 2 million tonnes of plastic waste are generated yearly, with just 25% recycled. Imports of plastic waste further burden local recycling systems and exacerbate environmental stress (Rujivanarom, 2021; World Bank Group, 2022).

Single-use plastics (SUPs)—such as bottles, bags, and straws—are among the most persistent pollutants, often requiring centuries to degrade and rarely recycled beyond a few cycles (WWF-Australia, 2018). As defined by Sedtha et al. (2023), SUPs are intended for one-time use and are predominantly (99%) made from non-renewable fossil fuels. These items have become deeply embedded in daily routines worldwide, including in Thailand (Jeanpakdeesombat, 2021). Figure 1 illustrates the issue through examples of plastic waste and sorting infrastructure at Chulalongkorn University in Bangkok.

Figure 1 : Plastic Waste (Left) and Waste Sorting Bins (Right) at Chulalongkorn University.

The global rise in plastic bottled water consumption—driven by health concerns, urbanization, and convenience—has become a major contributor to plastic pollution. In Thailand, this issue is particularly acute, as single-use plastic bottles significantly add to national waste and endanger marine ecosystems (Enviliance Asia, n.d.). To counter this, initiatives like Chulalongkorn University's Zero Waste program have implemented vending machines offering free, safe drinking water and introduced zero-waste cups to reduce plastic bottle reliance (Figure 2) (Chulalongkorn University, 2018). The private sector has also responded; for example, Coca-Cola launched awareness campaigns on proper plastic disposal and adopted recycled PET bottle packaging (Krisanaraj, 2023).

Figure 2 : Water Dispenser (Left) and a Zero-Waste Cup (Right) at Chulalongkorn University.

Recent advancements in technologies such as the Internet of Things (IoT), Artificial Intelligence (AI), and mobile applications have provided promising alternatives to traditional plastic reduction campaigns (Koh et al., 2024; Mendes et al., 2021). IoT-enabled systems have improved urban waste collection and recycling efficiency (Pratap et al., 2019), while AIoT integration has been explored for smart eco-cities to enhance environmental sustainability (Bibri et al., 2024). However, the application of these technologies specifically to combat single-use plastic water bottle consumption remains limited, particularly in Thailand, wherereliance on such bottles persists, as highlighted in a 2023 survey by Chulalongkorn University (Htun et al., 2023). To bridge this gap, our study introduces WaterMap—a user-centric mobile app designed for Chulalongkorn University—that integrates IoT sensors, real-time data, and gamified engagement to foster sustainable hydration. By offering real-time dispenser mapping, water quality updates, and refill-based rewards through a Human-Centered Design (UCD) framework, WaterMap not only addresses logistical concerns but also promotes behavioral change, positioning it as a pioneering solution for campus sustainability. The primary objectives of this study are:

1. To design and develop a user-centric mobile application that facilitates the discovery of nearby water dispensers on campus and provides real-time information, such as water quality,
2. To gamify the process of water refilling, making it engaging and enjoyable for users,
3. To develop an innovative system architecture for the *WaterApp* system, enhancing scalability and functionality, and
4. To evaluate the usability, user-friendliness, and overall user experience of the *WaterApp* system through systematic testing and feedback analysis.

We hypothesize that integrating accessible real-time information with gamified features in the WaterMap app will significantly reduce single-use plastic water bottle consumption on campus, promoting a culture of sustainability. This interdisciplinary approach—merging environmental science, behavioral psychology, and advanced technology—not only supports Chulalongkorn University's zero-waste goals but also offers a scalable model for other institutions in Thailand and beyond. The study’s findings have broader implications, from informing urban planning and shaping consumer behavior to advancing digital solutions for environmental sustainability. Additionally, data generated by WaterMap can guide future research in areas like resource management, sustained user engagement, and the long-term impact of gamified environmental interventions, contributing to more effective strategies in addressing global plastic pollution.

Related Studies

The critical need to address plastic pollution is underscored by the United Nations' Sustainable Development Goals (SDGs), specifically SDG 12 and SDG 14, which emphasize sustainable consumption and the reduction of marine pollution, respectively (United Nations, 2015). These global goals serve as a foundation for our work on reducing single-use plastic water bottle consumption. However, a persistent challenge exists in translating global policy into individual and community-level action—a disconnect our WaterMap app seeks to bridge by embedding sustainability directly into students' daily routines.

Wichaiutcha and Chavalparit (2019) identify this gap in Bangkok, where, despite strong awareness of plastic waste, 3Rs (Reduce, Reuse, Recycle) practices remain underutilized. This highlights the need for solutions that not only raise awareness but actively convert it into habitual action—an approach central to WaterMap's gamified, behavior-driven design. In line with this, Mendes et al. (2021) demonstrated the potential of ICT/IoT through Project Refill_H20, though their solution lacked scalability across diverse institutions. Water Map differs by offering a lightweight, mobile-first architecture built for scalability, adaptability, and integration within campus ecosystems.

Likewise, SmartOne (Vithanage et al., 2019) introduced a personalized hydration system via a smart water bottle. However, their product primarily targeted individual ownership and usage. In contrast, WaterMap targets shared, public infrastructure (e.g., campus dispensers), allowing broader reach and promoting collective participation in sustainable hydration. Koh et al. (2024) explored a Smart Water ATM in Singapore that personalizes hydration via technology—yet their work, though informative for Southeast Asia, is not tailored to the Thai educational context. Our app directly responds to Thai-specific data and needs, as evidenced by the 2023 Chulalongkorn University survey (Htun et al., 2023), making WaterMap both locally grounded and regionally adaptable.

Gamification is another key component of WaterMap, inspired by a growing body of evidence on its potential to foster sustainable water behavior. Di Paolo & Pizziol (2024) found that gamification increased prosocial behavior in primary school students, revealing behavioral shifts through play-based engagement. WaterMap adapts this principle for a university audience, using QR code scanning and reward systems to incentivize sustainability without relying on age-specific play mechanics. Coskun et al. (2021) emphasized the role of ambient feedback in water intake, while Yildiz & Coskun (2019) explored community-based motivation through smart water dispensers. Our app blends both perspectives by combining personal incentives (via gamified points) with system-level feedback on water quality and availability—bridging individual and collective motivations.

Meng et al. (2023) examined how digital refill map tools foster environmental action through spatial and data agency. Their study stresses the power of maps to enable activism, but calls for local adaptations. WaterMap addresses this need with real-time dispenser mapping linked to IoT sensors—ensuring hyper-local data relevance and immediate usability on campus.

From this comprehensive literature review, several critical gaps emerge: the limited exploration of mobile solutions for sustainable water consumption in Thai university settings; the lack of real-time water quality and location integration; minimal research on the long-term effects of gamification on plastic reduction; a need for scalable, flexible digital tools; and the gap between awareness and sustained behavioral change.

WaterMap is unique in how it integrates all these components—localization, gamification, real-time data, and campus-scale architecture—into a cohesive mobile platform. By tailoring a user-centric solution for the Thai university context, we address practical and motivational barriers to sustainability. Our evaluation of real-time water quality data, combined with dispenser accessibility and user feedback loops, offers a more holistic engagement strategy than existing models.

Through systematic usability testing and qualitative analysis, we assess WaterMap's effectiveness in terms of user-friendliness, engagement, and potential for impact. This ensures alignment with global sustainability goals while addressing Thailand’s unique challenges. Ultimately, our work not only targets plastic pollution at Chulalongkorn University but also proposes a replicable model for similar institutions across Southeast Asia.

User-Centered Design Approach

In the development of the WaterMap mobile application, we employed the User-Centered Design (UCD) methodology, a comprehensive approach that prioritizes user needs and perspectives throughout the entire design process. As defined by the Interaction Design Foundation (2024), UCD is an iterative methodology that consistently places user requirements at the forefront of each design stage. This approach, further elucidated by Lowdermilk (2013), emphasizes the critical importance of user experiences in product development, necessitating continuous engagement with users through diverse research and design methods. The goal of UCD extends beyond mere aesthetic enhancement; it focuses on creating products that are not only highly usable and accessible but also practical and efficient in meeting specific user needs. Abras et al. (2004) reinforce this understanding, highlighting that UCD aims to deliver optimal technological solutions by deeply integrating user perspectives.

Guided by these comprehensive insights from the literature, our application of the UCD process to the WaterMap project involved several key, interconnected steps: understanding the context of use, specifying user requirements, designing solutions, and evaluating these solutions against the defined requirements. Each of these phases was meticulously crafted to align with the foundational principles of UCD, ensuring a robust and user-focused product development cycle. This systematic approach allowed us to iteratively refine our design based on user feedback and evolving requirements, ultimately aiming to create a mobile application that effectively addresses the challenge of reducing single-use plastic water bottle consumption in a way that resonates with and is easily adopted by our target users.

In adapting UCD to our specific context, we integrated concepts from environmental science and behavioral psychology, enhancing the methodology's applicability to sustainability challenges. We employed techniques such as user personas and journey mapping to gain deep insights into the behaviors and motivations of our target users. This interdisciplinary approach allowed us to address unique challenges in promoting sustainable behaviors through technology, contributing to both UCD methodology and environmental sustainability research. Our UCD process directly supports the United Nations' Sustainable Development Goals, particularly SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), by focusing on reducing plastic waste through user-centric technological interventions. This alignment demonstrates the potential of UCD in creating impactful solutions for global sustainability challenges. Figure 3 shows the UCD process and its phases and tasks, illustrating how each stage of our development process contributed to creating a solution that is both technologically sound and environmentally impactful. This iterative approach not only enhanced the usability of WaterMap but also ensured its effectiveness in promoting sustainable behaviors among our target users.

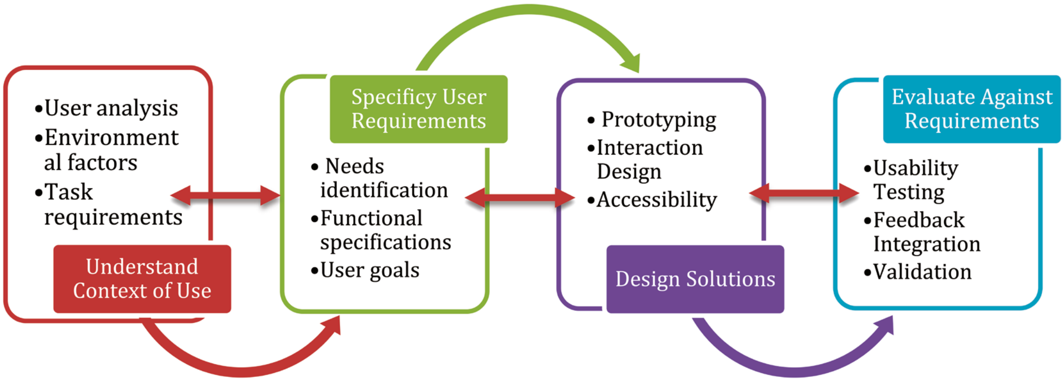

Figure 3 : User-Centered Design Process.

WaterMap Design and Development

In this study, the *WaterMap* app was developed using an innovative adaptation of UCD methodology, tailored for environmental sustainability challenges in a university setting. Our five-phase process integrated insights from environmental science, behavioral psychology, and human-computer interaction. We began with a comprehensive context analysis, followed by requirements specification based on targeted user research. This interdisciplinary approach informed our ideation of innovative features addressing both immediate needs and long-term behavioral change. We then prototyped a high-fidelity version of *WaterMap* and conducted rigorous user testing with a diverse target group. This methodical, user-centric process ensured the app effectively addresses single-use plastic water bottle consumption in a user-friendly, engaging, and potentially scalable manner.

Design Requirements, Analysis, and Ideation

To gain a comprehensive understanding of the study context, including user demographics and specific challenges, our team conducted an in-depth analysis of data from a previous interview study performed by the Department of Environmental and Sustainable Engineering at Chulalongkorn University (Htun et al., 2023). This survey, a collaborative effort with the University of Tokyo (UT) in August 2023, encompassed 141 Chulalongkorn University students. The research employed a robust mixed-methods approach, integrating qualitative and quantitative elements to capture diverse student experiences and perspectives. We applied Structural Equation Modeling (SEM) to analyze the survey data, a sophisticated statistical technique that allowed us to uncover complex relationships between variables and provide a nuanced understanding of user behavior and motivations.

Our analysis revealed four primary pain points encountered by users, providing crucial insights for our design process. First, students primarily opt for single-use plastic water bottles due to their convenience, low cost, and widespread availability. Second, a pervasive mistrust of the quality of water served via campus dispensers significantly influences students' decisions. Third, frequent malfunctions of water dispensers emerge as a major source of user frustration. Lastly, the expansive campus area creates difficulties in locating water dispensers and confirming their operational status. These insights formed the foundation of our user-centered design approach, highlighting critical issues requiring immediate attention and informing our focus on improving convenient access to water for both students at Chulalongkorn University.

To translate these findings into actionable design strategies, we employed the *'How Might We'* (HMW) technique, a design thinking tool that reframes challenges as opportunities (Lewrick et al., 2020). This method allowed us to generate innovative solutions that directly address user needs while promoting sustainable behaviors. Table 1 details our HMW questions, providing a structured approach to developing effective interventions that address the specific needs and challenges faced by the campus community. By grounding our design process in rigorous data analysis and user-centric methodologies, we ensure that our solutions are not only technically sound but also deeply resonant with the target users. This approach positions the *Water Map app* as a tailored, evidence-based intervention to improve the overall experience with water dispensing facilities at Chulalongkorn University while contributing to broader sustainability goals and offering potential scalability to other educational institutions facing similar challenges.

Table 1 : How-might-We Questions Table

	Questions
HMW1	How might we help students conveniently locate nearby water dispensers?
HMW2	How might we increase users' trust in the quality of water provided by campus dispensers?
HMW3	How might we ensure users have real-time information about the quality and accessibility of nearby water dispensers?
HMW4	How might we encourage users to refill their water bottles through a fun and engaging experience?

Empathy Map

In developing the *WaterMap* app, we employed an empathy map as a crucial tool to gain a deep, multifaceted understanding of the emotional and psychological state of Chulalongkorn University's students regarding campus water dispensers (Gibbons, 2018; Lewrick et al., 2020). This innovative application of empathy mapping to environmental sustainability challenges allowed us to bridge the gap between user needs and eco-friendly solutions. Our empathy map, visualized in Figure 4, separated user experiences into four interconnected quadrants: *'Think & Feel,' 'Hear,' 'See,'* and *'Say & Do.'* This comprehensive approach enabled us to capture a holistic view of user interactions with dispensing facilities, revealing complex behavioral patterns and motivations.

The *'Think & Feel'* quadrant uncovered a significant tension: while users appreciate on-campus water availability, they harbor concerns about water quality, affecting their trust and overall satisfaction. This insight highlighted the critical need for transparent quality assurance measures in our design. In the *'Hear'* quadrant, we identified a dual narrative. Users are exposed to positive peer feedback about dispenser advantages, including cost savings and environmental benefits. However, shared experiences of service disruptions create a conflicting narrative, influencing perceptions and usage patterns. This finding underscored the importance of reliability in promoting sustainable behaviors.

The *'See'* quadrant revealed a powerful visual cue: the ubiquitous presence of plastic bottles on campus. This observation directly impacts users' environmental consciousness and their assessment of current solutions' effectiveness, emphasizing the need for visible, sustainable alternatives. The *'Say & Do'* quadrant exposed a gap between intentions and actions. Users express a desire for improved dispenser accessibility and reliability, indicating a willingness to adopt more sustainable practices if their needs are consistently met.

By meticulously mapping and analyzing these insights, our design team developed a nuanced understanding of user challenges and expectations. This deep empathy informed the creation of targeted features in the *WaterMap* app, such as real-time quality checks and locator service for operational dispensers. These features directly address the concerns highlighted across all quadrants, enhancing user experience while promoting sustainable practices. This empathy-driven approach represents a significant advancement in applying user-centered design principles to environmental sustainability challenges. By aligning technological solutions with user needs and motivations, we have created an app that not only improves campus water accessibility but also nudges users towards more sustainable behaviors. Our method demonstrates the potential of empathy mapping as a powerful tool in developing effective, user-friendly solutions to complex environmental issues, contributing to broader sustainability goals in higher education settings and beyond.

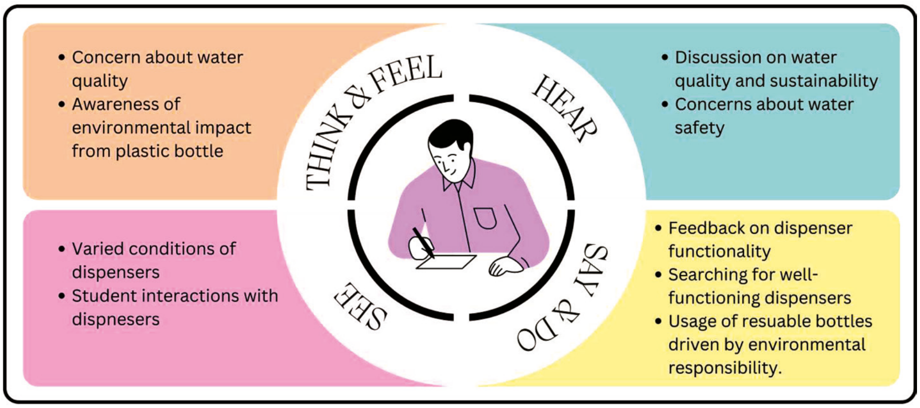

Figure 4 : Empathy Map.

User Persona

To deepen our understanding of study requirements and bridge the gap between empirical data and user-centric design, we developed a user persona (Lewrick et al., 2020). This innovative approach in sustainability-focused app development combines traditional UX methodologies with environmental behavior insights, creating a powerful tool for designing effective eco-friendly solutions. Our persona, *"Nat,"* represents a 22-year-old undergraduate at Chulalongkorn University, embodying the key characteristics, behaviors, and needs of our target user group. *Nat* exemplifies the complex interplay between environmental consciousness and practical constraints faced by many students. This persona vividly illustrates the tension between sustainability aspirations and the realities of campus life, providing a nuanced view of user motivations and barriers to adopting eco-friendly practices.

Nat's profile reveals critical insights: while environmentally conscious, *Nat* struggles with inconvenient and unreliable water access on campus. Lack of confidence in water quality from campus dispensers emerges as a significant barrier to sustainable choices. Difficulty in locating functional dispensers highlights infrastructure and information gaps, while frequent out-of-service machines create frustration, driving users towards less sustainable options. By focusing on *Nat's* experiences, we gained invaluable insights into the intricate decision-making processes that influence sustainable behaviors on campus. The use of *Nat* as a guiding persona significantly enhanced our design process. It helped prioritize crucial features like real-time quality monitoring and dispenser location services. *Nat's* preferences informed the app's interface design, ensuring it resonates with our target users. Understanding Nat's motivations allowed us to incorporate effective nudges toward sustainable choices, and Nat's profile helped us preemptively address potential barriers to app adoption and consistent use.

Figure 5 presents a visual representation of *Nat's* persona, encapsulating the key attributes that guided our design decisions. This persona-centric approach represents a significant advancement in applying user experience design principles to sustainability challenges. By humanizing our data and grounding our solutions in real user needs and behaviors, we have created an app that not only addresses practical water access issues but also effectively promotes sustainable practices. This methodology demonstrates the potential of integrating UX design techniques with environmental behavior studies, offering a model for developing user-centric solutions to complex sustainability challenges.

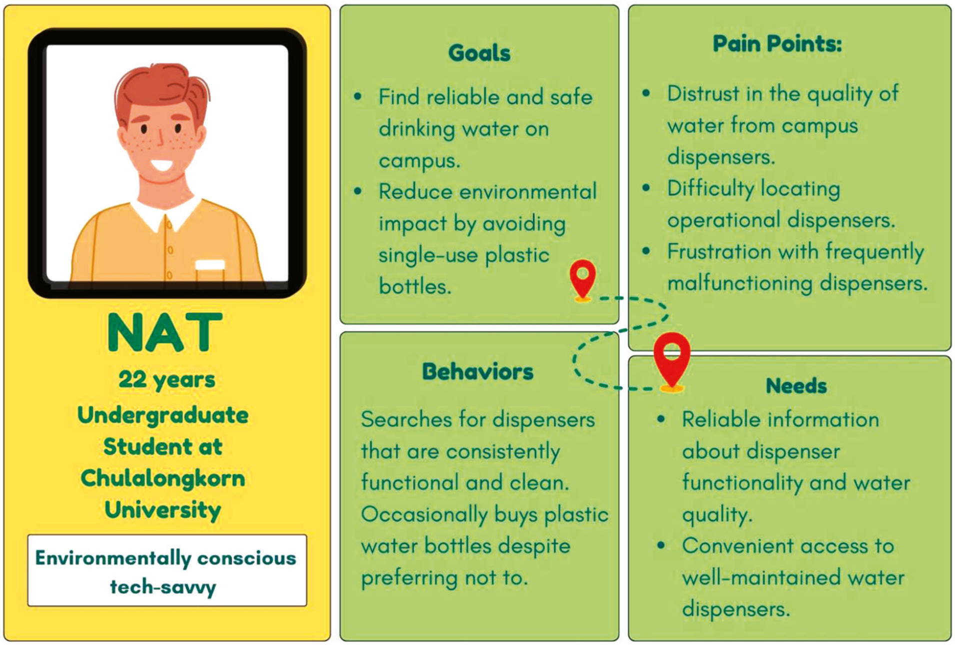

Figure 5 : Persona of the WaterMap System.

Customer Journey Map

We developed a comprehensive customer journey map (see Figure 6) to analyze the interactions between user behavior and sustainable practices on campus. This map integrates traditional UX methodologies with environmental psychology, offering insights into the barriers to adopting eco-friendly habits. Our map centers on *Nat*, a 22-year-old undergraduate at Chulalongkorn University, whose daily experiences highlight the challenges environmentally conscious students face. *Nat* starts each day intending to use his reusable water bottle, but often has to buy single-use plastic bottles due to unreliable campus water dispensers. This disconnect between intention and action underscores how infrastructure issues can hinder sustainable practices.

Nat's frequent encounters with out-of-service or poorly maintained dispensers not only waste his time but also cause disappointment and ethical conflict. The lack of reliable water sources poses a significant barrier, shaking confidence in sustainable options and making hydration a daily struggle that competes with his academic priorities. By mapping these touchpoints, we identified critical areas where technology could bridge the gap between environmental intentions and actions. Our analysis shows that sustainable behavior is deeply influenced by systemic factors, not just individual choice.

This customer journey mapping approach marks a significant advancement in applying UX design principles to address sustainability challenges in higher education. It provides a nuanced understanding of the user experience, facilitating the creation of effective, user-centric solutions to complex environmental issues. Our methodology serves as a replicable model for institutions aiming to promote sustainable behaviors through technological interventions, contributing to broader sustainability goals in education and beyond.

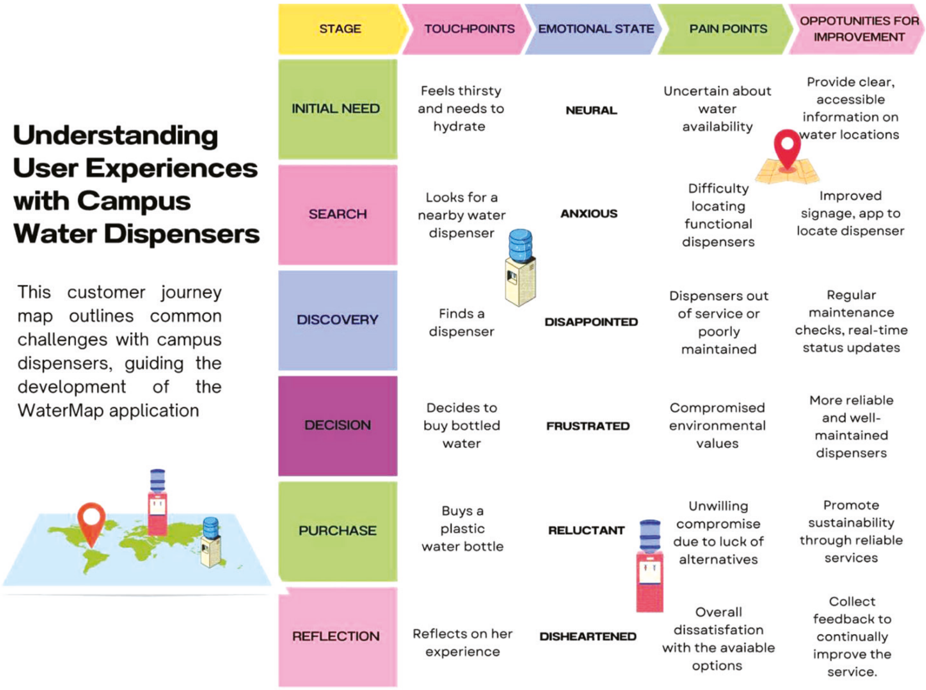

Figure 6 : Customer Journey Map of the WaterMap System.

System Features and Functionalities

In the development of the WaterMap app, our design team meticulously mapped specific user needs to corresponding system functionalities to ensure an intuitive and efficient user experience. Recognizing the need for convenience, the app includes a feature for locating nearby water dispensers, allowing users to quickly find the closest available sources without unnecessary hassle. To address concerns about trust, which primarily stem from doubts about water purity, the app integrates a real-time water quality check functionality, providing users with instant data on the safety and drinkability of water from any dispenser on campus. Additionally, acknowledging the necessity for accessibility, the system offers a real-time water level check to ensure that users are informed of the availability of water at these locations, thereby avoiding the frustration of finding empty dispensers. To foster behavior change towards sustainable practices, the app includes a gamified refilling process where users earn points for each refill, which can be further engaged through in-app games, making the act of refilling both fun and rewarding. Moreover, to enhance motivation and prolong engagement with the app, users can trade the points they accumulate for items from a range of merchandise, incentivizing continued use through tangible rewards. As shown in Table 2, this strategic alignment of user needs with functional features is pivotal in driving the adoption and sustained use of the *WaterMap* app, ultimately contributing to a reduction in single-use plastic bottle consumption on campus.

Table 2 : Mapping User Needs and System's Functionalities

User's Needs	System's Functionalities
Convenience	Locating nearby water dispensers
Trust	Real-time water quality check
Accessibility	Real-time water level check
Behaviour Change	Gamified refilling process
Motivation	Earning points and trading for merchandise

SWOT Analysis

A SWOT analysis serves as a cornerstone of strategic planning, offering pivotal insights into the internal strengths and weaknesses of a project, alongside external opportunities and threats (Helms & Nixon, 2010). This analysis informs critical decision-making processes, enhances performance, guides strategic directions, and bolsters competitive edges.

The *WaterMap* mobile application exemplifies the exceptional application of User-Centered Design (UCD) principles, guaranteeing a product finely tuned to user expectations and satisfaction. By providing real-time updates on water dispensers and water quality, the application directly addresses and alleviates user concerns regarding reliability and accessibility. Moreover, the incorporation of gamification elements incentivizes sustainable practices such as refilling water bottles, thus fostering user engagement while promoting environmental stewardship. Dependence on continuous internet connectivity and optimal performance of IoT devices constitutes a notable vulnerability, particularly in regions with unreliable technological infrastructures. The application's success hinges on user acceptance and integration into daily routines, posing a risk of initial skepticism or resistance to adoption. Additionally, ongoing maintenance and updates are imperative to preserve functional integrity and security, which could impose substantial resource demands.

WaterMap presents substantial growth prospects, extendable to other educational campuses and public venues both domestically and globally. Strategic partnerships with environmental NGOs and technology firms could augment app functionality and scalability. Future iterations of the app could integrate enhanced community engagement features, advanced water quality analytics, and synergies with other health and sustainability applications, broadening its utility and user base. Technical disruptions or inconsistencies in-app or IoT sensor performance can significantly impair user trust and diminish app engagement. The competitive landscape presents another challenge; emergent applications with comparable or superior functionalities could capture *WaterMap's* market share. Additionally, evolving digital privacy laws and environmental regulations may impose new compliance burdens, impacting operational modalities. Table 3 encapsulates the SWOT analysis for the *WaterMap* application, outlining strategic insights essential for navigating the complexities of technological integration in environmental sustainability initiatives.

Table 3 : SWOT Analysis

User's Needs	System's Functionalities
Strengths	User-Centered Design Real-time updates on water dispenser status and water quality Gamification to encourage sustainable behaviors Extensive user research
Weakness	Dependence on technology and connectivity Requires high user adoption rate Needs continuous maintenance and updates
Opportunities	Potential for expansion to other educational institutions and public spaces Opportunities for partnerships and collaborations Possibility to add advanced features in future updates
Threats	Risk of technical failures impacting user trust Competition from other apps Potential regulatory changes affecting operations

System Architecture

The *WaterMap* system represents an innovative approach to water quality monitoring and distribution, leveraging cutting-edge IoT technology, cloud computing, and mobile applications. At its core, the system is built around a decentralized water tank infrastructure, equipped with advanced sensors for real-time monitoring of water quality and levels. The primary data collection occurs at the decentralized water tank, which is fitted with a Proteus water quality sensor. This sophisticated device continuously monitors various water quality parameters, ensuring that the water meets the required standards at all times. Connected to this central tank are multiple water dispensers, each equipped with a Holykell H2600 sensor. These sensors provide real-time data on water levels within each dispenser, enabling efficient management of water distribution and refilling processes. The system's data processing and storage layer is built on a robust cloud infrastructure. The Proteus sensor data is initially aggregated by the Adroit Platform, which serves as a preliminary processing point. From there, the data is transmitted to the AWS Cloud, which acts as the central hub for data storage and advanced processing. The Holykell sensor data, meanwhile, is sent directly to the AWS Cloud, likely through a local processing unit. An API Gateway facilitates secure and efficient data transmission between these various components, ensuring that real-time information is always available for analysis and user access.

The presentation layer of the *WaterMap* system is primarily embodied in its mobile application. This user-friendly interface serves as the primary point of interaction for end-users, offering a range of features designed to enhance the water consumption experience. Through the app, users can locate nearby water dispensers, check real-time water quality metrics, and monitor water availability levels. The app also incorporates gamification elements to encourage sustainable water use practices. Users can earn points by scanning QR codes at water dispensers, which can then be exchanged for products from business partners or used within the app for virtual pet features. From a business perspective, the *WaterMap* system incorporates several innovative elements. It supports both in-app and physical advertisements, creating revenue streams while promoting eco-friendly products from business partners. The system also allows for partnerships with businesses to provide exclusive water dispensers, further expanding its reach and impact. All user transactions and important system data are recorded in an AWS-based database, enabling comprehensive data analytics for continuous improvement and business intelligence.

The *WaterMap* system architecture features an administrator interface that enables efficient ecosystem management and monitoring, ensuring swift issue resolution to maintain service quality and user satisfaction. Future expansions include plans for IoT-based water bottle storage lockers, highlighting the system's capacity for growth and adaptation. The *WaterMap* system embodies a comprehensive approach to water management, utilizing a 3-tier architecture for scalability and maintainability. It integrates IoT sensors, cloud computing, and mobile technology to deliver a seamless user experience focused on water quality and accessibility. This proactive strategy positions *WaterMap* as an innovative solution to contemporary water distribution challenges. Figure 7 illustrates the system's overall architecture.

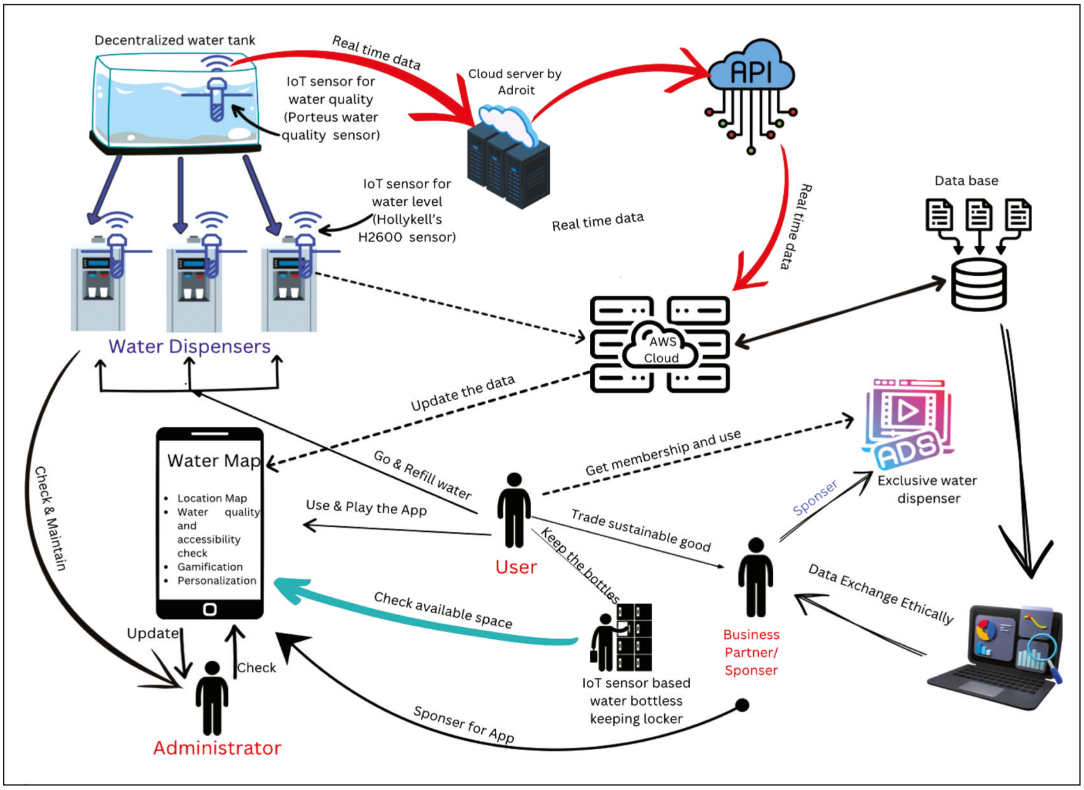

Figure 7 : System Architecture of the WaterMap System.

System Development

The *WaterMap* system integrates advanced technologies to deliver an efficient, scalable, and user-friendly experience for monitoring and distributing water quality. At the core of its architecture, the mobile application uses React Native for cross-platform functionality across Android and iOS, enhancing the user interface with Material-UI for its consistent and intuitive components. On the server side, the system is powered by Node.js, capable of handling high concurrency for real-time data processing, with Express.js to optimize API responses and server-side logic. AWS services, including RDS for scalable database management and EC2 and S3 for computing and data storage, support robust data integrity and extensive processing needs. Data from IoT sensors, including Proteus water quality sensors and Holykell H2600 water level sensors, is initially processed through the Adroit Platform, then further handled by AWS. The MQTT protocol ensures efficient real-time data transmission. System API communications are managed via AWS API Gateway, maintaining secure, reliable data flow. The application also incorporates gamification to encourage sustainable water use. The backend uses MongoDB for non-relational data about user interactions and rewards, while Redux within React Native manages app state across complex interactions. Overall, the *WaterMap* system's development involves a strategic combination of technologies and frameworks to optimize functionality, user engagement, and future scalability..

User Interface Design

The user interface (UI) of the WaterMap app is designed using foundational principles from user experience (UX) theory to ensure clarity, efficiency, and user engagement at Chulalongkorn University. Key design laws—Fitts's, Hick's, and Miller's—along with Nielsen's 10 Usability Heuristics, collectively shape the interface and user journey (see Figure 8–10). The landing page features a clean layout with a prominent logo and tagline ("Refill & Play"), employing Fitts's Law to make touch targets like search bars easily accessible (Yablonski, 2020).

Upon launch, users are presented with a map-centric interface that dynamically displays nearby dispensers based on GPS. This screen applies Hick's Law, minimizing cognitive load by simplifying choices and prioritizing relevant data such as location, distance, and dispenser status (Yablonski, 2020). Tapping a dispenser opens a detailed view (see Figure 9), displaying photos, water quality metrics, reviews, and gamification options. Miller's Law guides this screen by chunking information for easier retention (Yablonski, 2020).

Gamification is integrated via a QR code scanning feature located on physical dispensers (see Figure 10), encouraging repeated engagement and reinforcing sustainable behavior. This interaction is grounded in both Fitts's Law (quick, efficient actions) and Nielsen's heuristics, including feedback, error prevention, and user control. Operational status indicators (e.g., available/unavailable) help users avoid non-functional stations, improving satisfaction and minimizing friction.

The user interface of the WaterMap app is grounded in a theoretical framework that integrates key usability principles to enhance interaction, engagement, and behavioral outcomes. Specifically, Fitts's Law supports the design of easily tappable interface elements by optimizing target size and placement for faster user action (Yablonski, 2020). Hick's Law informs the streamlined navigation structure, reducing cognitive load by limiting visible choices on screen, particularly in the map and menu layouts. Miller's Law guides the organization of information—such as dispenser details and water quality metrics—into manageable chunks to improve user retention and understanding. Complementing these, Nielsen's 10 Usability Heuristics ensure intuitive interaction through consistent feedback, error prevention, and a minimalist visual design that maintains clarity and user control throughout the app. Collectively, these principles form the foundation of a user-centered interface that promotes ease of use, trust in water quality data, and engagement with gamified sustainability features

Overall, the app follows a user-centered design framework grounded in usability theory. As shown in Figure A, these UX principles collectively ensure intuitive navigation, real-time utility, and sustainability reinforcement through gamified behavior.

Table 4 : User Interface Design Heuristics and Laws

Heuristics and UX Laws	Guidelines
Nielsen's 10 Usability Heuristics	• Visibility of system status • Match between the system and the real world • User control and freedom • Consistency and standards • Error prevention • Recognition rather than recall • Flexibility and efficiency of use • Aesthetic and minimalist design • Help users recognize, diagnose, and recover from errors • Help and documentation

Table 4 : User Interface Design Heuristics and Laws (Contiuned)

Heuristics and UX Laws	Guidelines
Fitts's Law	• Fitts's Law states that the time required to rapidly move to a target area is a function of the ratio between the distance to the target and the width of the target.
Hick's Law	• Hick's Law states that the time it takes to make a decision increases logarithmically with the number of choices available.
Miller's Law	• Miller's Law states that the average person can hold 7 (plus or minus 2) items in their working memory.

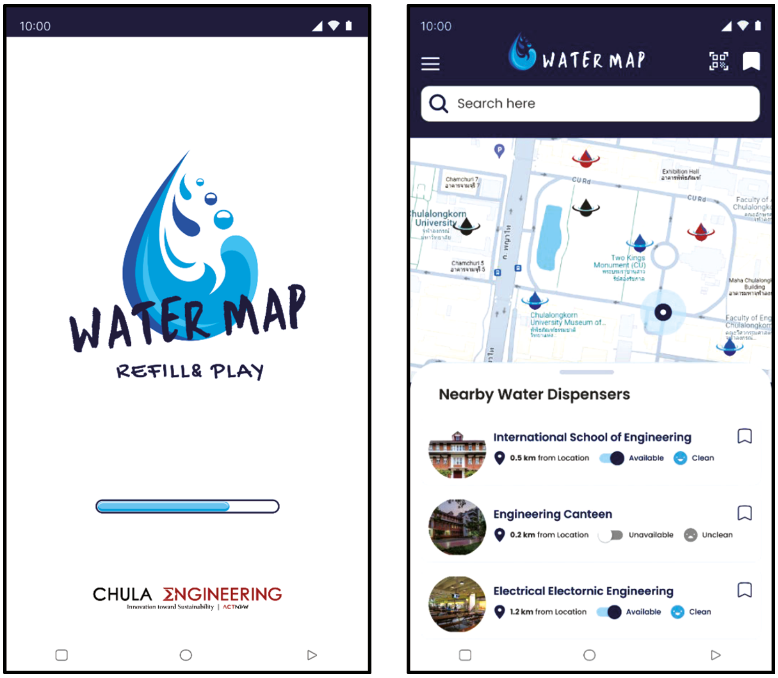

Figure 8 : Landing Page (Left) and Map Visualization with Nearby Water Dispensers (Right).

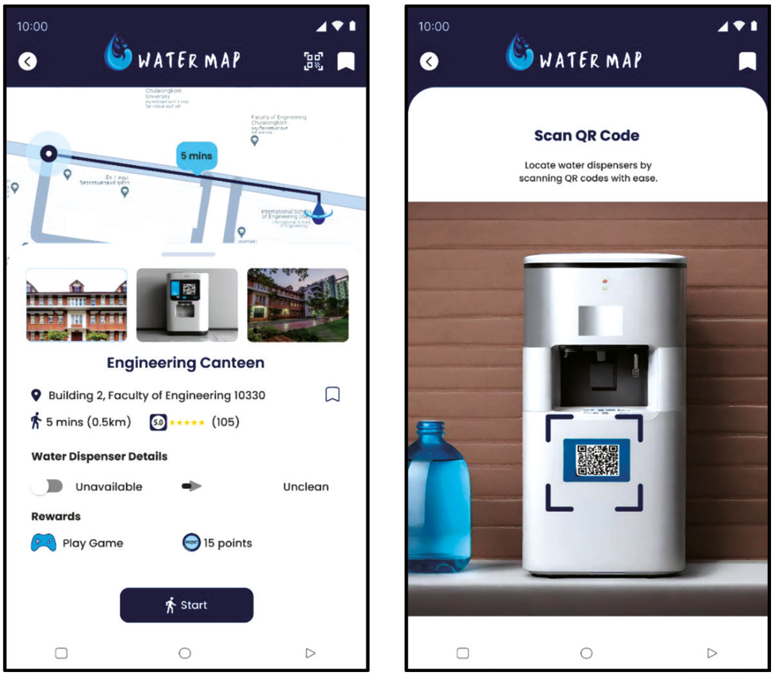

Figure 9 : Detailed Water Dispenser Page (Left) and a Sample Image of Physical Water Dispenser (Right).

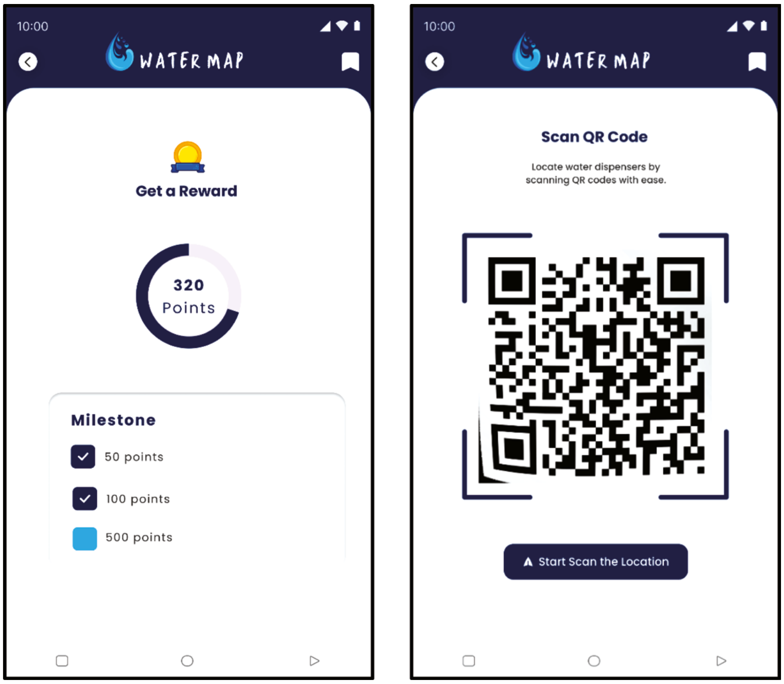

Figure 10 : Gamification Page (Left) and QR Code (Right).

Method

We conducted a mixed-methods usability evaluation of the *WaterMap* system among students at Chulalongkorn University. Participants (N=17) were recruited through targeted posts on the university's official social media pages using purposive sampling. Inclusion criteria required participants to be aged 18–55 and have prior experience using mobile applications, ensuring a diverse and relevant user base. The evaluation was structured into three phases: pre-test, in-test, and post-test.

In the pre-test phase, participants received a 10-minute briefing on the study's objectives and completed a short demographic and behavioral survey covering age, gender, water consumption habits, and use of single-use versus reusable bottles.

The in-test phase (approximately 20 minutes) involved interacting with *WaterMap* to complete specific tasks: locating nearby water dispensers, checking real-time water quality and availability, viewing dispenser details, scanning QR codes to earn points, and providing feedback on dispenser performance (see Figure 11).

Quantitative data were collected through a 15-item structured questionnaire delivered via Google Forms, using a 5-point Likert scale to assess usability, usefulness, and user experience. The questionnaire was developed collaboratively with environmentalists, software engineers, and business researchers to ensure cross-disciplinary relevance and content validity. Responses were analyzed using descriptive statistics to compute mean scores and identify patterns in system usability.

For the qualitative component, all 17 participants also engaged in a brief (15-minute) post-task interview. These interviews served to gather deeper feedback on user perceptions, satisfaction, and perceived impact. Thematic analysis was used to code and extract recurring insights. Themes were verified through investigator triangulation, where at least two researchers independently reviewed and discussed coding results to enhance reliability.

All procedures followed Chulalongkorn University's ethical guidelines. Participants provided informed consent, were assured of confidentiality, and were free to withdraw at any time. This dual-method approach enabled a robust evaluation of WaterMap’s functionality and user alignment. Table 5 summarizes the testing sequence, while Figure 11 illustrates a participant in the evaluation process.

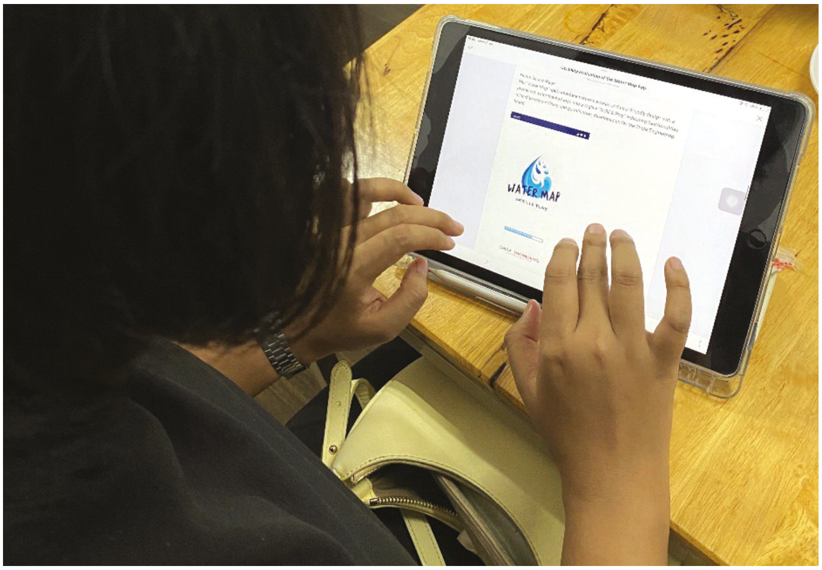

Figure 11 : Usability Test Session with a Participant.

Table 5 : Usability Testing Design and Procedures

Steps	Task	Duration
1. Pre-Test	1.1 Introduction to the test and the WaterMap app 1.2 Pre-test questionnaires (e.g., age, gender, behaviours)	10 minutes
2. In-Test	2.1 Test and evaluate the landing page 2.2 Test and evaluate the function of 'locating nearby water dispensers' 2.3 Test and evaluate the function 'water dispenser detailed page' 2.4 Test and evaluate the function 'scan QR code and earn points'	20 minutes
3. Post-Test	3.1 Answer the questionnaires about the usability, usefulness, and user experience 3.2 Answer open-ended interview questions	15 minutes

Results

This section presents the findings from the usability evaluation of the *WaterMap* prototype, combining quantitative metrics and qualitative insights to assess user interaction, satisfaction, and system effectiveness among Chulalongkorn University students.

Quantitative Analysis and Findings

The sample included 17 participants, a number determined based on Nielsen's (2000) usability principle that testing with 5-20 users can uncover the majority of usability issues. Graduate students formed the largest group (64.71%, *N*=11), followed by equal representation from postgraduate and undergraduate levels (each 17.65%, *N*=3). The gender distribution skewed female (58.8%, *N*=10), with an average participant age of 27.18 years. Academic affiliations were diverse, mainly from engineering and sciences, with strong representation from the Graduate School (*N*=6) and Civil Engineering (*N*=4).

Participants demonstrated strong environmental awareness: 52.9% (*N*=9) reported high awareness of plastic waste issues, and 70.6% (*N*=12) preferred reusable bottles. Trust in water quality from campus dispensers was moderate for most (76.5%, *N*=13), with small groups expressing full trust or distrust (11.8%, *N*=2 each). Most found dispenser access either very (41.2%, *N*=7) or somewhat convenient (52.9%, *N*=9), suggesting generally effective infrastructure.

Sustainable hydration habits were notable: 88.2% (*N*=15) frequently or always refilled their bottles. The usability survey results were positive overall. Participants rated the system layout favorably (M=4.18, SD=0.9), with 47.06% (*N*=8) strongly agreeing on ease of understanding. Navigation was also rated highly (M=4.12, SD=0.9), though 29.4% (*N*=5) remained neutral, and 5.9% (*N*=1) disagreed, indicating minor areas for improvement.

Instructions and labels were well-received (M=4.3, SD=0.8), and users found key features such as dispenser location and water quality monitoring easy to access (M=4.05, SD=0.8). The app largely met their needs (M=4.1, SD=0.9), and water quality information features were also positively reviewed (M=4.1, SD=0.7).

Users reported that WaterMap supported daily refilling routines (M=4.12, SD=0.7) and had potential to reduce plastic bottle usage (M=4.40, SD=0.9), with 64.71% (*N*=11) strongly agreeing on the latter. Regular usage intention scored moderately (M=3.94, SD=0.9), suggesting areas to explore for increasing user retention.

Gamification was seen as engaging (M=3.70, SD=0.7), though 29.41% (*N*=5) were neutral, pointing to opportunities for refinement. Recommendations were strong (M=4.29, SD=0.9), with 58.82% (*N*=10) strongly endorsing the system. Relevance to campus issues scored well (M=4.05, SD=0.9), and the majority viewed WaterMap as necessary for students (M=4.11, SD=1.1). Willingness to learn how to use the app (M=4.17, SD=1.0) and overall satisfaction (M=4.23, SD=0.9) were both high.

In summary, *WaterMap* was positively received, with strong recognition of its potential to improve sustainability and water access on campus. While a few areas—like feature accessibility, gamification appeal, and navigation—may benefit from further refinement, the findings support its overall usability and value. Table 6 presents summarized usability testing results.

Table 6 : Questionnaire Items and Results

Questionnaire Items	M	SD	Strongly Agree (5)	Agree (4)	Neutral (3)	Disagree (2)	Strongly Disagree (1)
Q1: Layout and design simplicity	4.17	0.88	47.0%	23.53%	29.41%	0.00%	0.00%
Q2: Interface ease of navigation	4.11	0.90	47.06%	23.53%	23.53%	5.88%	0.00%
Q3: Clarity of instructions and labels	4.29	0.84	52.94%	23.53%	23.53%	0.00%	0.00%
Q4: Ease of locating features	4.05	0.84	35.29%	35.29%	29.41%	0.00%	0.00%
Q5: Meeting dispenser finding needs	4.05	0.96	41.18%	29.41%	23.53%	5.88%	0.00%
Q6: Meeting water quality information needs	4.05	0.74	29.41%	47.06%	23.53%	0.00%	0.00%
Q7: Helpfulness for daily refilling	4.11	0.78	35.29%	41.18%	23.53%	0.00%	0.00%
Q8: Potential to reduce plastic bottle use	4.35	0.99	64.71%	11.76%	17.65%	5.88%	0.00%
Q9: Likelihood of regular use	3.94	0.96	35.29%	29.41%	29.41%	5.88%	0.00%
Q10: Appeal of gamification features	3.70	0.77	11.76%	52.94%	29.41%	5.88%	0.00%
Q11: Recommendation likelihood	4.29	0.98	58.82%	17.65%	17.65%	5.88%	0.00%
Q12: Addressing campus issues	4.05	0.96	41.18%	29.41%	23.53%	5.88%	0.00%
Q13: Necessity for students	4.11	1.16	52.94%	17.65%	23.53%	0.00%	5.88%
Q14: Willingness to learn usage	4.17	1.01	52.94%	17.65%	23.53%	5.88%	0.00%
Q15: Overall satisfaction with the system	4.23	0.97	52.94%	23.53%	17.65%	5.88%	0.00%

Qualitative Analysis and Findings

The qualitative data were analyzed using thematic analysis, following Braun and Clarke's (2006) six-phase approach: familiarization with data, generating initial codes, searching for themes, reviewing themes, defining and naming themes, and producing the report. Two researchers independently coded the interview transcripts, followed by collaborative review sessions to reach agreement on major themes, ensuring analytical rigor and inter-coder reliability. Quotes were selected to represent key themes and provide participant voice in the findings. The analysis revealed several core themes related to the usability, suggested improvements, and perceived impact of the WaterMap system on campus life.

Participants praised the system's ease of access and integration into daily routines. One user noted that it is "Easy and convenient to access one of my necessary routines," emphasizing how naturally the app supports habitual behaviors. The strategic placement of dispensers was frequently mentioned as a strength, highlighting the system's practical utility.

Environmental sustainability emerged as a dominant theme. Users valued the system's role in promoting eco-friendly behavior, especially in reducing plastic use. One remarked it is "more supportive to reduce the plastic bottle usage," indicating alignment with growing ecological consciousness.

The app's innovative features, particularly QR code scanning, were seen as engaging and efficient. As one participant shared, "I like the QR code scanning feature the most because it's quick and easy," underscoring the appreciation for technology that simplifies sustainability actions.

Language accessibility was a notable concern, with users requesting multi-language functionality. One user suggested it "would be better if put multi-language in Water Map system," signaling the need to accommodate non-Thai speakers on an international campus.

Motivational feedback was also frequently recommended. Participants desired features that visualize their impact—e.g., "Should encourage the users by showing the 'amount of plastic saved'"—to increase engagement and reinforce sustainable behaviors. Personalization features were requested, such as alerts on water quality and hydration tracking, suggesting users want tools that combine environmental and health benefits.

Economic and ecological value was a recurring theme. A participant noted it offers "Environmental friendly and economical savings," reflecting the system's alignment with both environmental and financial goals of users.

Finally, education and awareness were highlighted. Participants viewed the app not only as a functional tool but also as a platform for promoting environmental consciousness. Its integration into daily routines was seen as a way to "foster a more informed and environmentally conscious community," suggesting long-term cultural impact.

These themes—ease of use, environmental support, innovation, inclusivity, motivational feedback, personalization, and broader educational value—were refined through iterative review and validated by triangulating participant quotes, coder agreement, and relevance to the system's objectives.

In summary, the expanded qualitative findings complement the quantitative results by offering richer insights into how users experience and perceive the WaterMap system. Users recognize its practicality and sustainability value while expressing a need for enhanced personalization, inclusivity, and engagement strategies. These perspectives point to actionable directions for system refinement and broader implementation.

Discussion

The findings from this study offer valuable insights into the potential of user-centric mobile applications to promote sustainable behaviors in university settings, particularly in addressing the pressing issue of single-use plastic water bottle consumption. The *WaterMap* system, developed and tested at Chulalongkorn University, demonstrates the power of combining technological innovation with environmental awareness to create meaningful change in daily habits.

The overall positive reception of *WaterMap* underscores a growing readiness among young adults to embrace digital tools that align with environmental values—particularly relevant in Southeast Asia, where plastic pollution is a critical issue. Participants appreciated modern features like QR code scanning, suggesting that integrating sustainability initiatives with interactive technology can effectively engage users and encourage eco-friendly habits. These findings echo earlier studies (e.g., Yildiz & Coskun, 2019), which showed that feedback and engagement features support sustainable behavior. However, unlike previous studies such as Project Refill_H_2O (Mendes et al., 2021) or SmartOne (Vithanage et al., 2019), which focus on personal devices or localized dispenser networks, *WaterMap* uniquely combines real-time water quality updates, gamified engagement, and campus-wide dispenser mapping into one integrated platform tailored for a large-scale academic environment. This multidimensional approach—anchored in user-centered design—sets WaterMap apart by addressing not only functionality but also motivation, trust, and inclusivity.

The high environmental awareness observed among users reinforces *WaterMap's* alignment with user values and its potential as a catalyst for behavior change. The strong willingness to adopt and recommend the system indicates that such targeted interventions can effectively bridge the gap between awareness and action, supporting goals outlined in the United Nations' Sustainable Development Goals (United Nations, 2015).

While well-received, the mixed reactions to the app's gamification features reveal the complexity of designing universally engaging mechanisms. This finding aligns with Di Paolo & Pizziol (2024), who found that gamified tools need to be audience-specific. Future designs must tailor incentives and feedback to diverse motivations to maximize engagement.

Accessibility and inclusivity also emerged as critical factors. The need for multi-language support highlights the diversity within university communities and the necessity for broader language integration in environmental applications.

By integrating real-time data on water quality and dispenser locations, *WaterMap* tackles two key barriers to sustainable hydration: trust and convenience. This aligns with Coskun et al. (2021), who found that reliable feedback encourages behavior change—but *WaterMap* extends this by offering collective access, rather than personalized devices, making it more scalable and impactful.

In terms of the study's objectives, *WaterMap* successfully met its core aims. The app enabled easy discovery of dispensers, delivered real-time water quality info, and introduced gamified refill features. While gamification engagement was moderate, QR code integration and app architecture were highly effective. Usability testing confirmed that the system was intuitive and helpful, although some users desired additional personalization and language options.

This research contributes uniquely to the field by demonstrating how a comprehensive, campus-specific, user-designed app can outperform single-feature tools or regionally limited interventions. It provides a replicable model that could be implemented in similar institutions across Southeast Asia.

The findings suggest broader implications for policymakers and developers: digital platforms can successfully embed environmental behavior into everyday life if designed with user-centered principles. Nonetheless, the study's limitations—such as the lack of multilingual support and moderate enthusiasm for gamification—point to areas for refinement.

Future research should explore the long-term behavioral impact of *WaterMap* through longitudinal data and assess how similar systems could integrate with broader campus sustainability programs. Features like personalized hydration tracking, expanded reward systems, and user progress dashboards could further boost motivation.

In conclusion, *WaterMap* represents a promising direction in using mobile technology to combat plastic pollution. It advances the literature on sustainability-driven digital innovation and offers a scalable, adaptable model for engaging campus communities in everyday eco-conscious actions.

- Technology Integration: User-friendly apps like WaterMap can drive sustainable behaviors, particularly in reducing single-use plastic bottles in academic settings.
- Environmental Awareness: Strong ecological consciousness among students supports the adoption of sustainability-focused tools.
- Local Action, Global Impact: Focused, campus-based initiatives can scale to support international sustainability efforts.
- User-Centered Design: Empathetic, tailored design enhances usability, trust, and system adoption.
- Gamification Potential: Engagement strategies must be refined to appeal to diverse motivational profiles.

Conclusion

This study demonstrates the significant potential of user-centric mobile applications like WaterMap in addressing critical environmental challenges, particularly the reduction of single-use plastic water bottle consumption in university settings. Through its innovative integration of real-time information, gamification elements, and IoT technology, WaterMap successfully engages users in sustainable hydration practices, as evidenced by high user satisfaction and perceived potential for reducing plastic waste. The research contributes a novel, user-centered approach to promoting sustainable behaviors through mobile technology, offering insights into the readiness of young adults to adopt such solutions, especially in Southeast Asian contexts. However, it is important to note that the study evaluates usability, user experience, and perceived impact only; it does not directly measure actual reductions in single-use plastic bottle consumption. This limitation defines the scope of the research and points to the need for future behavioral and environmental impact assessments. While highlighting the importance of tailoring interventions to diverse user needs, the study provides a replicable model for localized sustainability initiatives with broader impact potential. As a significant step forward in applying user-centered design and mobile technology to environmental challenges, WaterMap offers valuable insights for policymakers, technology developers, and educational institutions. Future research should focus on longitudinal studies and exploring integration with broader sustainability efforts, paving the way for more comprehensive approaches to environmental stewardship in various settings and demonstrating the potential of targeted interventions to create far-reaching positive environmental impacts.

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