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Developing an automatic handwashing innovation for Thai preschool children

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ABSTRACT

Handwashing is vital in COVID-19 prevention and other infectious diseases. However, ensuring regular handwashing among children aged 3-5 proves challenging due to inconsistent compliance. This study aimed to develop and evaluate an automatic handwashing innovation for preschools, involving 13 executives from local organizations, a health-promoting hospital, and 77 children aged 3-5 from Khlong 6, Pathum Thani, Thailand. Evaluation tools included in-depth interview questionnaires, an automatic handwashing evaluation form, and preschool behavior assessment tools. Data collection methods included in-depth interviews and experimental group evaluations, with analysis involving content analysis, mean, and standard deviations. Findings indicated that: i) Caregivers struggle to consistently supervise children's handwashing, particularly before meals, after bathroom use, and when touching public surfaces; ii) The automatic handwashing innovation effectively caters to the community's needs in early childhood care; and iii) The design of this innovation should prioritize elements that enhance children's enjoyment and safety. The final prototype is a screen-based system that demonstrates automated handwashing. It features a bear character who guides the handwashing techniques and music for three minutes. Post-implementation, preschoolers demonstrated improved independent handwashing skills, achieving high scores (X=1.87, SD=0.212). Future advancements in this area should continue focusing on child-centric design to promote early childhood hand hygiene effectively.

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1. INTRODUCTION

The COVID-19 pandemic remains a profound global challenge, with its persistent transmission continuing to pose a significant threat to public health [1]. Despite widespread efforts to distribute vaccines, children aged 0-5, a particularly vulnerable demographic, are excluded from vaccination programs due to safety concerns [2]. This gap underscores the urgent need for innovative strategies to safeguard this age group from the virus. This research focuses on the Khlong 6 sub-district of Pathum Thani Province, Thailand, a local context where children predominantly attend local child development centers and primary schools. This community has two child development centers and two primary schools serving over 100 children aged 3-5 years [3]. Data from surveys conducted between 2019 and 2021 indicate that 5.60% of these children

have contracted COVID-19 [4]. Parental interviews have identified familial contacts and interactions within educational settings as the primary transmission sources. Many early childhood COVID-19 cases have been linked to non-compliance with disease control measures, including mask-wearing, physical distancing, and handwashing [5].

Handwashing is critical in reducing the spread of COVID-19 and other infectious diseases [6]. However, preschool-aged children (3-5 years old) often face challenges in adhering to proper handwashing practices due to developmental factors [7]. Research has demonstrated that targeted educational interventions can enhance handwashing habits among young children. For instance, role-playing activities in experimental groups have significantly increased the frequency and accuracy of handwashing compared to control groups [8]. Additionally, multicomponent handwashing interventions have proven effective in improving handwashing accuracy and cleanliness in preschoolers [9]. In Thailand, existing studies have primarily focused on enhancing handwashing practices through parental and caregiver education, with limited exploration into innovations directly targeting children's behavior. This study addresses this gap by developing an innovative automatic handwashing device for preschool children. This prototype aims to make hand hygiene engaging and enjoyable, promoting consistent handwashing practices and fostering lifelong hygiene habits.

The design of this automatic handwashing innovation is informed by early childhood perception and learning theories. Given that preschool children possess rapid learning capabilities [10], the device is intended to offer a hands-on experience that effectively communicates hygiene practices. The approach is designed to integrate seamlessly into local child development centers, making handwashing a regular part of preschool activities. By encouraging consistent handwashing, the innovation not only addresses COVID-19 risks but also supports the establishment of enduring hygiene habits [11].

Furthermore, efforts are being made to train childcare workers and health volunteers in the Khlong 6 community to use and maintain this innovation effectively. Caretakers play a vital role in facilitating its use and reinforcing positive behaviors [12]. This collaborative approach ensures sustainable practices in promoting hygiene among preschool children. The automatic handwashing device represents a proactive strategy to address the unique challenges of enhancing hygiene practices in young children during the COVID-19 pandemic. By leveraging principles of early childhood learning, this innovation aims to foster significant behavioral changes that contribute to community health resilience. Ongoing research and community engagement will be essential for optimizing its effectiveness and broadening its impact in similar contexts.

2. METHOD

The research follows the Innovation Research and Development framework [13], structured into four main steps:

2.1. Step 1: Exploring innovation requirements

This initial phase aims to identify and understand the specific needs and requirements for developing an automatic handwashing innovation tailored for preschool children. It focuses on childcare workers and educators at child development centers in the Khlong 6 sub-district, Thanyaburi, Pathum Thani Province. A purposive sampling method was employed to select thirteen executives from local sub-district service organizations and the sub-district health-promoting hospital as participants. In-depth interviews were conducted with these participants until data saturation was achieved [14].

2.1.1. Instrument

In-depth interview guide: The interview guide was adapted from a previously used methodology to gather parental opinions on preschool children's health during the COVID-19 outbreak 2019 [15]. The interview questions focused on the following areas: i) challenges related to hand hygiene for preschool children, ii) desired features and design elements for an automatic handwashing innovation, and iii) guidelines for developing such innovations tailored to young children. Three experts in the field, including two child and adolescent nursing lecturers and one pediatric physician, reviewed the interview guide to ensure its content validity. Based on their feedback, revisions were made to enhance the guide's effectiveness before it was used for individual interviews with each participant.

2.1.2. Data analysis

Content analysis: The qualitative data from the in-depth interviews were analyzed using content analysis techniques. This process involved systematically examining the data to extract rich insights and perspectives related to the requirements for handwashing innovation. Both inductive and deductive coding were used to ensure a thorough understanding of participants' perspectives.

2.2. Step 2: Creation and development of the innovation

This phase focuses on designing and developing an automatic handwashing innovation tailored to the specific needs of preschool children. The goal is to create a functional prototype that engages children and meets their developmental requirements following data given from step 1. Step 2 processes include:

2.2.1. Development process

The design began with a comprehensive review of relevant concepts, theories, and existing research, complemented by consultations with early childhood experts. This foundational work guided the development of an innovation that effectively addresses the needs identified in Step 1. Key principles from child development and health education were integrated to ensure the solution is age-appropriate and practical. Expert feedback further refined the design for real-world use.

2.2.2. Prototype development

The innovation integrates media and technology to capture children's interest and make handwashing enjoyable. Two 3-minute clips featuring singing and dancing cartoon bears were created. Cartoon bears were designed to foster a friendly and non-threatening environment, promoting positive handwashing behavior. Expert Guidance from Rajamangala University of Technology Thanyaburi was instrumental in refining critical features of the innovation to meet essential childcare needs.

2.2.3. Design features

The monitor size was chosen to be visually engaging and age-appropriate for preschool children [16]. The design accommodates varying heights within the target age group to ensure accessibility for all children. The handwashing station includes sensors and has passed safety inspections, confirming that it is safe for children.

2.2.4. Technological integration

When children enter the bathroom, a sensor at the entrance activates a video emphasizing the importance of handwashing. Another sensor triggers the water and soap dispensers as a child approaches. A child-safe infrared sensor activates the instructional video on proper handwashing techniques, ensuring interaction without physical contact [17].

2.3. Step 3: Prototype testing

The final prototype includes two engaging video clips, each under 3 minutes, featuring cartoon bears that sing and dance to promote handwashing. The Automatic Handwashing system includes sensors that automatically activate video content, water, and soap, ensuring a seamless and interactive experience. Design adjustments enhance child accessibility and comfort.

2.3.1. Instrument

The evaluation form for the automatic handwashing innovation was adapted from a framework assessing achievement motivation in children's art media production [18]. This form, designed to evaluate multimedia integration, consisted of 19 items. Again, three experts reviewed the form for accuracy and appropriateness, achieving a content validity index (CVI) of 0.89. Based on their feedback, the form was revised. The form was a reliability test administered to a non-sample group of 30 individuals, yielding a Cronbach's alpha coefficient of 0.88.

2.3.2. Validation and refinement prototype

- Assessment

The innovation was evaluated by experts in computer science, early childhood care, and pediatric nursing lectures. The mean evaluation results indicated high satisfaction (M = 3.71, SD = 0.342). Expert feedback led to further refinements to optimize the innovation.

- Trial

The prototype was tested with ten preschool children (five females and five males, aged 3-5). Teachers reported high satisfaction with the prototype (M = 1.80, SD = 0.263), noting effective engagement and usability. Children engaged enthusiastically with the prototype and followed the handwashing steps with minimal guidance. Teachers noted its classroom suitability and potential to promote hygiene in a fun, accessible way.

- Refinement based on feedback

The video was modified to include a segment where children press a button to dispense soap, demonstrating proper handwashing techniques. The monitor's angle was adjusted to reduce children's neck strain.

The water flow was fine-tuned to minimize splashing and maintain cleanliness. A catchphrase for children to use after hand drying was added, encouraging frequent handwashing. These refinements aimed to enhance the innovation's overall effectiveness and ensure it meets the practical needs of both children and educators.

2.4. Step 4: Examining behavior associated with using the innovation

This step aims to evaluate the impact of automatic handwashing innovation on preschool children's handwashing behavior over eight weeks.

2.4.1. Procedure

- Week 1: The research team trained teachers on using the automatic handwashing innovation and observed preschool children's handwashing behavior to establish a baseline.
- Week 2-7: Teachers supervised and facilitated the automatic handwashing innovation at the child development center. This period allowed regular observation of the children's interaction with the innovation and their handwashing habits.
- Week 8: Teachers completed the children's handwashing behavior assessment form to evaluate the children's handwashing behavior while using the innovation.

2.4.2. Sample

The study sample included 77 preschool children from the following institutions in the Khlong 6 subdistrict, Thanyaburi District, Pathum Thani Province, including the child development center at Wat Phalahan School and Wat Wan Bun School. The participants were aged 3-5 years. Purposive sampling was employed, guided by specific inclusion and exclusion criteria to ensure a representative sample.

- Sample size calculation

The sample size was determined using the G*Power program with a t-test, an effect size set at 0.40, and a significance level (α) of 0.05 [19]. The desired power (1 - β) was 0.95, with degrees of freedom (df) = 69. The calculations indicated a required sample size of 70 children. To account for potential data loss, 77 preschool children were included in the study.

2.4.3. Instrument

Children's Handwashing Behavior Assessment Form was adapted from a 7-step handwashing evaluation to include 14 items specifically designed to assess handwashing activities among preschool children. Three experts reviewed the form for content validity, achieving a content validity index (CVI) of 0.92. Based on expert feedback, revisions were made. The form was tested on a non-sample group of 30 individuals, resulting in a Cronbach's alpha coefficient of 0.90, indicating high internal consistency.

2.4.4. Data analysis

Descriptive statistics, including mean and standard deviation, were used to analyze the preschool children's handwashing behavior using the automatic handwashing innovation. This analysis provided insights into the innovation's effectiveness in improving handwashing practices among children. These findings highlight the potential of the prototype to influence hygiene practices in early childhood settings positively.

3. RESULTS AND DISCUSSION

This research is divided into two sections following the study's method. The first section presents the view of healthcare workers on handwashing innovation issues and other issues related to preschool children's handwashing ability. The second section demonstrates the study's outcome on handwashing machines and preschool children's habits after using innovation.

3.1. Results

3.1.1. The content analysis of the innovation needs identified three primary themes following

- Theme 1: Challenges for child caretakers in teaching handwashing

Child caretakers need help consistently monitoring handwashing practices among preschool children. Key moments such as before meals, after using the bathroom, and after touching public surfaces are particularly challenging. Caretakers noted that children frequently engage in hand-to-mouth behaviors without prior handwashing, leading to potential hygiene issues. Even when children wash their hands, adherence to proper handwashing procedures must be more consistent. Therefore, this suggests a need for more effective methods to ensure children follow recommended handwashing practices thoroughly.

- Theme 2: Benefits of innovation for children's health

Introducing automatic handwashing innovations is a significant advancement in supporting early childhood care. Such innovations are expected to aid childcare workers and teachers in maintaining hygiene standards in child development centers, promoting better health outcomes for children. These innovations

contribute to overall children's well-being by facilitating more consistent and effective handwashing, reducing the risk of illness and infection.

- Theme 3: Enhancing engagement through joyful design

To effectively engage children, automatic handwashing innovations should incorporate elements that make the learning process enjoyable. Features such as singing and rhythmic dancing can transform handwashing into a fun activity. Age-Appropriate Content: The timing and content of these features should be tailored to children's developmental stages. Relative role models like peers or friendly animated animals can create a non-intimidating and engaging learning environment. This approach encourages children to practice proper handwashing techniques in a manner that resonates with them and keeps them interested. These findings underscore the need for innovation that addresses practical handwashing challenges and engages children educationally and enjoyably.

3.1.2. Preschool children's behavior using an automatic handwashing innovation

Supervising teachers evaluated automatic handwashing innovations among preschool children in two child development centers. The experimental findings revealed that the sampled children exhibited high-level behavior in utilizing the innovation across all assessed items. According to the scale provided, a mean less than 0.67 = low, means between 0.67-1.33 = moderate, and an average higher than 1.33 = high; this study revealed that the activity with the highest average involved walking and standing in front of an automatic faucet, placing hands under it to wet them, washing hands with soap, creating foam across the hands, and enjoying the process by the video on the television screen (M = 2.00, SD = 0.000). The washing hands step with the lowest mean value involved using the backs of the fingers and rubbing the palms alternately on both sides (M = 1.70, SD = 0.515), as indicated in Table 1.

Table 1. Preschool children's behavior using an automatic handwashing innovation (n = 77)

No	Innovation using behavior	Mean	SD	Level
1	Walk and stand in front of the automatic faucet to wash your hands	2.00	0.000	High
2	Put your hand on the automatic faucet to get your hand wet	2.00	0.000	High
3	Lather hands with soap to foam all over the hands	2.00	0.000	High
4	Rub palms together	1.96	0.195	High
5	Rub the back of the hand and between fingers with the palm	1.81	0.460	High
6	Rub palms and between fingers	1.83	0.441	High
7	Rub the back of your fingers and palms alternately on both sides	1.70	0.515	High
8	Rub your thumb alternately on both sides	1.73	0.504	High
9	Rub the palms alternately on both sides with your fingertips	1.79	0.468	High
10	Rub around your wrists	1.73	0.504	High
11	Wash your hands for at least 15 seconds	1.79	0.439	High
12	Rinse with water without letting it flow back	1.92	0.315	High
13	Wipe your hand with a dry towel that is one's own	1.96	0.253	High
14	Wash your hands with fun, according to the video on the television screen	2.00	0.000	High
Total		1.87	0.212	High

3.2. Discussion

The evaluation of an automatic handwashing innovation among preschool children in this study yielded promising results regarding the engagement and behavior of children using the technology. The findings illuminate distinct patterns in children's interaction with technology during handwashing. Particularly noteworthy is the step receiving the highest average involvement, which encompasses multiple actions: approaching the automatic faucet, wetting hands, applying soap, generating foam, and engaging with a video on a television screen (M = 2.00, SD = 0.000). This interactive component suggests visual stimuli significantly enhance children's engagement and participation in hand hygiene routines. Conversely, the step with the lowest mean score still demonstrated a high level of engagement (M = 1.70, SD = 0.515), indicating consistent adherence to the overall handwashing procedure facilitated by the innovation.

These results underscore the effectiveness of integrating technological innovations to promote handwashing practices among preschool children in childcare settings. Automatic handwashing systems simplify the procedure and enrich children's interaction and learning experiences through multimedia integration. These findings align with prior research emphasizing technology's role in enhancing children's hand hygiene behaviors [20], [21]. Moreover, the results corroborate earlier studies highlighting the efficacy of interactive elements, such as videos and songs, in fostering preschool children's enhancement of their acquisition of literacy and skills of handwashing [22]-[24]. A designed educational resource for hand hygiene can improve handwashing behavior and understanding in young children. Incorporating interactive elements such as songs can further sustain children's engagement and reinforce the importance of thorough

handwashing practices [25]. Compared to traditional handwashing methods and other automated systems, the innovation in this study exhibited distinct advantages and limitations. Integrating multimedia elements, such as video clips featuring animated characters, is a notable strength. Previous studies have shown that multimedia interventions can effectively capture children's attention and enhance learning outcomes [26]. However, traditional handwashing methods, which rely on direct supervision and manual guidance, still offer advantages in terms of simplicity and immediacy of feedback compared to these methods, the automatic handwashing innovation provides a more structured and interactive approach but may require additional support to ensure consistent adherence to all handwashing steps.

Nevertheless, this study identifies variability in adopting specific handwashing techniques that the automatic system facilitates. The step involving using the backs of the fingers and rubbing the palms alternately on both sides received the lowest mean value (M = 1.70, SD = 0.515). This result suggests that while children readily engage with visible and interactive aspects of handwashing, they may need to consistently practice more emphasized techniques facilitated by the automatic handwashing innovation. Related to the study of handwashing in preschool children, it was found that the experimental groups consistently needed to complete essential handwashing steps correctly: some did not wet their hands before dispensing soap, lather their fingernails, or dry their hands [27]. Preschool children are still developing their fine motor skills, essential for tasks requiring precise movements and coordination [28]. Activities such as using the backs of the fingers or rubbing around the wrist demand dexterity and hand control, which may not fully develop in young children. Consequently, despite understanding the basic handwashing procedure, children may need help consistently executing these steps effectively.

Handwashing behavior of preschool children can be influenced by cognitive factors, including attention span and the ability to follow multi-step instructions. Preschoolers may become distracted or lose focus, affecting their thorough completion of each step. Therefore, to promote handwashing skills, should cooperate with parents and childcare takers. This study emphasizes that the innovation involves preschool children and incorporates parents and caretakers in child development centers to supervise and engage children using the technology. Consistent with existing literature, educators and caregivers can support children's skill development by offering structured guidance, modeling correct techniques, and providing opportunities for practice in a supportive environment [25], [29].

Additionally, while technological innovations enhance engagement, they should be complemented with targeted educational interventions to ensure holistic skill development in hand hygiene practices [30]. Integrating engaging video clips and interactive elements in the innovation aligns with Piaget's understanding of how children in this stage learn best through concrete experiences and visual aids [31]. The high engagement with video content suggests that multimedia elements effectively cater to the cognitive strengths of preschoolers, facilitating better understanding and adoption of handwashing practices.

Future research on automated handwashing innovation should explore the long-term behavioral impact on children's hand hygiene practices. Investigating different types of interactive prompts and educational interventions could provide insights into optimizing the design and implementation of such technologies in educational settings. In conclusion, this study underscores the potential of automatic handwashing innovations to enhance hygiene practices among preschool children. Child development centers can promote lifelong hygiene and health habits by integrating interactive technologies and targeted educational strategies.

4. CONCLUSION

Creating an automatic handwashing innovation for preschoolers can significantly improve handwashing skills, which can help combat COVID-19 transmission and other infectious diseases. It is essential to carefully consider community needs, child development, and safety during development. Teaching preschool children proper handwashing establishes healthy habits. This proactive approach is crucial, given how vulnerable preschool-aged children are.

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AUTHOR CONTRIBUTIONS STATEMENT

In research, the contributions of each team member are essential to ensuring the study's success. This research study was no exception, where the collaborative efforts of the authors ensured the project's rigor, accuracy, and academic integrity. Each team member played a vital role, contributing to various aspects of the research, from conceptualization and methodology design to software development and manuscript preparation.

Phatcharaphan Chaiyasung, as the primary investigator, led the conceptualization and design of the study's methodology. Chaiyasung was responsible for formulating the research questions, establishing the theoretical framework, and selecting the appropriate research methods. This foundational work was crucial for the success of the study, ensuring it addressed relevant and important research topics. In addition to conceptualizing and designing the methodology, Chaiyasung played a significant role in the software development process. This was a key aspect of the study, as the research required specific technological tools. Chaiyasung ensured that the software met the study's needs, which contributed to the seamless data collection and analysis process.

Nuttaya Sritakaew worked closely with Chaiyasung during the study's conceptualization phase. Sritakaew played a central role in refining the study's methodology, ensuring it was both practical and aligned with the study's goals. Sritakaew's expertise in methodology design helped shape the study's direction and provided a solid foundation for data collection. Beyond the design phase, Sritakaew contributed significantly to the data validation process. Ensuring the accuracy and reliability of the data was a critical task, and Sritakaew's focus on data validation maintained the integrity of the study. This was essential for ensuring the credibility of the study's results. Sritakaew also played a key role in manuscript revision. She worked tirelessly to revise the manuscript, improving its clarity and ensuring that the study's findings were communicated effectively. Her attention to detail ensured that the manuscript adhered to academic standards and was well-received by the scholarly community.

Pilailak Rojanaprasert, Usa Thohinung, and Nisapichayapak Meesomsak contributed primarily to the technical aspects of the research. Their expertise in software development and data collection was invaluable. They helped ensure the study's tools were functional, providing reliable data for analysis. Their contributions allowed the research to progress smoothly and meet its objectives. In addition to their technical roles, Rojanaprasert, Thohinung, and Meesomsak also assisted with manuscript writing and revision. They provided key input into various sections of the manuscript, ensuring that technical details were clearly communicated. Their efforts were critical in ensuring the paper met the standards required for academic publication.

Sirichai Triamlumlerd played a key role as the software expert, contributing technical expertise to the development and implementation of the research tools. Additionally, Triamlumlerd was involved in editing the manuscript, ensuring it adhered to rigorous academic standards and was prepared for publication.

In conclusion, the research study was a success due to the combined efforts of all the authors. Each team member contributed their unique expertise, from conceptualization and methodology to technical development and manuscript preparation. Their collaborative efforts ensured the study's rigor and academic quality, demonstrating the power of teamwork in research.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest related to this research project. All authors have read and agreed to the manuscript, and each has made significant contributions to its development. This

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ETHICAL APPROVAL

This research project has received approval from the Human Research Ethics Committee at Rajamangala University of Technology Thanyaburi (RMUTT_REC No. Full 3/65). Before the research begins, caregivers and parents will receive a detailed project outline. Results will be presented in aggregate to maintain personal confidentiality. Children's participation in the project requires parental consent via an assent form agreeing to the outlined procedures.

DATA AVAILABILITY

The data that supports the findings of this study are available on request from the corresponding author, [NS]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions. The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

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