



Design Thinking in Home-visit Education Among Undergraduate Public Health Students in Thailand

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Received: 31 May 2026; Revised: 4 August 2026; Accepted: 31 August 2026

Abstract

Background: Community-based home visits are an essential component of public health education, yet traditional approaches may provide limited opportunities for students to develop both technical and transferable skills through authentic community engagement. Integrating design thinking with experiential learning may enhance students' capacity to apply knowledge, solve problems creatively, and respond to community needs. **Objective:** This study aimed to evaluate the effectiveness of a design thinking-integrated home-visit module (DTHV module) within a CAR framework on knowledge, attitudes, and skills (KAS) among undergraduate public health students and explore their reflective learning experiences during community-based practice. **Methods:** Mixed-methods classroom action research (CAR) was conducted from January to May 2023 at Mahidol University, Amnatcharoen Campus, Thailand, the study involved 53 third-year public health students in a 15-hour intervention integrating design thinking with experiential home-visit learning. Statistical analysis revealed significant improvements across all assessed domains ($p < 0.001$, Cohen's $d = 0.52-1.06$), including home-visit knowledge, self-esteem, creative thinking and problem-solving, collaboration and leadership, and information and digital literacy. **Results:** Mean scores for home care practice and innovation reached 83.01 (SD = 5.65), with 64.2% of participants achieving a good performance level. After action review, student reflections highlighted enhanced empathy, stronger professional identity, greater self-confidence, and improved integration of theory with real-world practice. Innovations developed during the module also received positive acceptance from community stakeholders. **Conclusion:** Overall, the DTHV module strengthened both hard skills, including home

care knowledge and practice, and soft skills such as empathy, collaboration, and professional identity, offering a promising pedagogical approach for community-based public health education; however, findings should be interpreted cautiously given the one-group pre–post design.

Keywords: Design thinking, Home-visit learning, Public health education, Professional competency, Classroom action research

What was Known

- Home-visit education often focuses on checklist-based assessment.
- Design thinking supports empathy and problem-solving in health education.
- Experiential learning improves community-based health competencies.

What's New and Next

- Design thinking improved empathy in integrated home-visit education.
- Community-based learning strengthened professional identity in students.
- Future studies should examine long-term community health outcomes.

Introduction

Health systems globally are facing rapidly evolving complexity driven by demographic transition, multimorbidity, and technological change, necessitating a fundamental shift toward people-centered, integrated, and home-based models of care ^(1,2). This transformation demands health professionals capable of systems thinking, innovation, empathetic communication, and effective community collaboration, competencies that require educational approaches moving well beyond didactic instruction toward authentic, practice-based learning ⁽³⁾.

In Thailand, strengthening primary care and home-based services is a strategic national priority under universal health coverage and aging policy reforms, particularly in preparation for a super-aged society ^(4,5). Despite this urgency, undergraduate public health training in home-visit care remains largely checklist-oriented and reliant on summative examination, limiting meaningful engagement with patients' lived realities and constraining the development of higher-order cognitive, psychosocial, and professional competencies necessary for community-based practice ⁽⁶⁾. Such limitations are evident in existing home-visit curricula, which typically rely on checklist-based assessment and summative examination without authentic community engagement, constraining the development of higher-order competencies ⁽⁷⁾. This gap between educational preparation and the

demands of contemporary public health practice represents a critical challenge for health workforce development.

Design thinking and classroom action research (CAR) are increasingly applied in health professions education as frameworks for active, reflective, and innovation-oriented learning^(8,9,10). Design thinking offers a human-centered, iterative problem-solving approach that engages learners in empathy-based assessment, problem definition, ideation, prototyping, and solution testing within real-world contexts⁽¹¹⁾. Design thinking is particularly well-suited to home-visit education because the empathize and define phases directly mirror the core competencies of home-visit practice, namely, understanding patients' and families' lived contexts, identifying unmet needs, and developing person-centered care solutions, making it a natural pedagogical fit for this learning context. CAR supports continuous pedagogical refinement through cyclical Plan–Act–Observe–Reflect (PAOR) processes, enabling instructors to adapt learning experiences responsively to student development; prior research has demonstrated that CAR promotes reflective practice, collaborative inquiry, and continuous improvement in teaching and learning outcomes in higher education contexts^(12,13). When integrated with experiential community-based learning, these approaches strengthen collaboration, reflective practice, and professional readiness^(14,15), with evidence supporting home visits as an effective interprofessional learning activity for undergraduate health professions students in primary care settings⁽¹⁶⁾. A growing body of evidence, including systematic reviews, supports the use of design thinking in nursing and health sciences education^(10,17), and demonstrates that experiential learning in public health education produces positive outcomes in knowledge acquisition, skill development, and professional identity formation⁽¹⁸⁾. Importantly, their combined application promotes higher-order cognitive processes within Bloom's revised taxonomy, particularly analysis, evaluation, and creation, through iterative engagement in authentic problem-solving contexts⁽¹⁹⁾.

Although design thinking and CAR have each been applied independently in health professions education, integrating both within a single curriculum-embedded module is methodologically novel, combining human-centered problem-solving with continuous pedagogical refinement in a way that neither framework achieves alone. In this study, design thinking stages were mapped onto the CAR cycle such that each home visit corresponded to specific stages, enabling student learning and instructor refinement to occur concurrently.

Nevertheless, existing evidence predominantly focuses on cognitive and technical competencies in classroom or short-term simulation settings, with insufficient attention to psychosocial outcomes, including self-esteem, empathy, and professional identity formation which correspond directly to the attitude (A) domain of the KAS framework measured in this study^(8,10,17). The fragmentation of interprofessional learning and limited integration of community-based experiences further constrain the development of practice-ready graduates⁽²⁰⁾. Empirical evidence on the integrated application of design thinking and CAR within authentic home-visit and primary care training remains scarce, particularly within the Southeast Asian and Thai public health education contexts.

This evidence gap identified a clear need to develop and evaluate an integrated pedagogical model for home-visit education that addresses both professional competency development and psychosocial learning outcomes. Accordingly, this study evaluated the effectiveness of a design thinking–integrated home-visit module (DTHV module), implemented within a CAR framework, on knowledge, attitudes, and skills (KAS) outcomes among undergraduate public health students, and explored their reflective learning experiences during community-based home-visit practice. Specifically, the study addressed the following research question: Does the DTHV module produce significant improvements across KAS domains, including home-visit knowledge, self-esteem, professional competencies, and home care practice performance, among undergraduate public health students in Thailand?

Materials and Methods

This study employed a CAR design with a mixed-methods approach to examine the effects of a DTHV module on undergraduate public health students' learning outcomes across KAS domains. Following Kemmis and McTaggart's model⁽¹³⁾, the CAR framework comprising three iterative Plan–Act–Observe–Reflect (PAOR) cycles in which the instructor: (1) reviewed prior curriculum evaluations and student performance data to identify learning gaps informing workshop design (Plan); (2) observed student performance, collected reflective journals, and facilitated AAR sessions during home visits 1 and 2, using findings to refine facilitation strategies and provide targeted feedback prior to Visit 3 (Act and Observe); and (3) synthesized findings from the final home visit and AAR sessions to evaluate learning outcomes and inform future module iterations (Reflect).

The five design thinking stages, empathize, define, ideate, prototype, and test, were mapped onto the three CAR phases, with each home visit corresponding to specific design thinking stages within an iterative CAR loop, enabling student learning and instructor refinement to occur concurrently. The DTHV module was delivered as a 15-hour intervention embedded within a 15-week course curriculum in authentic community settings.

A one-group pre–post design was employed, as the curriculum-embedded intervention precluded student exclusion, and CAR's participatory nature is incompatible with randomization. Primary outcomes were the KAS domains; reflective learning experiences served as the secondary outcome. Data collection combined pre- and post-intervention assessments with reflective writing and AAR processes across cognitive, affective, and skill domains.

Setting and participants

The study was conducted from January to May 2023 at the Amnatcharoen Campus, Mahidol University, Thailand. Third-year undergraduate public health students were selected as participants because: (1) they had completed foundational coursework, providing the prerequisite theoretical knowledge for community-based practice; (2) the home-visit module is curriculum-embedded within the third-year family health, health communication, and community mental health course, making them the designated participants; and (3) they are at a stage of professional formation developmentally suited to the reflective and experiential learning demands of the CAR framework.

Participants were recruited via census sampling: all 53 third-year public health students enrolled in the target course who met the eligibility criteria were included. Inclusion criteria were: (1) enrollment in the third year of the public health program, (2) completion of all 15 hours of the intervention, and (3) provision of written informed consent. Students absent for more than 20% of intervention hours or who withdrew were excluded. The sample of 53 participants provides adequate statistical power to detect medium effect sizes ($d \geq 0.5$) at $\alpha = 0.05$ with power > 0.80 , consistent with recommendations for paired-samples t-test analyses. All 53 enrolled students completed the intervention with no exclusions.

Intervention

The DTHV module was implemented through three phases aligned with the CAR cycle.

Phase 1: Preparation (Plan): Students attended a 6-hour preparatory workshop comprising two components: (1) design thinking concepts and empathy-based assessment tools, including

empathy maps (3 hours); and (2) home-visit skills training using the INHOMESSS framework, immobility, nutrition, home environment, other people, medication, examination, safety, spiritual, and services, for holistic family health assessment (3 hours). This phase developed foundational competencies in empathetic communication, contextual assessment, problem identification, and human-centered care planning prior to community engagement.

Phase 2: Action and Observation (Act and Observe): Students conducted three structured home visits at Weeks 5, 10, and 15 (3 hours each), comprising a pre-visit discussion, field-based home visit, and post-visit reflection (1 hour each). Working in groups of 8–12, students were assigned to five target populations: (1) postpartum women, (2) young children aged 0–5 years, (3) adolescents with cerebral palsy, (4) working-age adults with chronic kidney disease, and (5) older adults with hypertension.

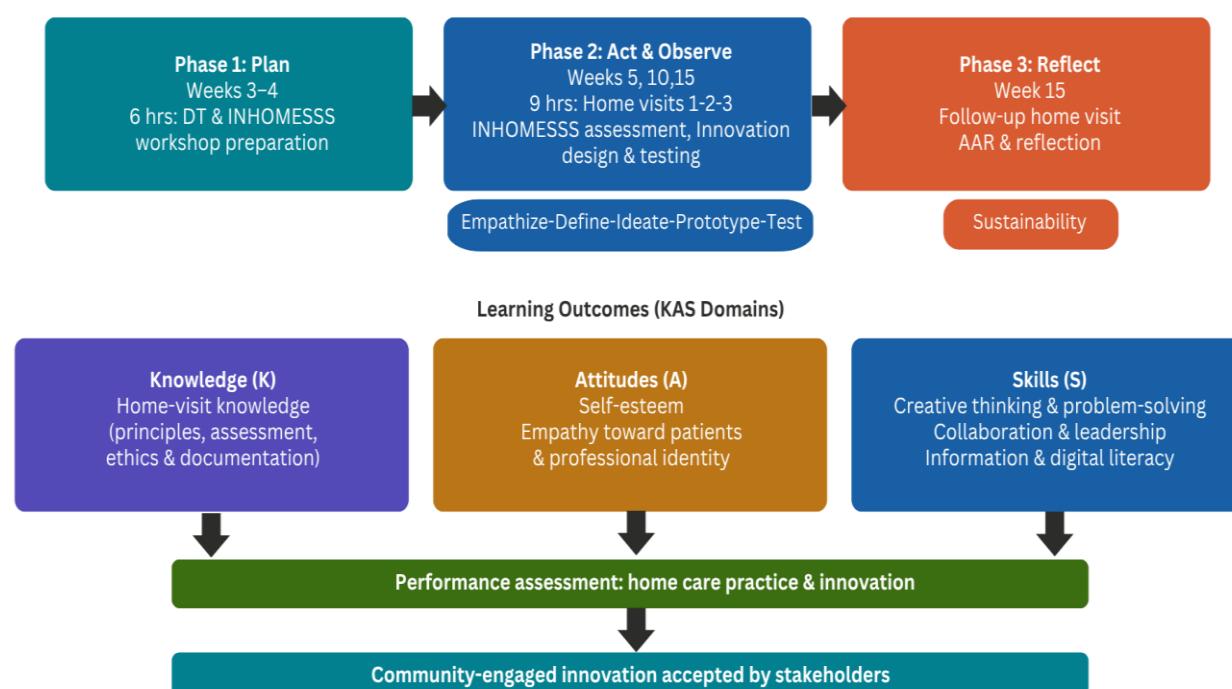
During Visit 1 (Empathize and define), students assessed family health across nine INHOMESSS dimensions through in-depth interviews and contextual observation to identify health problems and unmet needs. Between visits (Ideate), instructor-facilitated brainstorming sessions generated innovative, context-sensitive solutions. During Visit 2 (Prototype and test), students implemented innovations including assistive devices, educational media, and health promotion activities and collected feedback from service users and caregivers to assess feasibility and appropriateness.

Phase 3: Reflection (Reflect): Visit 3, conducted during Week 15, focused on follow-up and sustainability assessment of implemented innovations in collaboration with community stakeholders, including village health volunteers. Students participated in AAR sessions to consolidate learning and reflect on professional growth. The module concluded with a student project presentation at an academic forum attended by provincial public health and social development experts, who provided evaluative feedback and recommendations.

Research Instruments

Data were collected using a self-administered questionnaire, a home care practice and innovation performance assessment, and reflective journal and after-action review (AAR).

1. Self-administered questionnaire comprising four parts: (1) Demographic data, including participants' sex and cumulative grade point average (GPAX). (2) Home visit knowledge test assessed knowledge of public health home-visit principles, including preparation, communication, health and



Note. AAR = After Action Review; CAR = Classroom Action Research; DT = Design Thinking; KAS = Knowledge, Attitudes, Skills.

Figure 1 The design thinking–integrated home-visit module (DTHV module)

environmental assessment, care planning, documentation, referral systems, and professional ethics. The instrument comprised 10 dichotomous items (1 = correct, 0 = incorrect), with higher scores indicated greater knowledge. Internal consistency reliability was KR-20 = 0.54, considered acceptable given the multidimensional content spanning heterogeneous domains.²¹ (3) Self-esteem questionnaire used a modified Coopersmith Self-Esteem Inventory²² consisting of 10 Likert-scale items (1–5), with higher scores indicated greater self-esteem (Cronbach's α = 0.83). And (4) Professional skills questionnaire comprised 12 self-report items measuring three domains: creative thinking and problem-solving (4 items), collaboration and leadership (4 items), and information and digital literacy (4 items), rated on a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree), with higher scores indicated greater perceived competency (Cronbach's α = 0.89).

2. The home care practice and innovation performance assessment comprised an instructor-rated rubric evaluating students' performance across four components: home visit 1 (family health assessment and problem identification), home visit 2 (innovation design and implementation), home

visit 3 (sustainability and follow-up), and the innovation project. Mean percentage scores were calculated for each component and classified into three performance levels: good ($\geq 80\%$), moderate (60–79%), or poor ($< 60\%$).²³ Assessments were rated by the course instructor and reviewed by a second faculty member to ensure scoring consistency; discrepancies were resolved through discussion and consensus prior to final scoring.

3. The reflective journal and AAR form collected student and instructor reflective data on learning experiences, professional development, and instructional feedback, grounded in reflective and experiential learning frameworks.

All instruments underwent content validity review by three subject-matter experts (IOC = 0.70–1.00) and were pilot-tested with a comparable population to confirm clarity and reliability prior to data collection.

Data collection procedure

Data collection occurred concurrently with the intervention across three phases. During the preparation phase, students completed baseline assessments of knowledge, self-esteem, and professional skills prior to workshops covering design thinking concepts, the INHOMESSS framework, and family and community communication skills. During the action and observation phase, students conducted three supervised home visits in authentic community settings, performing family health assessment, in-depth interviews, and contextual observation using the INHOMESSS framework. Students iteratively designed, prototyped, and tested health innovations under faculty supervision, maintaining reflective journals throughout to document learning experiences and professional development. During the reflection phase, students completed post-intervention assessments across all KAS domains, participated in group AAR sessions, and submitted individual reflective journals. Instructor also completed AAR forms to provide feedback and inform iterative course refinement in accordance with the CAR framework.

Data analysis

Quantitative data were analyzed using IBM SPSS statistics version 31 (IBM Corp., Armonk, NY, USA). Descriptive statistics, including means and standard deviations, were used to summarize participant characteristics and outcome variables. Pre- and post-intervention differences across all KAS domains were examined using paired-samples t-test. Statistical significance was set at $p < 0.05$. Prior to inferential analysis, skewness (range: -0.884 to -0.125) and kurtosis (range: -0.230 to 1.231)

values for all difference scores were within acceptable limits ⁽²⁴⁾, supporting the use of parametric paired-samples t-tests.

Qualitative data derived from student reflective journals, and group AAR sessions were analyzed using inductive content analysis to identify themes related to learning experiences, professional development, and role identity formation. Analytical rigor was enhanced through two strategies: credibility via investigator triangulation, with two researchers independently coding the data and resolving discrepancies through consensus; and confirmability via grounding all thematic interpretations in verbatim participant data, supported by representative quotations for each theme.

Quantitative and qualitative findings were subsequently integrated using a convergent mixed-methods approach, whereby results from both data strands were compared and synthesized to provide a comprehensive understanding of the intervention's effects on student learning outcomes.

Results

Participants were 53 third-year undergraduate public health students, of whom 19% were male and 81% were female, with a mean cumulative GPA (GPAX) of 2.85 (SD = 0.32).

Knowledge, Attitudes, and Skills Outcomes. Pre- and post-intervention comparisons revealed statistically significant improvements across all KAS domains ($p < 0.001$), as presented in Table 1. Home-visit knowledge scores increased from 5.1 (SD = 2.2) to 6.6 (SD = 1.3). Self-esteem from 39.4 (SD = 3.9) to 43.5 (SD = 4.8). Among professional skill domains, creative thinking and problem-solving improved from 17.2 (SD = 2.6) to 21.1 (SD = 3.0), collaboration and leadership from 10.6 (SD = 1.7) to 13.1 (SD = 1.6), information and digital literacy from 13.9 (SD = 2.2) to 15.9 (SD = 3.0).

Home Care Practice and Innovation Performance. Performance assessment findings are presented in Table 2. The overall mean percentage score was 83.1 (SD = 5.7), with 64.2% of participants at the good level ($\geq 80\%$; $n = 34$), 35.8% at the moderate level (60–79%; $n = 19$), and none at the poor level ($< 60\%$). Performance improved progressively across home visits. The first visit yielded a mean of 74.1 (SD = 6.2), with 96.2% at the moderate level ($n = 51$). The second visit improved to 80.5 (SD = 14.8), with 52.8% at the good level ($n = 28$) and 47.2% at the moderate level ($n = 25$). The third visit yielded the highest home-visit score of 91.9 (SD = 6.7), with 94.3% at the good level ($n = 50$). The innovation component yielded a mean of 90.0 (SD = 10.1), with 83.0% at the good level ($n = 44$).

Table 1 The comparison of mean scores for knowledge, skills, and attitudes (n=53)

Factors	Pre-test	Post-test	t (df)	p-value	Cohen's d
	Mean (SD)	Mean (SD)			
Home visit knowledge	5.1 (2.2)	6.6 (1.3)	6.20 (52)	<0.001	0.85
Self-esteem	39.4 (3.9)	43.5 (4.8)	4.45 (52)	<0.001	0.61
Creative thinking and problem-solving skills	17.2 (2.6)	21.1 (3.0)	6.63 (52)	<0.001	0.91
Collaboration and leadership skills	10.6 (1.7)	13.1 (1.6)	7.70 (52)	<0.001	1.06
Information and digital literacy skills	13.9 (2.2)	15.9 (3.1)	3.79 (52)	<0.001	0.52

Note. SD, standard deviation; t, t-values; df, degrees of freedom; p-value of paired-samples t-test.

Table 2 The comparison of mean scores for home care practice and innovation performance (n=53)

Factors	Percentage score		Level; n (%)		
	Min-Max	Mean (SD)	Good	Moderate	Poor
Home visit 1st	50.0-80.0	74.09 (6.2)	1 (1.9)	51 (96.2)	1 (1.9)
Home visit 2nd	62.5-97.5	80.5 (14.8)	28 (52.8)	25 (47.2)	0 (0.0)
Home visit 3rd	66.6-96.7	91.9 (6.7)	50 (94.3)	3 (5.7)	0 (0.0)
Project/ Innovation	68.8-97.5	90.1 (10.1)	44 (83.0)	9 (17.0)	0 (0.0)
Overall	70.9-90.6	83.0 (5.7)	34 (64.2)	19 (35.8)	0 (0.0)

Note. SD, standard deviation

Reflective Learning Outcomes. Reflective analysis of student journals and group AAR sessions identified three overarching themes related to students' learning experiences during the DTHV module.

Theme 1: Developing empathy and holistic understanding (n = 48, 90.6%): Prior to the intervention, students perceived home visits primarily as structured activities for data collection and health screening. Following the empathize phase, students reported a qualitatively deeper understanding of patients' and families lived experiences—including caregiver burden, economic

hardship, functional limitations, and psychosocial needs—and described shifting from a task-oriented to a person-centered approach to family health assessment:

“Before this module, I thought home visits were simply about filling out forms. After meeting the family, I realized that behind every health problem, there is a story, a life that we need to understand before we can truly help.”

Theme 2: Professional identity transformation (n = 45, 84.9%): Students described a meaningful shift in professional self-concept, moving from perceiving themselves as data collectors to identifying as “designers of well-being,” “supporters of quality of life,” and “community motivators.” Experiential learning within real community settings enabled students to connect theory with practice and develop a stronger sense of purpose within the public health profession:

“I never thought that I, as a student, could actually create something that makes a real difference for a patient at home. This experience made me feel like a real public health professional for the first time.”

Theme 3: Enhanced self-efficacy and professional confidence (n = 51, 96.2%): Students reported increased self-efficacy and professional pride following the implementation of community-based innovations. Positive feedback from service users, family caregivers, and community stakeholders reinforced their sense of competence and motivation for future practice:

“When the family told us that our innovation actually helped them in their daily life, I felt proud and confident that what I learned in class could be applied to help real people in the community.”

Students also provided constructive feedback for curriculum development, recommending greater continuity of home visits, exposure to more diverse cases, and expanded practice-based learning opportunities to strengthen professional preparedness.

Across all three themes, the qualitative findings demonstrated convergence with the quantitative results: Theme 1 corresponded with improvements in home-visit knowledge ($d = 0.85$), Theme 2 with collaboration and leadership ($d = 1.06$), and Theme 3 with self-esteem ($d = 0.61$).

Discussion

This study examined the effectiveness of the DTHV module on knowledge, attitudes, and skills outcomes among undergraduate public health students within a CAR framework. Findings demonstrated statistically significant improvements across all assessed domains, indicating that the module effectively enhanced both professional competencies and 21st-century skills, including creative thinking, collaboration, and digital literacy, consistent with prior evidence that practice-based learning combined with design thinking promotes competency development in health professions education. ^(8,10,17)

The progressive improvement in home care practice scores across sequential home visits, alongside the qualitative evidence of increased self-confidence, professional role awareness, and contextual understanding, suggests that the DTHV module facilitated more than knowledge acquisition. It supported a deeper process of professional identity formation, consistent with Kolb's experiential learning theory ⁽²⁵⁾, which posits that meaningful learning arises through cycles of direct experience, reflective observation, abstract conceptualization, and active experimentation. The concurrent CAR cycle enabled instructors to iteratively refine the learning process in response to student development, reinforcing deeper and more sustained learning outcomes ⁽¹³⁾.

The integration of CAR and design thinking functioned as a dual mechanism for deep learning. Design thinking provided students with a structured, human-centered framework for analyzing real-world community problems, generating innovative solutions, and testing interventions in authentic settings, thereby promoting active learning, creative thinking, and collaborative problem-solving ⁽²⁶⁾. The CAR cycle simultaneously ensured that instructional decisions remained responsive to emerging student needs, aligning with principles of reflective and adaptive teaching practice ⁽¹³⁾.

Post-intervention improvements in home-visit knowledge reflect the DTHV module's capacity to promote applied understanding across multiple domains, including health assessment, communication, care planning, documentation, and professional ethics. These gains align with the WHO's emphasis on integrated competencies for community-based care ⁽¹⁾ and the Home Ward guidelines of the Department of Medical Services, which prioritize continuity of care at the family and community level ⁽⁶⁾. The empathize and define phases of design thinking created structured opportunities for students to analyze patients' and families' lived contexts, facilitating contextual knowledge construction rather than rote memorization, consistent with principles of deep and applied

learning^(27,28). These findings align with prior research demonstrating that experiential, community-based learning enhances knowledge acquisition and clinical confidence among health professions students⁽¹⁴⁾, and with evidence that community-based learning programs for undergraduate health students produce significant improvements in self-evaluated competence scores and professional confidence⁽²⁹⁾.

Significant improvements in self-esteem suggest that the DTHV module supported not only professional skill development but also students' self-perception and emerging professional identity. The observed shift from perceiving themselves as data collectors to identifying as designers of well-being and community motivators reflects a qualitative transformation in professional self-concept, consistent with 21st-century professional identity development.⁽³⁾ This aligns with Bandura's self-efficacy theory, which identifies mastery experiences, such as successful performance in authentic tasks, as the most influential source of self-efficacy beliefs. Students' direct involvement in designing, implementing, and receiving community validation of their innovations constituted such mastery experiences, consistent with Coopersmith's conceptualization of self-esteem as shaped by competence and social recognition⁽²²⁾. Similarly reported improvements in students' professional confidence following interprofessional home-based care education⁽¹⁴⁾.

Significant improvements in creative thinking and problem-solving are consistent with Brown's characterization of design thinking as a framework that develops creativity, innovation, and user-centered problem-solving through iterative ideation and prototyping⁽¹¹⁾. The iterative structure of the ideate, prototype, and test phases required students to generate context-sensitive solutions, implement them in real community settings, and refine their approaches based on feedback, a process that is central to developing creative problem-solving as a core 21st-century competency.⁽³⁾ These findings are supported by evidence that design thinking in health professions education enhances students' capacity to define systemic problems and develop contextually appropriate solutions, and develop problem-solving competency as a primary learning outcome^(9,10,17). Integration with constructivist and experiential learning frameworks promotes creative thinking, innovation, and complex problem-solving^(27,30). The design-iterate-reflect cycle has further been shown to strengthen critical thinking and applied problem-solving beyond single-method instructional approaches^(31,32).

Improvements in collaboration and leadership skills reflect the inherently team-based and community-engaged nature of the DTHV module. Students were required to plan cooperatively,

negotiate roles, and coordinate with health teams and community stakeholders across multiple home visits. These activities operationalize higher-order learning as described by Anderson and Krathwohl⁽¹⁹⁾ and directly cultivate collaboration and leadership as 21st-century professional skills⁽³⁾. Brown's design thinking framework further characterizes collaborative inquiry and co-creation as foundational to the design process^(10,11), supporting the development of teamwork, shared decision-making, and collective accountability. The CAR framework's emphasis on participatory reflection⁽¹³⁾, reinforced a collaborative learning environment conducive to leadership development, consistent with evidence that students engaged in design thinking processes demonstrate increased motivation to seek collaborative opportunities⁽³⁰⁾. The interprofessional dimensions of community-based home-visit learning further support collaborative competencies essential for integrated primary care practice^(14,20).

Improvements in information and digital literacy may be attributed to the requirement for students to search for, critically evaluate, and apply digital health information when designing and refining community innovations, tasks that demand evidence-based information retrieval, source appraisal, and the appropriate use of digital tools. These competencies represent core 21st-century skills for health professionals operating in increasingly digital practice environments⁽³⁾. The findings are consistent with evidence that design thinking promotes digital literacy and self-directed learning through practice-based engagement^(8,32), and that design-based learning enhances informatics literacy among health professions students more effectively than conventional instructional methods⁽³¹⁾. Future iterations of the DTHV module may benefit from incorporating more structured digital health literacy components to further strengthen this competency domain.

The progressive improvement in performance scores across the three home visits, from predominantly moderate levels at Visit 1 to predominantly good levels at Visit 3, reflects the cumulative benefits of iterative, community-engaged practice guided by the CAR and design thinking framework. The CAR cycle enabled continuous instructional refinement, while design thinking supported students in developing innovations directly responsive to identified community needs^(11,13). Unlike traditional practicum models, the DTHV module engaged students in co-designing, piloting, and iteratively improving their innovations across visits 2 and 3 in collaboration with community stakeholders. This co-creation processes reinforced students' professional confidence and sense of competence, consistent with Kolb's Experiential Learning Theory⁽²⁵⁾ and Bandura's concept of mastery-based self-efficacy⁽²⁸⁾, and aligns with prior evidence that integrating design thinking into

experiential public health education enhances learners' ability to apply professional concepts in real-world community contexts ^(9,10).

Although practice effects cannot be fully excluded, three features support genuine intervention effects: (1) each visit targeted distinct design thinking stages requiring qualitatively different competencies, precluding task repetition; (2) concurrent improvement in self-reported KAS measures, which are less susceptible to practice effects, alongside performance scores suggests genuine competency development; and (3) high innovation scores reflect original creative output co-designed with community stakeholders. This acceptability among stakeholders further underscores the value of community-engaged learning for developing practice-ready graduates ^(14,16).

The qualitative themes provide explanatory context for the quantitative findings. Theme 1 contextualizes the improvement in home-visit knowledge through students' shift from task-oriented to person-centered family assessment. Theme 2 explains the largest effect in collaboration and leadership through students' reconceptualization as community motivators. Theme 3 corroborates the improvement in self-esteem, reflecting Bandura's mastery experience mechanism ⁽²⁸⁾ whereby real-world innovation implementation reinforced self-efficacy beliefs.

The DTHV module was implemented as a curriculum-embedded intervention within authentic community settings, enhancing the ecological validity of the findings and supporting the practical applicability of the module to similar public health education programs. The mixed-methods design enabled triangulation of quantitative and qualitative data, providing a comprehensive understanding of both the magnitude and process of learning change. Three iterative home visits allowed observation of progressive competency development over time, providing stronger evidence of learning trajectories than single-point assessments. The reporting of effect sizes alongside significance testing further strengthens the practical interpretability of the findings.

The single-group pre-post design limits causal inference, as maturation or concurrent learning experiences may have contributed to the observed improvements; however, three features support attribution to the DTHV module: domain-specific effect patterns consistent with module competencies, concurrent KAS improvements less susceptible to practice effects, and qualitative corroboration from student reflections. Improvements in home visit performance may also partly reflect increasing familiarity with the context across sequential visits, not fully disentangled from module effects. Outcomes were assessed immediately post-intervention, precluding conclusions regarding long-term

sustainability. Self-report instruments may be subject to social desirability bias, and reflective submissions as course requirements may have introduced response bias; instructor-rated performance may similarly be subject to leniency bias or halo effects. The qualitative analysis was limited to two trustworthiness strategies, constraining rigor. Finally, the single-institution design limits generalizability to other public health programs or healthcare contexts.

Conclusion

Using a one-group pre–post CAR design, this study demonstrated that the DTHV module was associated with significant improvements across all KAS domains among undergraduate public health students, supporting holistic learner development beyond theoretical knowledge. Findings suggest the module strengthened both hard skills, home care knowledge and practice, and soft skills such as creative thinking, collaboration, empathy, and professional identity, competencies essential for community-based public health practice.

The integration of design thinking within a CAR framework provided an iterative, reflective, and learner-centered educational structure that promoted active learning and community-engaged innovation in authentic field settings. While causal inference is limited by the single-group design, these results suggest that the DTHV module offers a promising pedagogical approach for developing a public health workforce equipped with both professional competencies and 21st-century skills for primary care and community health practice.

Strengthening experiential, community-based education is critical for preparing graduates to address complex health needs at the family and community levels, particularly amid ageing populations, rising chronic disease burden, and growing demand for integrated home care. The DTHV module a replicable, curriculum-embedded model that public health programs can adopt to bridge academic preparation and real-world professional practice, supporting a workforce aligned with national and global primary health care goals. Generalization to other public health program, student populations, or healthcare settings cannot be assumed without further multi-site validation.

Future research should employ controlled experimental designs with long-term follow-up to strengthen causal inference and assess sustainability of learning outcomes. Multicenter studies across diverse institutions would enhance generalizability and clarify whether the module's effectiveness holds across educational settings, student populations, and community contexts. Cost-

effectiveness analyses would further support evidence-based decisions regarding broader implementation.

Ethical Approval Statement

This study was approved by the institutional review board of the institute for population and social research, Mahidol university (COA No. 2022/09-187; approved 14 December 2022). All participants received written study information prior to enrolment and provided voluntary written informed consent. Participants were informed of their right to withdraw at any time without academic penalty. All data were handled confidentially and anonymized prior to analysis to protect the privacy of both student and community participants.

Author Contributions

SP conceived and supervised the study, managed the project, curated the data, and secured research funding. SP and WK performed the formal analysis and designed the study methodology. SP and WK also prepared the visual materials. The initial manuscript draft was written by SP and WK. WS and TC contributed to manuscript editing. WK completed and prepared the final version of the manuscript for submission.

Acknowledgements

The authors would like to thank all participating students, faculty members, community members, and healthcare personnel for their contributions to this study and for their support in the implementation of the DTHV module.

Source of Funding

This study was supported by Mahidol University Amnatcharoen campus, Thailand (Grant No. AM 01/2023). The funder had no role in the study design, data collection, data analysis, interpretation of findings, decision to publish, or preparation of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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