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# Design-Based Learning in Nursing Informatics Education: A Mixed-Methods Participatory Action Research Study

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**Abstract**

The growing integration of digital technologies into healthcare has reshaped the knowledge and skills required of nursing professionals. However, most undergraduate nursing programs continue to emphasize theoretical instruction, offering limited exposure to experiential or technology-oriented learning. To better prepare students for data-rich clinical environments, innovative pedagogical models that merge nursing practice with informatics and design thinking are needed. This study investigated whether a Design-Based Learning (DBL) framework could strengthen informatics literacy among undergraduate nursing students by embedding authentic, problem-driven activities within a "Nursing Informatics" course. Over four academic years (2020–2024), a participatory action research project was carried out with 622 nursing undergraduates at a large Chinese university. The redesigned course guided students through iterative design cycles, encouraging them to co-develop digital solutions to genuine clinical informatics challenges. A 28-item Likert-scale instrument (total score range 28–140) assessed informatics literacy before and after the course. Quantitative data were analyzed using paired t-tests and Bayesian modeling to identify significant learning gains, while focus group discussions provided complementary qualitative evidence. Students' informatics literacy improved markedly across all cohorts ($p < 0.001$). For example, mean scores increased from 73.13 ± 13.38 to 86.55 ± 12.21 in 2018 (Cohen's $d = 2.21$) and from 73.17 ± 15.15 to 92.47 ± 12.07 in 2021 (Cohen's $d = 3.07$). Bayesian estimates corroborated these consistent gains. Qualitative findings revealed that the DBL experience nurtured interdisciplinary awareness, digital fluency, stronger professional identity, and collaborative problem-solving. Embedding design-based, participatory learning into a nursing informatics curriculum substantially enhanced students' technological competence and critical engagement. The findings highlight DBL as a promising strategy for cultivating future nurses capable of thriving in increasingly digitized healthcare contexts. Further investigation should compare DBL to other instructional models and examine its lasting influence on clinical performance.

**Keywords:** Design-based learning, Digital competence, Nursing informatics, Action research, Nursing education, Curriculum innovation, Interdisciplinary pedagogy

## Background

The ongoing digital transformation of healthcare has profoundly reshaped the nature of nursing practice. As a result, *informatics literacy*—the ability to effectively use information and communication technologies (ICT) for evidence-based clinical decision-making—has become an essential competency for nursing students. This literacy extends beyond technical proficiency; it encompasses ethical data management, responsible digital communication, and the integration of ICT into patient-centered care.

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Despite the growing importance of digital competence, recent systematic reviews indicate that many undergraduate nursing students remain underprepared for informatics-driven clinical environments. Studies report that over 70% of nursing students lack confidence in using electronic health records, more than half rate their computing abilities as insufficient, and fewer than half consider themselves competent in nursing informatics. Such deficiencies threaten graduates' readiness for technology-intensive clinical roles.

The relevance of informatics skills varies across nursing contexts. In acute care, proficiency is required for operating clinical decision-support systems, electronic medication records, and patient monitoring tools. Conversely, community and public health settings demand expertise in telehealth platforms, health databases, and information-sharing networks. Research consistently demonstrates that nurses with higher informatics literacy deliver safer and more efficient care, including lower medication error rates and better coordination of services. Consequently, embedding informatics training into undergraduate curricula is crucial to ensure that future nurses can practice effectively and safely in digitalized healthcare systems.

However, conventional nursing education often emphasizes theoretical instruction and procedural training, offering limited engagement with the complex, authentic problems characteristic of digital healthcare environments. While pedagogical strategies such as problem-based learning, simulation, and game-based learning can strengthen clinical reasoning, they frequently operate within predefined, simplified scenarios. These methods do not adequately mirror the iterative, interdisciplinary, and uncertain nature of real-world informatics challenges—leaving many students with fragmented and context-specific skills.

Design-Based Learning (DBL) presents a promising alternative to traditional approaches. Grounded in constructivist and experiential learning theories, DBL engages learners in continuous cycles of problem identification, design, testing, and reflection. Within this process, students collaboratively explore real-world challenges, synthesize knowledge from nursing, computer science, and information systems, and create practical solutions while considering regulatory, ethical, and technical standards. DBL has proven effective in engineering and medical education for fostering creativity, interdisciplinary reasoning, and innovation. Yet, its application within nursing informatics education remains underexplored. This study seeks to address that gap through systematic course design and evaluation.

*Aim*

This study aims to investigate the impact of a Design-Based Learning (DBL) framework on undergraduate nursing students' informatics literacy and interdisciplinary competence through the iterative design and implementation of a "Nursing Informatics" course. Specifically, the study seeks to:

- Develop a DBL-enhanced course model addressing authentic clinical informatics problems;
- Implement and refine this model through participatory action research (PAR) cycles;
- Evaluate its influence on students' information literacy, interdisciplinary integration, and ability to apply theoretical knowledge to practice.



*Hypotheses*

**H1:** Undergraduate nursing students' informatics literacy will show a statistically significant improvement following participation in the DBL-enhanced course.

**H2:** Successive participatory action research cycles will strengthen the course's design and effectiveness, yielding progressively improved learning outcomes.

**H3:** Engagement in authentic DBL activities will enhance students' capacity to translate theoretical understanding into practical solutions for nursing informatics challenges.

*Expected contribution*

The study aims to generate empirical evidence to guide educators, curriculum developers, and policymakers in adopting innovative, design-oriented pedagogies that prepare nursing graduates to thrive in increasingly data-driven and technology-rich clinical settings.

## Method

To investigate the effectiveness of a Design-Based Learning (DBL) approach in nursing informatics education, this study adopted a Participatory Action Research (PAR) framework. PAR was chosen because its iterative, collaborative cycles allow educators to refine teaching strategies in real time while engaging students and stakeholders directly in the learning process. The methodology's focus on continuous observation, reflection, and adaptation makes it particularly suitable for bridging the gap between classroom instruction and practical nursing applications [23].

*Setting and participants*

The research took place at a nursing college within a major Chinese university from 2020 to 2024. The program enrolls roughly 160 undergraduate students per year. Over the course of the study, 622 students who took the *"Nursing Informatics"* course participated. Students had no prior exposure to formal nursing informatics instruction, ensuring similar baseline knowledge across all cohorts.

Participants were predominantly female (82%, n =510) with a smaller proportion of male students (18%, n=112). The average age was 20.4 years (SD = 0.61, range 20–21). Enrollment and demographic data were verified through official university records and cross-checked with course attendance.

In addition to the student body, the project engaged 22 stakeholders, including faculty, clinical mentors, and administrative personnel **(Table 1)**, who contributed to course design, implementation, and iterative improvement. A stable teaching team of five instructors facilitated the course throughout the study period, ensuring consistent delivery and minimizing variability across cohorts.

**Table 1.** Participant roles and contributions

| Role | Number of Participants | Key Contributions |
|---|---|---|
| **Nursing Informatics Faculty Team** | 5 | Developed curriculum, delivered instruction, and refined content iteratively |
| **Clinical Practice Mentors** | 12 | Guided students during clinical placements and shared real-world expertise |
| **Teaching Supervisors** | 3 | Maintained educational standards and gave feedback on DBL execution |
| **Educational Specialists** | 2 | Aligned learning goals with cross-disciplinary and industry requirements |
| **Students** | **622** (2021: 155 2020: 155 2019: 156 2018: 156) | Actively participated in all DBL learning activities |

Note: Demographic data were drawn from the university's student-affairs registry and verified lecturer's roll call at the start of each semester

*Study design*

This investigation was structured as a four-year participatory action research (PAR) project (2020–2024), preceded by a six-month preparatory period devoted to laying the foundation for curricular innovation. The study followed four iterative PAR cycles, each progressing through the stages of planning, action, observation, and reflection. At the heart of the intervention was Design-Based Learning (DBL), which engaged students in project-centered activities that mirrored real-world clinical informatics challenges, fostering applied problem-solving and critical thinking.

To comprehensively examine both the outcomes and processes of learning, the study employed a convergent mixed-methods approach [24]. This design integrated quantitative measures, including surveys and literacy assessments, with qualitative insights obtained through focus groups. While the quantitative data offered evidence of measurable improvements in informatics literacy, the qualitative findings illuminated how students interacted with DBL tasks, negotiated interdisciplinary knowledge, and applied theoretical concepts in authentic contexts.

Structured reflection was a central component of the study design. Stakeholder debriefings, faculty workshops, and curriculum review sessions allowed the teaching team to systematically evaluate each cycle, identify challenges, and implement adjustments in subsequent iterations. This iterative refinement ensured that pedagogical strategies evolved responsively based on both empirical evidence and participant feedback.

*Preparatory Phase: Establishing the DBL framework*

Prior to commencing the PAR cycles, the research team conducted a three-stage preparatory process to embed DBL principles within the nursing informatics course. Activities included curriculum mapping, development of authentic project scenarios, and alignment of assessment strategies with learning objectives. The timeline, critical tasks, and expected outputs of this preparatory stage are summarized in **Table 2**, providing the foundation for the subsequent iterative cycles.

**Table 2.** Timeline of the preparatory phase

| Timeframe | Stage | Key Activities | Key Outcomes |
|---|---|---|---|
| Feb 2020 | Audit & Self-Assessment | 1. Reviewed current course content 2. Evaluated students' baseline interdisciplinary knowledge | Pinpointed three critical gaps: 1. Outdated materials 2. Weak higher-order thinking skills 3. Need for full redesign |
| Mar–Apr 2020 | Planning & Redesign | 1. Conducted literature review on DBL in nursing/health education 2. Convened expert panels and aligned with global informatics standards | Decision: Embed an 8-hour DBL module into the core curriculum |
| May–July 2020 | Evaluation & Refinement | 1. Course leaders collaborated with engineering experts 2. Added content on design principles, data | 1. Reorganized course into four cohesive modules 2. Refreshed all |

| | | |
|---|---|---|
| | privacy, and prototyping 3. Incorporated real-world case studies and improved grading rubrics | teaching materials 3. Validated and finalized assessment tools |

In February 2020, the team conducted a detailed review of the existing course materials, including syllabi, lesson plans, and lecture slides, with input from both educational specialists and instructors. This evaluation revealed several critical gaps: the content was not aligned with current hospital informatics practices, it relied on simulated rather than authentic clinical data and systems, and it provided few opportunities for students to engage in higher-order thinking. These findings made it clear that a thorough course overhaul was necessary.

From March to April 2020, the course was restructured based on the audit results. The redesign process incorporated insights from relevant literature and two rounds of consultations with expert panels. The literature review focused on the use of Design-Based Learning (DBL) in health and nursing education and on international standards for informatics competencies. As a result, eight hours of DBL activities were incorporated into the curriculum.

The DBL framework was adapted to the program's dual-site setup, spanning both classroom and hospital ward settings, in line with Kolodner's Learning by Design cycle. The approach consisted of two interconnected cycles. In the first, students collaborated with clinical mentors to identify practice-related questions, develop hypotheses, conduct ward-based investigations, and analyze their observations. In the second cycle, students translated their findings into prototype informatics solutions, testing and refining these designs through repeated iterations. The cycles were linked by two driving prompts: "Need to know," which guided new rounds of clinical inquiry, and "Need to do," which directed further classroom-based development. By alternating between practical and theoretical contexts, students were able to combine knowledge with hands-on experience, enhancing their critical thinking, creativity, and informatics competencies.

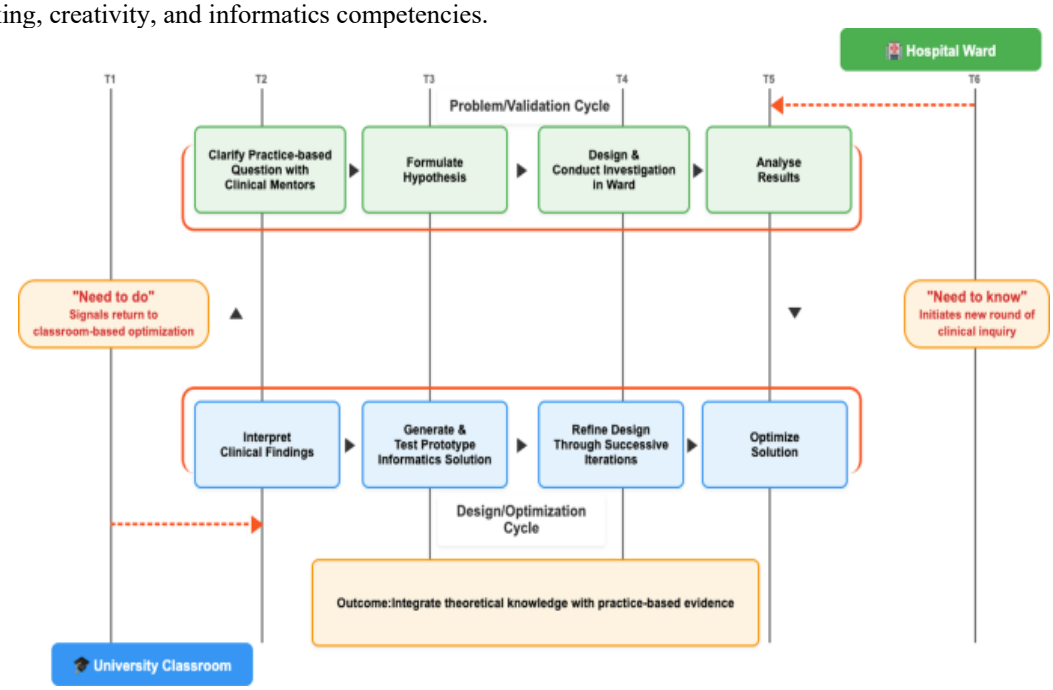


**Figure 1.** Applied research framework based on Kolodner's learning by design cycle

Between May and July 2020, course leaders and instructors, together with information engineers from partner hospitals, focused on refining and updating the curriculum. The content was reorganized into four progressive modules: Basic Introduction, Consolidation Application, Advanced Practice, and Innovation Enhancement. New learning materials were introduced, including resources on user-centered design, data privacy, system security, and prototyping tools. Students were also exposed to case studies of existing nursing information systems and applications. Assessment rubrics and task guidelines were clearly defined to align with the Design-Based Learning (DBL) approach and support structured student engagement.

Starting in September 2020, the DBL strategy was rolled out and improved over four successive Participatory Action Research (PAR) cycles, each designed to implement, evaluate, and refine the learning approach.

The first cycle (February–June 2021) integrated clinical internships with classroom-based design tasks. Student teams identified informatics challenges during ward rotations, developed initial project proposals, and refined their prototypes under faculty guidance. However, students frequently focused on technical functionalities while overlooking how nursing workflows could shape the solutions. This underscored the need for more structured guidance that better linked nursing knowledge to informatics practice.

The second cycle (February–June 2022) strengthened practical support by establishing a combined college–hospital teaching base and introducing industry mentorship. Mentors, trained on DBL principles, project design, and nursing informatics, were assigned to student teams to help identify real clinical problems, navigate data access, and provide ongoing feedback. Weekly seminars allowed teams to present progress for joint evaluation by mentors and faculty. Despite these improvements, students found balancing DBL projects with other academic responsibilities challenging, prompting the third cycle to extend project timelines for more focused engagement.
In the third cycle (September 2022–January 2023), a one-month summer clinical immersion was added to allow intensive mentor-guided problem identification. Students then entered a ten-week design phase and returned to the ward for a one-week validation of prototypes. COVID-19 restrictions forced many activities online, limiting direct observation of ward practices and reducing spontaneous mentor interactions. This highlighted the importance of maintaining authentic, in-person clinical engagement.
The fourth cycle (September 2023–January 2024) restored all activities to an in-person format. Students returned to hospital wards to identify challenges, test solutions, and receive immediate feedback from clinical staff. On-campus weekly seminars facilitated discussion and peer review, while faculty and mentors monitored project milestones to ensure that nursing knowledge was effectively integrated into informatics solutions. With the removal of pandemic restrictions, the cycle achieved full engagement, and a joint audit confirmed that no major issues remained.

**Table 3.** Overview of PAR cycles

| Cycle & Timeline | Core Actions | Key Reflective Insights |
|---|---|---|
| Cycle 1 Feb–Jun 2021 | Launched first DBL with clinical placements, design challenges, and prototype iterations | Weak linkage between nursing practice and informatics skills |
| Cycle 2 Feb–Jun 2022 | 1. Added industry mentors 2. Established joint hospital–college training site | Time limitations restricted depth and complexity of projects |
| Cycle 3 Sep 2022–Jan 2023 | 1. Shifted schedule to leverage summer break 2. Extended project duration 3. Switched to virtual internships with remote guidance due to COVID-19 | Virtual format diminished hands-on realism and student interaction |
| Cycle 4 Sep 2023–Jan 2024 | Returned to in-person ward-based projects and seminars | Achieved strong integration and practical feasibility; no significant barriers |



**Data collection**

*Curriculum audit*
An extensive review of course materials was undertaken, including syllabi, lesson plans, presentation slides, seminar notes, and assessment records. Syllabi were examined to determine how well learning objectives reflected current hospital informatics practices. Lesson plans were evaluated to see if teaching strategies matched intended outcomes, while slides and seminar records were scrutinized for the accuracy of terminology and depth of concepts. This qualitative review focused on alignment with Design-Based Learning goals and emerging industry trends, guiding annual refinements to the curriculum.

*Student surveys*
To measure students' self-perceived nursing informatics competence, the study used the Self-Assessment of Nursing Informatics Competencies Scale (SANICS), a 28-item questionnaire rated on a five-point scale. Scores ranged from 28 to 140, with higher totals indicating stronger perceived literacy. The scale addressed four dimensions: awareness of information, knowledge, applied ability, and ethical considerations. Reliability of the original English version was high ($\alpha > 0.91$), and the Chinese adaptation used in this study demonstrated similar consistency ($\alpha = 0.93$) and test-retest reliability ($r = 0.88$).

*Focus group interviews*
Following the fourth DBL cycle, two focus groups were convened to gather qualitative feedback on participants' experiences and learning outcomes. One group consisted of ten nursing students who had completed all DBL activities, and the other included six educators—three nursing informatics instructors and three clinical mentors. Participants were chosen purposefully to capture a range of perspectives. Semi-structured interviews were conducted based on a guide developed from the literature and study objectives, refined collaboratively within the research team to ensure questions were open-ended and free from bias.
Two researchers with expertise in nursing informatics and education, who were not involved in teaching or assessment, led the interviews in a quiet university setting. Sessions lasted 60–75 minutes and were audio-recorded with consent. Transcriptions were completed within 24 hours and cross-checked with field notes to ensure accuracy. Analysis followed a content analysis approach using Python-based QualCoder software.

Researchers first immersed themselves in the data, then conducted line-by-line open coding to capture the meaning of each statement. Codes were subsequently organized into broader categories using a deductive framework aligned with the interview guide. Through repeated review and discussion, data saturation was confirmed, and final themes were validated with participants to strengthen credibility.

*Quantitative analysis*

Changes in nursing informatics competence were assessed by comparing pre- and post-course scores using paired t-tests, with normality checked via the Shapiro-Wilk test. Cohen's d values quantified effect sizes. Bayesian modeling provided posterior distributions of mean differences between pre- and post-course scores, with 94% High-Density Intervals (HDIs) expressing the uncertainty of observed gains. Analyses were conducted in Python, using reproducible workflows with fixed random seeds.

## Findings

Results are presented in two domains. Quantitative findings indicated clear improvements in students' informatics literacy across cohorts, with post-course scores consistently higher and less variable. Qualitative analysis revealed complementary benefits, including enhanced interdisciplinary thinking and better integration of theory with clinical practice. **Figure 2** displays the distributions of pre- and post-course scores, while **Figure 3** illustrates Bayesian posterior distributions, further supporting the observed improvements over time.

*Informatics literacy outcomes*

Analysis of each cohort's pre- and post-course scores **(Table 4)** showed clear and statistically significant improvements in nursing informatics literacy ($p < 0.001$). The 2018 cohort started at an average of $73.13 \pm 13.38$ and increased to $86.55 \pm 12.21$, a change of over 13 points on the 140-point scale, with a large effect size (Cohen's $d = 2.21$), reflecting a notable advancement from moderate to higher literacy levels. Subsequent cohorts built on this progress: the 2019 cohort's scores rose from $73.22 \pm 14.90$ to $90.28 \pm 13.34$ (Cohen's $d = 2.46$), and the 2020 cohort improved from $73.48 \pm 15.57$ to $90.86 \pm 13.11$ (Cohen's $d = 2.47$), even though pandemic-related disruptions affected some learning activities. The 2021 cohort achieved the most pronounced improvement, reaching an average post-course score of $92.47 \pm 12.07$ (Cohen's $d = 3.07$), suggesting that accumulated refinements to the DBL approach, coupled with increased student familiarity with informatics tools, resulted in the greatest gains in literacy.



**Table 4.** Paired t-test results for pre- and post-course scores across cohorts

| Cohort(*n*) | Pre-course score (Mean ± SD) | Post-course score (Mean ± SD) | t | *p* | Cohen's d |
|---|---|---|---|---|---|
| 2018 (156) | 73.13 ± 13.38 | 86.55 ± 12.21 | -26.07 | < 0.0001 | 2.21 |
| 2019 (156) | 73.22 ± 14.9 | 90.28 ± 13.34 | -29.00 | < 0.0001 | 2.46 |
| 2020 (155) | 73.48 ± 15.57 | 90.86 ± 13.11 | -29.14 | < 0.0001 | 2.47 |
| 2021 (155) | 73.17 ± 15.15 | 92.47 ± 12.07 | -36.14 | < 0.0001 | 3.07 |

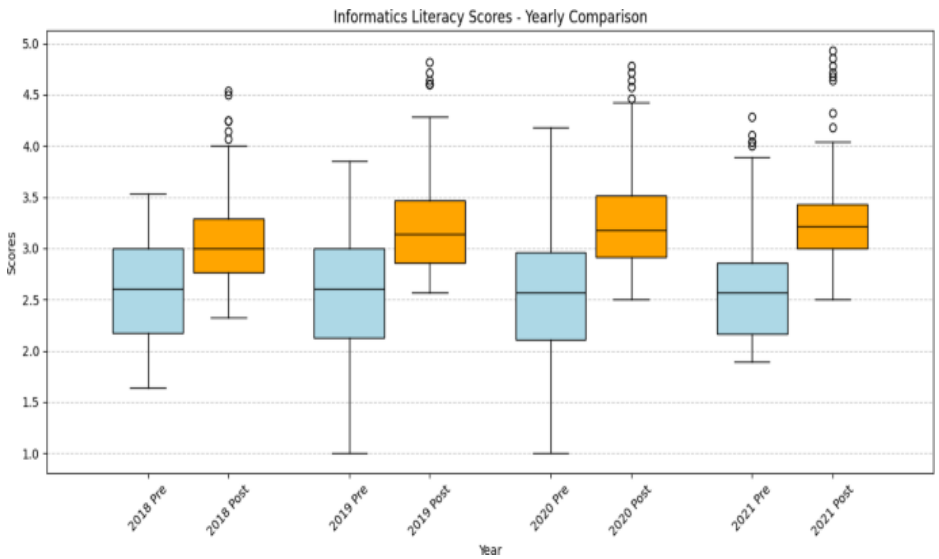


**Figure 2.** Yearly comparison of informatics literacy: pre- and post-course assessments

*Trends in informatics literacy gains*

Bayesian analysis offered a nuanced perspective on both the scale and reliability of the observed improvements **(Figure 3)**. Across all cohorts, the posterior mean differences between post- and pre-course scores were positive and clearly separated from zero. In detail, the 2018 cohort showed a mean increase of 0.478 (94% HDI: 0.440–0.514), the 2019 cohort 0.626 (94% HDI: 0.579–0.670), the 2020 cohort 0.620 (94% HDI: 0.580–0.660), and the 2021 cohort 0.689 (94% HDI: 0.650–0.722). In each instance, the 94% High-Density Intervals excluded zero, providing strong evidence that the curriculum changes were linked to genuine improvements in student informatics literacy.

Estimates of variability (sigma) indicated moderate dispersion in 2018 (0.238, 94% HDI: 0.213–0.265), which increased slightly in 2019 (0.296, 94% HDI: 0.263–0.330), before stabilizing in 2020 (0.253, 94% HDI: 0.223–0.281) and 2021 (0.227, 94% HDI: 0.203–0.253). This pattern suggests that early gains occurred under more variable conditions, while iterative refinements to the instructional approach over time resulted in more consistent and uniform outcomes across later cohorts.

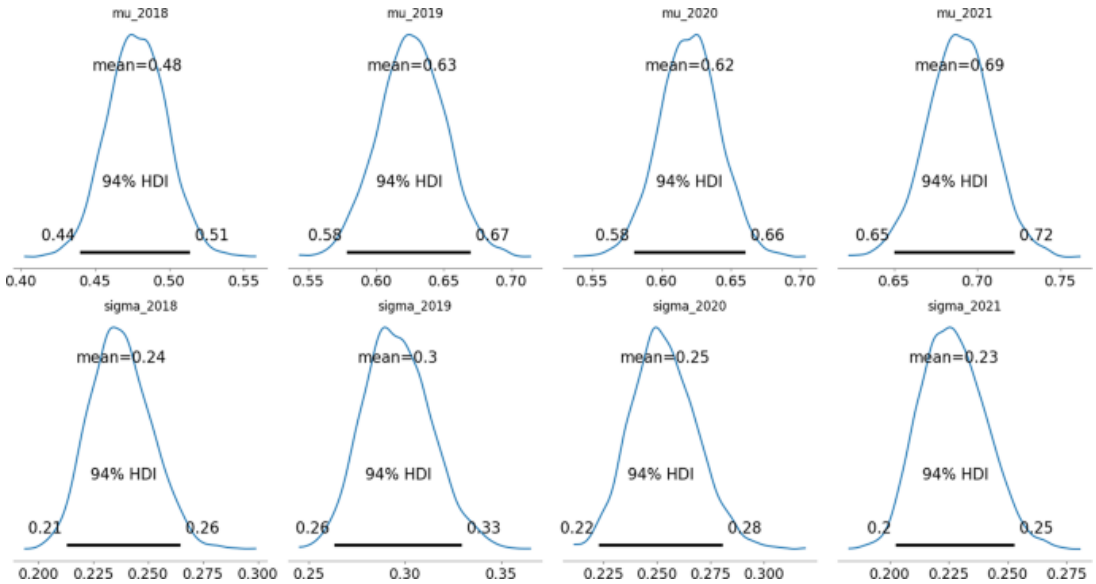


**Figure 3.** Bayesian estimates of informatics literacy improvements: mean and variability by year

*Insights from focus group interviews*

To complement the quantitative findings and explore aspects not captured by standardized measures, focus group interviews were conducted. Following the principle of data saturation, analysis of the transcripts revealed four central themes: (1) development of interdisciplinary thinking, (2) integration of theory and practice through informatics skill mastery, (3) formation of professional identity, and (4) teamwork and leadership. These themes were derived through thematic analysis, highlighting the mechanisms through which DBL influenced student learning.

*Theme 1: Cultivating interdisciplinary thinking*

Both students and instructors emphasized that the DBL approach promoted interdisciplinary reasoning by bridging nursing, computer science, and information technology. Students noted that the method reshaped their perspective on clinical challenges, while educators observed its role in nurturing innovative, cross-disciplinary problem-solving.

One student reflected, "Working on the DBL project introduced me to big data analytics. The breakthrough came when I realized my nursing knowledge helped pinpoint which patient indicators were meaningful for predictions. It showed me how clinical judgment and data science can complement each other."

Educators shared similar observations. A nursing informatics instructor explained, "At first, students treated nursing and IT as separate domains. In DBL projects, however, they began asking questions like, 'How can sensor data predict patient falls?' or 'Which clinical workflows should guide app design?' They started to combine disciplines creatively to solve real clinical issues."

Mentors highlighted the practical impact: "One team developed a fall-prevention system for older adults, integrating data analytics directly with patient care. It was impressive to see theory translated into practice," noted a clinical nursing mentor. Collectively, these experiences demonstrate how DBL encouraged students to synthesize nursing knowledge with technological skills, fostering genuine interdisciplinary thinking.

*Theme 2: Linking theory and practice through informatics mastery*

DBL projects enabled students to move beyond passive learning, equipping them with the skills to design and apply nursing information systems that addressed real clinical needs. Educators noted that this process allowed students to apply theoretical concepts in practical contexts, strengthening the connection between classroom learning and clinical practice.

One student shared, "During the DBL project, I gained hands-on experience with electronic medical records and learned how to balance efficiency with privacy protection." Instructors observed that students were not only learning to operate existing systems but were also questioning design choices and developing prototypes tailored to actual clinical workflows.

The design-centric nature of DBL further stimulated creativity. Another student explained, "I created an app prototype using the TAM model. 'Ease of use' wasn't just about interface—it required understanding how nurses make decisions under stress. Theory became a practical tool for design." Mentors echoed these observations, emphasizing that students' solutions were aligned with real-world clinical problems, improving both workflow efficiency and care accuracy.

*Theme 3: Professional identity and sense of purpose*

Engagement in DBL projects helped students reconceptualize the role of nursing informatics in contemporary healthcare, fostering confidence and a clearer professional identity. Students reported recognizing themselves as key contributors capable of linking clinical knowledge with technological solutions. One student reflected, "Designing a medication error prevention system made me realize I wasn't merely using software; I was applying clinical insight to improve patient care" [31]. Another explained, "I became a bridge between clinical requirements and the technical team. This showed me that I could influence patient outcomes through informatics without abandoning bedside nursing" [32].

Educators observed a corresponding shift: students who initially saw informatics as supplementary began to regard it as central to modern nursing. Clinical mentors noted that students actively connected DBL projects to real-world clinical problems, demonstrating emerging professional identity and ownership of their learning [31]. Several students reported that these experiences clarified career aspirations in nursing informatics [32].

*Theme 4: Teamwork and leadership development*

The DBL approach also promoted collaborative and leadership skills. Students worked in interdisciplinary teams, negotiating clinical and technical perspectives to produce coherent solutions. One participant noted, "Some teammates focused on clinical care while others handled system design. Learning to communicate and integrate these perspectives was challenging but necessary" [33]. Another described redistributing tasks without blame when a member struggled, enhancing team performance [33].

Faculty highlighted students' natural assumption of leadership roles, coordinating efforts, motivating peers, and managing deadlines. These experiences provided transferable skills such as decision-making under pressure, conflict resolution, and project management, directly applicable to both clinical and informatics contexts [34].



*Discussion: Impact of DBL on nursing informatics education*

The study demonstrates that DBL significantly enhances nursing informatics literacy among undergraduate students. By embedding authentic clinical challenges into an iterative, participatory learning process, students developed technical skills, critical thinking, and professional competence. The use of a participatory action research framework enabled continual curriculum refinement, maintaining relevance as healthcare technologies evolved [31, 32].

DBL's effectiveness arises from its constructivist, active-learning approach: students apply theoretical knowledge to design real-world solutions rather than passively absorbing content [33, 34, 35]. This methodology bridges the persistent theory-practice gap in nursing informatics education, allowing learners to engage with practical problems while reinforcing conceptual understanding [36, 37].

Iterative feedback loops among students, instructors, and clinical mentors created a collaborative learning environment mirroring modern interdisciplinary informatics practice. Engaging with authentic problems strengthened both technical literacy and professional readiness, confirming the value of learner-centered, problem-focused pedagogies in preparing students for complex healthcare environments [31–37].

*Connecting theory to clinical practice through DBL*

Across multiple cohorts, students' informatics literacy steadily increased, suggesting that the Design-Based Learning (DBL) approach successfully links classroom theory with practical application. Instead of simply memorizing concepts, learners engaged in iterative projects where they combined nursing expertise with informatics problem-solving. This active, hands-on approach not only deepened understanding but also strengthened competencies required for technologically advanced clinical settings. The stepwise improvement observed across successive cohorts points to the cumulative effect of ongoing course refinements and faculty

adaptation. Similar iterative improvements have been noted in other nursing education innovations, where repeated curriculum adjustments enhanced both student engagement and instructional quality [38].
While traditional nursing informatics courses may improve student knowledge, the magnitude of gains and the rich qualitative feedback from DBL participants indicate that this method provides additional value. Students reported higher confidence, stronger professional identity, and more effective problem-solving than typically observed with lecture-based approaches.

*Lessons from implementation*
Deploying DBL through four participatory action research (PAR) cycles revealed challenges that offer guidance for future initiatives. Both educators and students initially struggled with the transition. Faculty needed to shift from delivering content to facilitating inquiry, a change requiring structured professional development [39]. Students, accustomed to predictable lectures, often felt uncertain about open-ended design tasks, reflecting broader tensions between traditional assessment-driven expectations and active learning approaches [40]. Scaffolding projects, clarifying assessment criteria, and implementing regular check-ins gradually eased these challenges. By the fourth cycle, students reported increased comfort with ambiguity and enhanced confidence in designing solutions.
Securing authentic yet manageable clinical problems posed another hurdle, especially during COVID-19 when virtual rotations limited access to real-world data. Establishing a joint college-hospital teaching base and leveraging the iterative PAR framework allowed for quick identification and resolution of these logistical challenges [41]. Beyond skill development, the qualitative findings showed that students' professional identity, teamwork, and leadership abilities were strengthened, highlighting DBL's broader educational impact [42].

*Implications for practice and research*
The results underscore that effective educational innovation requires a holistic approach addressing faculty readiness, student expectations, and institutional support. Structured documentation of implementation challenges can serve as a practical roadmap for others aiming to adopt design-based approaches in nursing informatics [43, 44].
For curriculum developers, embedding authentic, design-oriented tasks is crucial. Protected time for faculty training and formal feedback mechanisms supports iterative curriculum improvement. Clinical leaders can enhance student learning by offering access to real-world informatics challenges, effectively creating innovation "laboratories" within practice settings [45].
Future studies should evaluate DBL across multiple sites and include comparison groups to isolate its effects. Longitudinal tracking of graduates could provide insight into whether DBL training leads to improved clinical performance, leadership, and engagement in digital health initiatives, which is increasingly relevant as healthcare systems embrace digital transformation.



## Conclusion

This study demonstrates that DBL, supported by participatory action research, can advance nursing informatics literacy while fostering critical thinking, innovation, and collaborative problem-solving. By combining theoretical knowledge with real-world application, students acquire not only technical skills but also the professional competencies necessary for modern healthcare. Limitations include the single-institution setting, lack of a control group, and COVID-19-related disruptions. Nonetheless, these findings highlight the potential for DBL to transform nursing informatics education, establishing a model that prepares nurses to lead in technology-integrated care delivery.

## Abbreviations

**DBL:** Design-Based Learning
**PAR:** Participatory Action Research

**Acknowledgments:** None.

**Conflict of interest:** None.

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**Ethics statement:** None.

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