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Enhancing EMR Programming through a TPACK-Based Interactive Application in Health Informatics Education

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ABSTRACT

This study explores the potential of an interactive learning application, designed using the Technological Pedagogical Content Knowledge (TPACK) and Self-Regulated Learning (SRL) frameworks, to enhance student competence in basic Electronic Medical Record (EMR) programming within health informatics education. Using a quasi-experimental pretest-posttest design, the research involved 64 third-semester students in a vocational Health Information Management program. Participants were divided into two groups: an experimental group utilizing the interactive application and a control group receiving traditional instruction. Data were collected through achievement tests, motivation surveys, and usage log analysis. Results revealed that the experimental group demonstrated significantly higher learning achievement (M = 78.6 vs. 65.9), improved motivation (Likert mean = 4.35), and stronger self-regulated learning behaviors (87.1% module completion and 81% repeated simulations). These findings suggest that interactive tools grounded in pedagogical frameworks can effectively bridge abstract programming logic with clinical relevance, fostering both engagement and autonomous learning. The study contributes a scalable and replicable model for integrating simulation-based programming instruction in health informatics curricula.

I. Introduction

In an era increasingly shaped by digital transformation, health informatics education must rapidly evolve to prepare students for the realities of a technologically enabled healthcare system. One essential yet underdeveloped area is Electronic Medical Record (EMR) programming [1], a subject that intersects health data management, clinical workflow understanding, and software logic. Despite its practical importance, the pedagogical approach to EMR programming remains complex, particularly for students in non-computer science backgrounds such as Health Information Management (HIM) [2]. The abstract syntax of programming languages and the lack of contextualized learning often lead to low engagement and poor comprehension [3], [4].

The urgency of improving digital competencies in healthcare education is reinforced by national mandates, such as Indonesia's Regulation No. 24 2022, which requires the implementation of electronic-based medical records in all healthcare facilities. Educational institutions are now challenged to equip students not only with technical coding skills, but also with self-directed learning strategies and digital literacy to operate in flexible and hybrid learning environments [6], [7]. However, traditional lecture methods often fall short, especially in applied domains like EMR programming, where students benefit more from iterative, visual, and simulation-based learning approaches [8].

To bridge this gap, interactive digital applications have emerged as promising tools that can deliver programming instruction through animations, simulations, and guided feedback [9]. However, many

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such tools suffer from superficial engagement due to a lack of pedagogical grounding. This shortfall highlights the importance of using frameworks such as Technological Pedagogical Content Knowledge (TPACK), which emphasizes the integration of subject matter, pedagogy, and technology in instructional design [10], [11], [12].

Although TPACK has been widely studied in general education and teacher training, its implementation in applied health informatics remains limited [13]. Most studies focus on STEM fields or theoretical instruction, leaving a gap in domains like health data systems or electronic documentation [14], [15]. In tandem with this, the importance of fostering Self-Regulated Learning (SRL) has also gained attention in digital learning environments. SRL, when supported by real-time feedback and user autonomy, has been linked to improved academic performance, especially in asynchronous or hybrid settings [16], [17], [18].

Building on this foundation, the present study aims to evaluate the effectiveness of a TPACK-based interactive learning application specifically designed for the Basic EMR Programming course. The application integrates core programming concepts with contextualized simulation of medical data environments and incorporates SRL-supportive features like feedback, progression control, and chunked materials [19].

This study uses a quasi-experimental design with pretest–posttest comparison and student perception surveys. Participants are third-semester students in a vocational HIM program, who are expected to master EMR programming as part of their competency requirements. The study investigates whether this application can improve students' performance, engagement, and motivation more effectively than conventional instruction.

By situating its analysis at the intersection of TPACK, SRL, and EMR simulation, this research contributes to the growing discourse on digital pedagogy in health professions education [12]. It offers practical insights for educators, instructional designers, and policymakers who seek to transform health informatics instruction through evidence-based digital innovation [20], [21], [22].

II. Method

This study employed a quantitative evaluative approach with a quasi-experimental pretest-posttest design, aimed at measuring the effectiveness of a TPACK-based interactive learning application in improving students' understanding of basic programming in the context of electronic medical records (EMR) [23]. The research was specifically conducted to examine how well-designed digital tools—anchored in pedagogical theory—can enhance engagement, comprehension, and learner autonomy among students in health informatics education [24].

The study was carried out at the Department of Health Information Management, Indonusa Polytechnic of Surakarta, during the odd semester of the 2024/2025 academic year. The research population consisted of third-semester students who were enrolled in the course "Basic Programming for Electronic Medical Records." Out of a total of 98 students across three classes, 64 students were selected through purposive sampling based on their availability and course participation status [25].

A. Participants were randomly divided into two equal groups:

- Experimental group (n = 32): Students in this group used the TPACK-based interactive application throughout the learning period.
- Control group (n = 32): Students in this group received traditional instruction using slide-based presentations and textbooks, without the aid of the application.

B. Research Variables and Operational Definitions

- Independent Variable: Use of the TPACK-based interactive learning application that incorporates simulation, feedback, and instructional chunking.
- Dependent Variables: Learning outcomes: Measured by differences in pretest and posttest scores related to programming logic, syntax, and structure in EMR; Learning motivation: Measured using a validated Likert-scale questionnaire; Self-regulated learning behavior:

Observed through the system's embedded analytics (completion rates, retries, and help requests).

C. Data Collection Instruments and Procedures

- Achievement Test:

  A structured multiple-choice test was administered in two treatment cycles—before, between, and after the intervention—to both the control and experimental groups. The test assessed participants' understanding of core programming topics, including variables, conditionals, loops, arrays, and simple EMR-based logic. Conducting two cycles allowed for evaluating improvement consistency and determining whether the experimental group achieved significantly better learning outcomes over time.

- Perception Survey:

  Adapted from validated instruments on learning motivation and self-regulated learning (El-Sayed & Abdelrahman, 2024; Jin et al., 2023), the survey was distributed after each treatment cycle. It included items measuring confidence, engagement, perceived usefulness, and behavioral indicators of autonomy, enabling comparison of motivational and perceptual changes across cycles.

- Observation Logs:

  For the experimental group, the application's usage logs were collected throughout both treatment cycles. These logs captured task completion patterns, simulation attempts, and progress pauses—behavioral indicators aligned with SRL (Self-Regulated Learning) features—to triangulate quantitative test results and survey findings.

D. Data Analysis Techniques

Quantitative data were analyzed using descriptive statistics (mean, standard deviation, percentage) and inferential statistics:

- Independent samples t-test was used to compare the mean score improvements between the experimental and control groups.
- Paired samples t-test was used within each group to assess pre-post differences.
- ANCOVA was considered to control for potential confounding variables, such as prior programming experience.

Significance was tested at $p < 0.05$, and all analyses were conducted using SPSS version 26. Qualitative responses from open-ended survey items were used to triangulate findings and enrich the interpretation of students' perceived experiences with the application.

This mixed-method approach allows for a nuanced understanding of how instructional design grounded in the TPACK framework can influence learning outcomes and behavioral engagement, particularly in the context of vocational health informatics education. The methodology also supports scalability and reproducibility, aligning with national goals to standardize EMR training in higher education.

III. Results and Discussion

The primary objective of this study was to evaluate the effectiveness of a TPACK-based interactive learning application in enhancing student understanding of basic programming for Electronic Medical Records (EMR) in a vocational health informatics education setting. The evaluation focused on three core indicators: learning achievement, student motivation, and self-regulated learning (SRL) behaviors.

A. Quantitative Outcomes

The study involved 64 third-semester students enrolled in the "Basic Programming for EMR" course, who were divided equally into two groups:

- Experimental group (n = 32): used a TPACK-aligned interactive application featuring simulations, guided coding, and feedback loops.
- Control group (n = 32): followed conventional teaching methods using slides and textbooks.

A summary of the comparative results is shown below:

Table 1. Summary of Learning Outcomes by Group

Indicator	Experimental Mean	Control Mean	Difference
Learning Achievement	78.6	65.9	+12.7
Learning Motivation	4.35 (Likert 1–5)	3.72	+0.63
SRL Behavior	87.1%	64.8%	+22.3

These differences are further illustrated in the visual below:

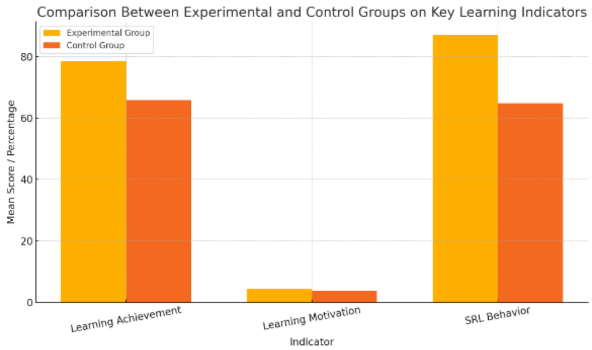

Fig. 1. Comparison Between Experimental and Control Groups on Key Learning Indicators

B. Learning Achievement

The experimental group showed a significantly higher posttest score (M = 78.6) than the control group (M = 65.9), with a +12.7 point improvement. This result suggests that the structured simulation and immediate feedback features in the application supported more effective learning.

This is consistent with findings by Elmabaredy and Gencel (2024), who highlight the power of interactive, feedback-rich platforms to boost conceptual mastery in health-related disciplines. Aldalalah et al. (2025) further support this by showing that digital content designed using the TPACK framework enhances cognitive engagement and clarity of complex content like programming.

C. Student Motivation

Motivation levels were also higher among students in the experimental group, who scored an average of 4.35 on a 5-point Likert scale, compared to 3.72 in the control group. Open-ended responses indicated that students felt less anxious, more excited, and more confident when using the app, especially when they could track their own progress and correct mistakes independently.

These findings echo those of Jin et al. (2023), who found that real-time feedback, gamification, and interface personalization are powerful triggers for sustained motivation in digital learning settings.

D. Self-Regulated Learning (SRL) Behavior

System log data revealed high levels of SRL behavior among experimental group users:

- 93% completed all modules,
- 81% repeated simulations before assessments,
- 64% actively used the feedback system to rewatch content.

This pattern reflects key elements of planning, monitoring, and reflection described in Zimmerman's SRL model. The findings are also aligned with recent insights by Domino and Shaffer (2025), who emphasize the importance of scaffolded autonomy and digital analytics in cultivating SRL habits among learners.

E. Interpretation and Broader Implications

The combination of higher scores, greater motivation, and demonstrated self-regulation behaviors suggests that TPACK-based interactive learning applications can be more than supplementary tools—they can serve as primary learning environments, especially for students in applied health education.

The application used in this study simulates real EMR systems without the administrative risk of patient data or legal constraints, enabling practice-based learning in a safe, scalable, and student-centered environment. This aligns with calls from Kuikka et al. (2024), Choi, and Kim et al. (2025) to expand simulation-based instruction in medical and health informatics education.

F. Strengths and Limitations of the Product

Table 2. Summary of Product Strengths and Limitations

Strengths	Limitations
EMR scenario-based coding increases relevance	Limited scope: basic programming logic only
Encourages SRL & motivation	No integration yet with national EMR sandbox
Can be used offline on low-spec devices	Needs iterative content updates

The application's primary strength lies in its contextual design—providing programming practice that mimics EMR functionality—while maintaining accessibility even on offline or low-resource setups. On the other hand, its limited content scope and lack of integration with national health data frameworks (e.g., SATUSEHAT) represent areas for future enhancement.

IV. Conclusion

This study concludes that the use of an interactive learning application designed based on the Technological Pedagogical Content Knowledge (TPACK) and Self-Regulated Learning (SRL) frameworks significantly enhances the learning process of vocational students in basic Electronic Medical Record (EMR) programming. The application's integration of simulation, real-time feedback, and scaffolded autonomy led to measurable improvements in learning achievement, increased intrinsic motivation, and strengthened SRL behavior.

Students in the experimental group achieved higher posttest scores (+12.7 points), reported greater engagement (mean motivation score 4.35), and exhibited active learning behaviors such as re-engaging with simulation content and using built-in guidance systems. These results support the claim that pedagogically grounded digital tools can act not only as supplements but also as core instructional platforms, particularly in applied health informatics education.

To support broader implementation and future development, the following recommendations are proposed:

- Expand the content scope to include advanced EMR functions and interoperability standards (e.g., HL7, FHIR).
- Integrate the application with national EMR sandbox systems, such as SATUSEHAT, to enhance realism and clinical relevance.
- Embed adaptive learning analytics to personalize feedback and support differentiated instruction based on individual learner progress.

By embedding evidence-based educational frameworks into simulation technology, this study offers a replicable and scalable model for enhancing health informatics instruction—one that aligns with current digital transformation mandates in healthcare and can serve as a foundation for future educational innovation.

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