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Digital Transformation in Higher Education: Integrating Higher STEM Education and Educational Technology in Pedagogical Innovation

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Abstract. This study aims to propose solutions to improve the quality of training in the context of digital transformation and the requirements for innovation in higher education. Under the impact of the Industrial Revolution 4.0, traditional teaching methods are no longer suitable for the goal of developing the comprehensive capacity of learners. The study uses a mixed-method design including two phases: (1) a survey of 138 lecturers at Hai Duong University to assess the level of readiness and current status of digital transformation in teaching; (2) a pedagogical experiment with 80 electrical engineering students to evaluate the effectiveness of the model of integrating advanced Science, Technology, Engineering, and Mathematics (STEM) education with modern educational technology. The sample was selected using a stratified random sampling method. Data was collected through online questionnaires and analyzed pre-test/post-test by descriptive statistics and t-tests. The results show that the experimental group had a significant improvement in average score ($t = 11.84$; $p < 0.001$) compared to the control group ($t = 2.12$; $p = 0.041$). The model combining 6E, engineering design process, project-based learning, and the application of educational technology helped to increase interactivity, personalization, and learning effectiveness. The lecturer survey pointed out the main barriers in technical infrastructure, digital capacity, and institutional support. The study concluded that integrating STEM education and educational technology is a viable direction for pedagogical innovation in the digital transformation era.

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1. Introduction

The Fourth Industrial Revolution has brought significant changes to all sectors, including higher education (Antonopoulou et al., 2023). Digital transformation is not only about using technology in teaching but also about fundamentally changing how universities organize, manage, and deliver learning (Bygstad et al., 2022; Fernández et al., 2023; Sych et al., 2021). The adoption of technologies such as artificial intelligence (AI), learning analytics, virtual reality, and learning management systems has created opportunities for personalized and innovative teaching (García-Peñalvo, 2021; Lyngdorf et al., 2024).

Recently, the emergence of AI-powered tools like ChatGPT has further accelerated digital transformation in education. These technologies are reshaping instructional design, feedback, and student engagement. As highlighted by Ampo et al. (2025), teachers lived experiences in integrating ChatGPT into classroom practices reveal both the potential and the pedagogical challenges of AI-assisted learning environments. This underscores the need to explore effective frameworks that blend technological innovation with sound educational design (Deroncele-Acosta et al., 2023).

However, higher education institutions still face many challenges. In Vietnam, most lecturers have not yet developed strong digital competence, and infrastructure and policy support remain limited (Dang et al., 2024). At an international level, research also shows that digital transformation is hindered by institutional, technological, and human barriers (Gkrimpizi et al., 2023). These challenges highlight the need for new pedagogical models that align with digital transformation and help both teachers and students build digital capabilities.

Science, Technology, Engineering, and Mathematics (STEM) education has emerged as an effective approach in this context. STEM not only builds technical knowledge but also develops creativity, critical thinking, and problem-solving skills (Aydın-Güç & Şahiner, 2022; Kelley & Knowles, 2016). Methods such as project-based learning and the 6E learning cycle have been shown to improve student engagement and learning outcomes (Brahic et al., 2024; Şahin & Kılıç, 2023). When combined with educational technology, STEM provides flexible and experiential learning environments that meet the demands of the digital economy (Lin et al., 2021).

Based on this background, the purpose of this study is to propose and evaluate an integrated pedagogical model that combines advanced STEM education and educational technology to enhance teaching quality and digital competence in higher education. The research question guiding this study is: *How can STEM education and educational technology be effectively integrated in the digital transformation of higher education?* The findings are expected to provide empirical evidence for pedagogical innovation and support universities in building flexible and sustainable educational strategies for the digital era (Lyngdorf et al., 2024).

2. Literature Review and Context

2.1 Overview of Research Literature

Recent research has increasingly focused on how digital transformation reshapes higher education and how integrating technology with pedagogical innovation can enhance learning outcomes. Fernández et al. (2023) conducted a multivocal literature review showing that while most universities recognize the importance of digital transformation, few have established coherent strategies to link digitalization with teaching innovation. Their findings highlight a methodological gap between technological adoption and actual pedagogical reform.

In a related analysis, García-Peñalvo (2021) emphasizes that the absence of institutional frameworks often limits the sustainability of digital initiatives. The study recommends that universities adopt holistic models that combine governance, pedagogy, and technology to avoid fragmented implementation. Similarly, Prabowo and Bandur (2023) identify a theoretical limitation in current practices, where digital transformation is often treated as a technical process rather than a learning-centered innovation.

At the pedagogical level, several experimental studies demonstrate the positive effects of integrating STEM-oriented and technology-enhanced approaches. Aydın-Güç and Şahiner (2022) implemented the 6E learning model with 88 students and reported significant improvement in academic achievement and STEM attitudes. Şahin and Kılıç (2023) found that combining the 6E cycle with project-based learning effectively develops engineering design thinking among preservice teachers. Likewise, Lin et al. (2021) demonstrate that incorporating the engineering design process into STEM-based learning significantly improves learners' creativity and problem-solving abilities. These findings collectively support the pedagogical potential of integrated STEM models.

From a methodological standpoint, most of these studies employed quasi-experimental or mixed-method designs, using pre-test and post-test comparisons to assess learning gains. However, a limitation noted by Brahic et al. (2024) is that many experiments remain small-scale and context-specific, limiting the generalizability of results. They recommend larger, longitudinal studies to validate the effectiveness of STEM integration across different cultural and institutional settings.

Overall, prior literature confirms that integrating educational technology and higher-level STEM education can enhance teaching and learning efficacy. However, the connection between digital transformation, pedagogical innovation, and STEM integration has not yet been fully conceptualized or empirically tested in higher education. This study seeks to address this gap by proposing a practical integration model and evaluating its impact in the context of Vietnam's digital transformation in education (Dang et al., 2024).

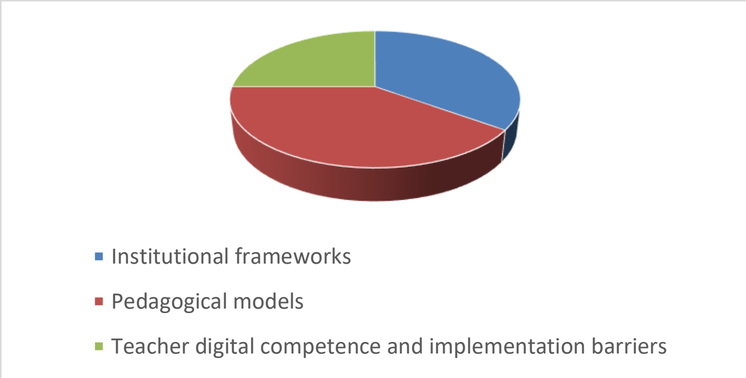


Figure 1: Trends in research on digital transformation and STEM integration in higher education (2021–2024)

Recent studies between 2021 and 2024 reveal three dominant research orientations in digital transformation and STEM integration in higher education. About 35% of the works focus on institutional frameworks and digital governance strategies (García-Peñalvo, 2021; Fernández et al., 2023), emphasizing the need for comprehensive alignment between technology, pedagogy, and university management.

Approximately 40% concentrate on innovative pedagogical models, including the 6E approach, project-based learning (PBL), and the engineering design process (EDP), which aim to foster creativity and problem-solving skills among learners (Aydın-Güç & Şahiner, 2022; Şahin & Kılıç, 2023). Meanwhile, 25% of studies address teachers' digital competence and implementation barriers, highlighting the urgent need for professional development and institutional support to ensure effective technology integration in teaching (Dang et al., 2024).

2.2 Digital Transformation in Higher Education: Current Status and Impact on Pedagogical Structure

Digital transformation in higher education goes beyond using new tools or digitalizing existing systems. It involves a broader shift in how teaching is organized, how learning is experienced, and how lecturers perceive their roles in a technology-driven environment (García-Peñalvo, 2021). As Mishra and Koehler (2006) emphasize, a sustainable transformation requires developing lecturers' technological–pedagogical–content knowledge (TPACK) in an integrated and practical way.

To explore this in the Vietnamese context, a survey was conducted with 138 lecturers at Hai Duong University, representing eight faculties across engineering, technology, social sciences, and teacher education. The sample was selected through stratified random sampling to ensure representativeness among disciplines and teaching experience levels. The survey focused on two aspects: (1) the level of digital transformation in teaching and learning (infrastructure, digital competence, and pedagogical innovation) and (2) lecturers' perceptions of STEM-oriented integration within digital teaching practices. Data were collected using a structured questionnaire based on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Descriptive statistics were used to summarize responses, and independent t-tests were applied to examine group differences.

Table 1: Summary of lecturers' responses on digital transformation readiness (n = 138)

Survey statement	Mean (M)	SD	Agreement (%)
The university has implemented learning management systems (LMS) and online portals for teaching.	4.52	0.61	87.7
I regularly use digital tools in my classes.	3.86	0.78	64.2
I feel confident using LMS and simulation software.	4.10	0.70	81.2
I am willing to innovate teaching methods using technology.	4.25	0.68	84.1
The role of lecturers must change to suit digital learning.	4.33	0.63	88.4
I have received adequate training in digital transformation.	3.42	0.85	59.4
I lack appropriate digital learning resources. *(reverse item)*	3.84	0.76	38.4
There is insufficient guidance on LMS use. *(reverse item)*	4.00	0.67	42.6
Digital administrative tasks create additional workloads. *(reverse item)*	3.78	0.72	33.7

Note. Items rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree). Reverse items indicate negative perceptions (Authors' field survey, 2024)

The results show that awareness and readiness for digital transformation among lecturers are generally positive. Most participants agreed that their university had deployed LMSs and online portals (87.7%), and over 80% felt confident using basic digital tools. However, only around two-thirds regularly applied these tools in teaching, indicating a gap between digital awareness and actual pedagogical practice. Several barriers were highlighted, such as limited digital resources, lack of clear LMS guidance, and administrative overload—findings consistent with previous studies in similar institutional contexts (Chahid et al., 2025; Dang et al., 2024). Statistical analysis also shows that lecturers in engineering and technology disciplines reported higher levels of technology use ($p < 0.05$), while younger lecturers showed greater adaptability, echoing the trend observed by Fernández et al. (2023).

Overall, these findings suggest that, while the digital infrastructure is in place, pedagogical transformation is still in progress. Most lecturers express willingness to innovate, but they require stronger institutional support, targeted training, and discipline-specific open educational resources. Digital transformation, therefore, is not just about tools; it is about reshaping teaching philosophy toward interactive, flexible, and personalized learning.

2.3 STEM Education as a Catalyst for Pedagogical Innovation

STEM education not only provides interdisciplinary knowledge but also acts as a driving force for innovation in teaching methods within the digital higher education environment. Its defining characteristics—practice-oriented learning, solving, and the integration of knowledge and skills—help learners develop systems thinking and creativity (Kelley & Knowles, 2016). When combined with educational technology, STEM learning becomes more interactive and adaptive. Tools such as simulation software, coding environments, microcontrollers, and LMS allow students to visualize abstract concepts and experiment with real-world scenarios.

The 6E learning model (Engage–Explore–Explain–Engineer–Enrich–Evaluate) and the EDP are among the most effective frameworks for organizing STEM-based learning activities. Studies have demonstrated that these models significantly enhance learning outcomes and student attitudes toward STEM fields (Aydın-Güç & Şahiner, 2022; Şahin & Kılıç, 2023). By integrating these models with PBL and educational technology, teaching becomes more collaborative, experiential, and student-centered.

A practical example illustrating this integration is the *"Electrical Transformer Station Project"*, designed within the electrical engineering curriculum to combine digital technology with core STEM principles. In this project, students worked in teams to design, optimize, and simulate a microgrid-based transformer system using software tools and digital resources. They applied interdisciplinary knowledge of electromagnetic theory, circuit design, and power systems (Abdelghany, Al-Durra, & Zeineldin, 2021; Amoiralis, Tsili, & Kladas, 2009; Heathcote, 2011).

Through PBL and EDP, students used AI-assisted simulations, microcontroller-based monitoring systems, and LMS-supported collaboration to evaluate transformer efficiency and operational stability in real time. This approach aligns with recent advancements in digital transformation and technology-supported engineering education (Lyngdorf et al., 2024) and cultivates essential 21st-century competencies such as creativity, critical thinking, and collaborative problem solving (Brahic et al., 2024; Lyngdorf et al., 2024).

The "*Transformer Station Project*" demonstrates how STEM education integrated with digital technology can move beyond theory into applied, data-driven, and interdisciplinary learning. It exemplifies a shift from traditional instruction toward experiential pedagogy, where students learn by designing, testing, and refining real engineering systems. This integration not only enhances professional competence but also nurtures the digital mindset and adaptability required for the industry 4.0 workforce.

2.4 Challenges in Implementing Digital-STEM Integration in the Context of Vietnamese Higher Education

Despite the promising potential of digital transformation and STEM education, integrating these two elements into higher education still holds numerous challenges, particularly in developing countries such as Vietnam. A major obstacle lies in the unequal distribution of technological infrastructure and accessibility across universities. Many regional institutions still lack the facilities and connectivity needed to implement digital learning and STEM-based teaching models effectively (Dang et al., 2024). This infrastructural gap results in uneven opportunities for innovation between urban and rural universities.

Another challenge concerns the limited digital competence of lecturers. The survey of 138 lecturers at Hai Duong University (see Section 2.2) revealed that while most lecturers were familiar with basic LMSs, only a modest proportion (around 64%) actively integrated digital tools into teaching. This finding echoes previous studies indicating that lecturers' digital readiness remains a bottleneck for pedagogical transformation (Gkrimpizi et al., 2023). Moreover, professional training programs focusing on STEM education and educational technology are often fragmented and lack continuity, leading to inconsistent adoption across faculties.

From a policy perspective, Vietnam's higher education system has not yet developed a coherent framework that connects digital transformation with STEM-oriented pedagogical reform. Most current strategies prioritize administrative digitization, such as e-governance and online documentation, rather than rethinking curriculum design or assessment in the digital era. According to Chahid et al. (2025) and Deroncele-Acosta et al. (2023), the absence of transparent institutional frameworks and sustainable funding mechanisms often leads to stagnation in digital pedagogical innovation. Bygstad et al. (2022) also argue that true digital transformation requires not just technology adoption but the reconfiguration of organizational culture, leadership, and teaching philosophy.

In the Vietnamese context, the integration of STEM and digital education thus faces both systemic (policy and infrastructure) and individual-level (capacity and mindset) barriers. Overcoming these requires synchronized strategies—investing in digital infrastructure, strengthening digital literacy training for lecturers, and embedding STEM principles into the design of technology-enhanced curricula. Only by addressing these foundational issues can universities shift from "digitizing teaching tools" to achieving pedagogical transformation through digital-STEM integration.

3. Methodology

This study employed a mixed-methods research design combining a quantitative lecturer survey and a quasi-experimental pedagogical intervention. In the first phase, a survey of 138 lecturers from eight faculties of Hai Duong University was conducted using stratified random sampling. The questionnaire included 28 Likert-type items (five-point scale) assessing digital readiness, perceived barriers, and the frequency of technology-enhanced pedagogy. Items were adapted from prior frameworks on digital transformation and the TPACK model (Mishra & Koehler, 2006; Fernández et al., 2023).

In the second phase, a quasi-experimental pre-test/post-test design compared two student groups (each n = 40). The experimental group was taught using an integrated model combining the 6E learning model, EDP, and PBL, supported by educational technology tools such as simulation software, microcontroller-based tasks, and LMS-supported collaborative learning activities. The control group followed a traditional instructional approach covering the same content. Pre-test/post-test assessments measured engineering design competence (EDC), focusing on creativity, problem solving, and system-thinking skills. Data analysis employed descriptive statistics and paired-sample and independent-samples t-tests at a 0.05 significance level. Participation was voluntary and anonymized, ensuring ethical compliance.

4. Results and Proposed Directions

4.1 Teaching STEM Project "Power Transformer Station"

The *"Power Transformer Station"* project exemplifies the application of an integrated STEM teaching model in the context of digital transformation in higher education. The project was implemented with third-year undergraduate students majoring in electrical engineering at Hai Duong University. It served as a pedagogical intervention, rather than a research outcome, designed to demonstrate how STEM-oriented learning and educational technology can be effectively integrated in engineering training.

The instructional model was built upon the 6E learning cycle (Engage – Explore – Explain – Engineer – Enrich – Evaluate), combined with the EDP and supported by digital tools such as AutoCAD Electrical for circuit design and Multisim for simulation and testing. Additional equipment included Arduino microcontrollers, voltage/current sensors, and digital measurement devices. This integrated model allowed students not only to master technical knowledge but also to develop design thinking, teamwork, problem solving, and digital competencies—core skills for engineers in the industry 4.0 era.

The project was structured around three main learning domains:

Knowledge objectives: Students understand and apply Faraday's law of electromagnetic induction; analyze the structure and operation of power transformer stations; calculate voltage ratios ($V_1/V_2 = N_1/N_2$), power ($P = V \times I$), and transmission efficiency ($\eta = P\_out / P\_in \times 100\%$); and practice using technical design and simulation tools.

Skills objectives: Students analyze and solve engineering problems; design and assemble a model transformer station (e.g., 220V–110V) using AutoCAD Electrical; simulate and test circuit performance using Multisim; and work collaboratively to present their technical designs.

Attitude objectives: Students develop curiosity, initiative, and creativity in learning; demonstrate responsibility for safety and efficiency in engineering design; and recognize the essential role of transformers in modern industry and daily life.

Table 2: STEM Components and Learning Focus of The Project

STEM Component	Learning Focus and Expected Outcomes
Science	Students apply physical principles such as electromagnetic induction (Faraday's law) and power transmission mechanisms. Scientific understanding forms the foundation for analyzing and designing transformer systems.
Technology	Students use AutoCAD Electrical for designing transformer circuits and Multisim for simulating and testing electrical systems. Technology enhances precision, supports measurement, and facilitates data analysis.
Engineering	Students conduct the full EDP: problem identification, requirement analysis, circuit design, assembly, testing, and model improvement.
Mathematics	Students apply formulas to calculate transformer ratios, power, and efficiency, ensuring accuracy and optimization in engineering design.

Note: The table illustrates how the four STEM components are integrated into the learning design of the "*Power Transformer Station*" project, highlighting the interdisciplinary and digital nature of the learning process.

4.2 Teaching Plan for STEM Project *"Power Transformer Station"* Using the 6E Model, Combining EDP and Educational Technology Application

The following teaching plan is designed for 3rd year students of electrical engineering, implemented according to the 6E model combined with the EDP and the application of modern educational technology. The goal is to help students develop engineering design skills, apply interdisciplinary STEM knowledge, and effectively exploit digital technology tools in learning.

Engage
- Objectives: Arouse interest and define technical problems
- Expected outcomes: Students are aware of the role of transformer stations in the power system

Teaching and learning activities and technology used

The lecturer showed a real video about a 110kV transformer station; raised the question: "How is high voltage from the factory converted for safe use in the home?"

Figure 2: 110kV Dong Nien Transformer Station, Hai Duong

Explore
- Objectives: Explore background knowledge, study system structure
- Expected outcomes: Understand the basic structure and operating mechanism of transformers

Teaching and learning activities and technology used

Students divided into groups to learn about the structure and operating principles of transformer stations through specialized documents and technical videos; performed simple experiments with homemade coils.

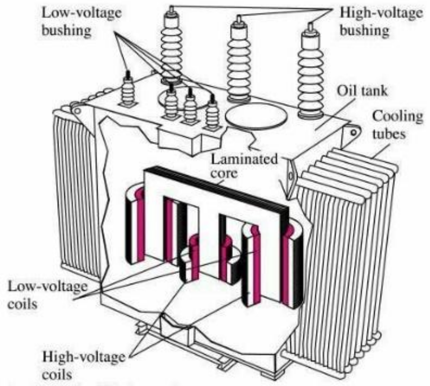


Figure 3: Power transformer structure

Explain

- Objectives: Clarify technical principles and develop solutions
- Expected outcomes: Building a solid theoretical foundation for model design

Teaching and learning activities and technology used

Lecturers teach Faraday's law, transformer formula, how to calculate power and transmission efficiency; students ask questions and discuss to consolidate understanding

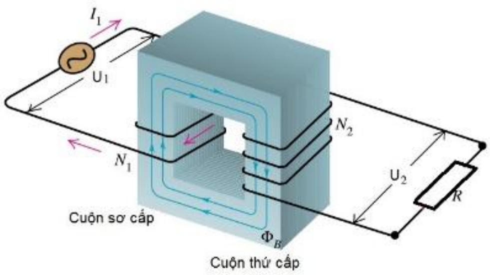


Figure 4: Working principle of a power transformer

Engineer

- Objectives: Design and manufacture of technical models
- Expected outcomes: The operating model is fully built and safe

Teaching and learning activities and technology used

* Step 1: Identify the technical problem to be solved
- Activity:
+ The lecturer sets up a real-life situation: "A small residential area needs a stable power supply through a transformer; design a suitable 1kVA transformer"
+ Students discuss technical requirements: capacity, input/output voltage, operating environment, load characteristics.

Figure 5: Real power transformer

- Learning objectives:

+ Correctly identify technical requirements and design constraints
+ Understand the practical application context of transformers
- Support tools:
Assignment sheet on Google Docs.
* Step 2: Research – Analyze design parameters
- Activities:
+ Student groups learn: type of steel core and magnetic properties; type of conductor: copper or aluminum; insulation: oil paper, epoxy…; technical standards: IEC 60076, maximum allowable loss
+ Note technical data in the summary table.

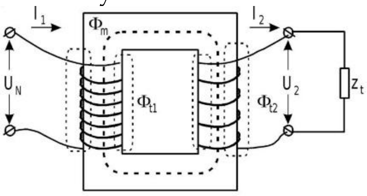


Figure 6: Physical quantity characteristic of a power transformer

- Learning objectives:
+ Practice the skills of searching, processing, and evaluating technical information
+ Understand the impact of each parameter on transformer performance
- Supporting resources:
+ Technical documents from Heathcote (2011), Amoiralis et al. (2009)
+ Websites of ABB, Siemens, or electronic learning materials from IEEE
* Step 3: Propose technical solutions
- Activities:
+ Students: Draw a schematic diagram of the transformer; calculate the number of primary and secondary turns; select appropriate wire cross-section and core
+ Receive feedback from other groups and instructors

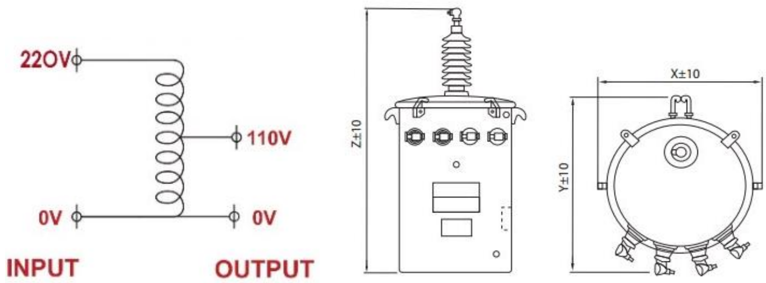


Figure 7: Calculating the number of turns of a power transformer
- Learning objectives:
+ Apply knowledge of physics and electrical circuits to practical design
+ Improve technical design thinking, create solutions
- Supporting tools:
+ Draw diagrams using AutoCAD Electrical or Fritzing
+ Excel spreadsheet to calculate electrical parameters
* Step 4: Create virtual models
- Activities:
+ Groups use software to build virtual transformer models: SolidWorks: create 3D mechanical models; LTspice/PSIM: simulate transformer circuits, analyze current - voltage
+ Test the ability to operate underrated load

Figure 8: Power Transformer Simulation Design

- Learning objectives:
+ Master digital simulation tools
+ Deeper understanding of transformer operating principles through virtual experiments
- Supporting tools:
+ Simulation software account
+ Video tutorial on using the software on LMS or YouTube
* Step 5: Check - Evaluate the design

- Activities:
+ Each group simulates the operation of the transformer with different load levels
+ Analysis: iron loss, copper loss, efficiency
+ Compare design options between groups
- Learning objectives:
+ Evaluate the feasibility and optimization of technical designs
+ Form critical thinking and improve technical solutions
- Support tools:
+ Evaluation table according to technical criteria (rubric)
+ Excel chart, Canva chart showing evaluation results
* Step 6: Present products and technology applications
- Activities:
+ Write a design report on Google Docs (one file per group)
+ Design a technical infographic showing the model, main parameters and advantages using Canva
+ Present the group report, receive feedback from the lecturer and your group
- Learning Objectives:
+ Develop technical communication skills
+ Use digital tools to present learning products professionally

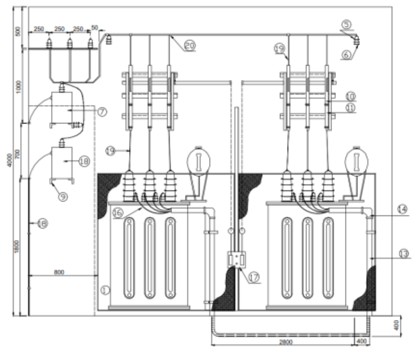
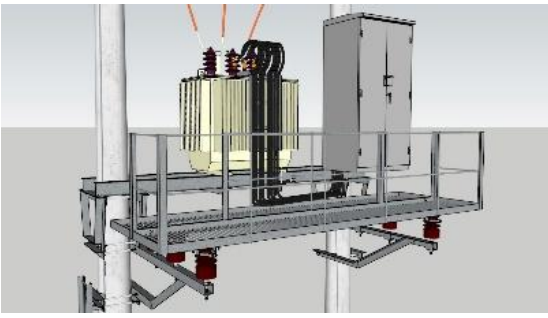


Figure 9: Power Transformer Design Drawing

Enrich - Objectives: Expanding applications and integrating technology - Expected outcomes: Model integrates modern technology, increasing practicality and creativity
Teaching and learning activities and technology used
Students improve the model using voltage/current sensors, programming Arduino to display the results; use Multisim software to simulate the operation and compare the results with the actual model  **Figure 10: Power Substation Simulation**
Evaluate - Objectives: Process and product evaluation - Expected outcomes: Students reflect on the learning process and suggest improvements to the model
Teaching and learning activities and technology used
Groups present models, explain principles and measurement results; teachers and students evaluate according to the following criteria: accuracy, efficiency, creativity, technology integration

The project enabled students to connect theory with practical application, strengthening both disciplinary knowledge and transversal skills such as collaboration, technical communication, and innovation. Reference materials such as Heathcote (2011) and Amoiralis et al. (2009) were used to ensure technical accuracy and alignment with international transformer design standards. Overall, the *"Power Transformer Station"* project demonstrates the potential of integrating *STEM pedagogy with digital technology* to foster creativity, design competence, and technological adaptability—key attributes for future engineers in the digital transformation era.

4.3 Proposing an Integrated Teaching Model in Engineering Training

The results of the pedagogical experiment show a clear improvement in students' EDC when applying the integrated 6E + EDP model with educational technology. Statistical analysis of pre- and post-test data revealed that students in the experimental group achieved significantly higher progress compared to those taught by traditional methods. Students' **EDC** was assessed before and after the intervention using identical performance-based tests. Statistical analyses were performed with SPSS 26.0 at a significance level of $\alpha = 0.05$.

Table 3: Comparison results of pre-test and post-test scores between the two groups (Pre-test/Post-test)

Group	Pre-score (Mean ± SD)	Post-score (Mean ± SD)	Difference	T (paired)	p-value
Experiment	6.82 ± 0.74	8.51 ± 0.69	+1.69	11.84	< 0.001
Control	6.75 ± 0.71	7.02 ± 0.68	+0.27	2.12	0.041

Table 4: Comparison of post-test scores between two groups (Independent T-test)

Group	Pre-score (Mean ± SD)	T	df	p-value
Experiment	8.51 ± 0.69	8.73	78	< 0.001
Control	7.02 ± 0.68			

The mean post-test score of the experimental group (8.51) was significantly higher than that of the control group (7.02), with $t = 8.73, p < 0.001$. Within-group analysis also indicated a notable improvement in the experimental class ($\Delta M = +1.69, p < 0.001$), while the control group's gain was modest ($\Delta M = +0.27, p = 0.041$). This confirms that the integrated teaching approach significantly enhanced students' ability to apply knowledge, design technical systems, and solve practical engineering problems.

Classroom observations also show that students became more active in exploring design ideas, using AutoCAD Electrical to sketch transformer circuits and Multisim to simulate operation and optimize performance. This transition from theoretical learning to experiential learning created stronger engagement and helped learners connect classroom knowledge with real-world engineering contexts.

The findings align with the results of previous studies emphasizing the benefits of combining STEM education with digital technology. Chen and Lee (2023) demonstrate that the 6E model integrated with PBL improves design thinking and technical performance. Similarly, Aydın-Güç and Şahiner (2022) report positive impacts of the 6E–EDP model on STEM attitudes and achievement, while Şahin and Kılıç (2023) confirm that project-based STEM learning fosters creative problem solving. The present study extends these insights by emphasizing the role of digital tools, such as simulation software and virtual labs, in amplifying these effects.

From a theoretical standpoint, these results support Mishra and Koehler's (2006) TPACK framework, which argues that effective digital transformation in teaching requires the combination of technology, pedagogy, and content knowledge. In practice, the experiment illustrates that digital-STEM integration can bridge the gap between theory and application in Vietnamese higher education—an issue previously highlighted by Dang et al. (2024) and Chahid et al. (2025). Despite clear benefits, challenges remain, including uneven access to technology infrastructure, limited training in educational technology, and insufficient open learning materials for engineering disciplines.

Overall, the experimental findings demonstrate that integrating the 6E model, EDP, and educational technology not only improves academic performance but also cultivates essential 21st-century skills—critical thinking, collaboration, and digital competence. These results reinforce the study's central argument that digital transformation in higher education must go beyond digitization to become a true pedagogical transformation. The "*Power Transformer Station*" project provides practical evidence that such integration is both feasible and effective for fostering innovation in engineering education in Vietnam.

4.4 Recommendations for Implementation at the School and National Levels

Based on the findings of the experimental study, the effective integration of STEM education and digital technology in engineering training requires coordinated action at both the institutional and national levels.

4.4.1 At the institutional level

Universities should first develop a digital transformation roadmap that explicitly connects technological modernization with pedagogical innovation. Rather than focusing solely on infrastructure or administrative digitization, digital transformation must be aligned with the reform of teaching methods and learning outcomes. Second, it is essential to restructure curricula toward integrated STEM–technology models. Courses, especially in engineering and technology, should embed project-based and problem-based learning activities that employ digital tools such as simulation software, virtual labs, and collaborative online platforms. The "*Power Transformer Station*" project implemented in this study demonstrates that such integration can substantially enhance students' technical design competence and digital literacy.

Third, institutions need to invest in technology infrastructure and the development of open digital learning resources, including interactive courseware, virtual experiments, and LMS-based assessment tools. These resources will help reduce the gap in access to quality learning materials among different universities, particularly those outside major urban centers. Finally, the digital and pedagogical competence of lecturers must be continuously strengthened. Training programs should follow the TPACK framework (Mishra & Koehler, 2006), helping educators harmonize content knowledge, pedagogical design, and technological application. This will ensure that lecturers can confidently adapt to new digital learning environments and deliver high-impact, student-centered instruction.

4.4.2 At the national level

The Ministry of Education and Training should play a leading role by establishing a national digital competence framework for both lecturers and students. This framework will guide universities in developing measurable digital skills and pedagogical innovation indicators across disciplines. In addition, a financial support mechanism is needed to encourage universities, especially regional and public institutions—to implement digital-STEM integrated learning models. A dedicated fund for educational innovation could be established to support pilot projects, similar to the "*Power Transformer Station*" initiative, and promote cross-institutional collaboration.

To ensure sustainability, the Ministry should also coordinate the development of a national open educational resource network, enabling the sharing of high-quality teaching materials and digital content among universities. Furthermore, a research and evaluation program should be implemented to systematically assess the outcomes and scalability of integrated digital-STEM pedagogies across different fields. In summary, the integration of higher STEM education and educational technology within digital transformation is not merely a technical upgrade represents a strategic and long-term reform direction. When supported by coherent policies, adequate resources, and strong institutional commitment, this approach can build a modern, flexible, and innovative higher education ecosystem capable of adapting to the rapid technological and professional changes of the future.

5. Conclusion

This study examines how integrating higher STEM education with educational technology can drive pedagogical innovation in the context of digital transformation in higher education. By employing a mixed-methods design that combined a lecturer survey with a quasi-experimental intervention, the findings confirm that technology–STEM integration enhances students' EDC, promotes active learning, and supports a learner-centered teaching approach.

Theoretically, this research contributes to the growing body of knowledge on digital pedagogy by demonstrating a feasible framework that links the 6E learning cycle, EDP, and PBL within the digital transformation agenda. Practically, the study provides universities with an actionable model for integrating STEM and digital tools into technical training programs. The *"Power Transformer Station"* project exemplifies how technology-assisted STEM learning can foster critical thinking, creativity, and collaboration—competencies essential for graduates in the digital economy. Furthermore, the results underline the importance of investing in digital infrastructure, open learning materials, and continuous professional development for lecturers.

However, this study has certain limitations. The sample was limited to one university and a specific discipline, which may constrain the generalizability of the findings. The data collection relied mainly on self-reported surveys and a short-term experimental design, which may not capture long-term learning outcomes or behavioral changes. Future research should therefore expand to multi-institutional contexts, employ longitudinal or mixed designs, and explore the use of AI-based adaptive learning systems to personalize STEM education in digital environments.

In conclusion, integrating higher STEM education with educational technology represents not only an effective teaching strategy but also a sustainable direction for higher education reform in the digital age. To ensure success, educational institutions and policymakers must work collaboratively to align infrastructure, pedagogy, and digital competence development toward a modern, inclusive, and innovative-oriented learning ecosystem.

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