MEKONG UNIVERSITY SCIENTIFIC JOURNAL

https://tapchikhdhcl.edu.vn/mkusj/ **P-ISSN 3093-3218**
https://vjol.info.vn/dhcl-e/index **E-ISSN 3093-3358**

AN INTEGRATED TRIPLE-HELIX FRAMEWORK FOR INTRODUCTORY CIVIL ENGINEERING EDUCATION: ADDRESSING CONTEMPORARY CHALLENGES, ACTIVE LEARNING, AND PROFESSIONAL ETHICS

Nguyen Dinh Kha*

Mekong University

Email: nguyendinhkha@mku.edu.vn

DOI: https://doi.org/10.65934/mkusj.2026.02.1141

Received: 14/05/2026 *Reviewed: 26/05/2026* *Accepted: 28/06/2026*

ABSTRACT

Civil engineering education is facing unprecedented challenges arising from climate change, rapid urbanization, and the accelerating digital transformation of the construction industry. For first-year students, introductory courses often present technical knowledge, learning strategies, and professional ethics as separate domains, limiting their ability to develop an integrated understanding of the profession. To address this gap, this study proposes the Triple-Helix Framework, an integrated pedagogical model designed for the Introduction to Civil Engineering course. The framework establishes a coherent relationship among three complementary pillars: (1) awareness of contemporary engineering challenges and core engineering processes; (2) the SQ3R active learning strategy as a catalyst for knowledge acquisition and self-directed learning; and (3) an ethical decision-making framework that strengthens professional responsibility. To evaluate the effectiveness of the proposed model, a controlled pedagogical experiment involving 20 first-year civil engineering students at Mekong University was conducted. The findings indicate that students exposed to the Triple-Helix Framework demonstrated substantial improvements in both cognitive and ethical competencies. The proportion of students successfully resolving ethical case studies increased from 65% to 88%, while the experimental group acquired technical terminology approximately 30% faster than the control group. These results suggest that integrating disciplinary knowledge, active learning strategies, and ethical reasoning within a unified educational framework enhances students' academic preparedness and professional development. The proposed framework provides a practical model for introductory civil engineering education and contributes to the broader discourse on integrated engineering education in the context of twenty-first-century societal and technological challenges.

Keywords: civil engineering education; Triple-Helix Framework; SQ3R; professional ethics; active learning; engineering education.

Introduction

Civil Engineering has long been recognized not merely as a pure technical discipline but as an art and science that shapes the world to serve human life. The essence of this field extends beyond mere reinforced concrete blocks or complex structural calculations; it constitutes the core foundation that sustains the operation of society. From proud ancient wonders like the Great Pyramid of Giza and the Great Wall of China to today's smart megacities, skyscrapers, and transcontinental transport networks, civil engineers have consistently acted as the silent architects of human civilization. Each structure created is not only a physical entity but also a testament to human intellect, creativity, and the aspiration to conquer nature throughout historical periods.

However, entering the third decade of the 21st century, the industry faces unprecedented epochal challenges. The global population explosion coupled with rapid urbanization has placed immense pressure on depleting natural resources. The requirements for sustainable adaptive infrastructure, green construction technologies, and renewable energy optimization have transitioned from theoretical concepts into vital demands for national development (Nguyen, 2026). Future engineers no longer merely need to be "proficient in math" or "skilled in drawing," but must also possess a strategic environmental vision and profound ethical responsibility toward the community.

In this context, for freshmen just entering the university, the "Introduction to Civil Engineering" course serves as the most crucial gateway, offering the first glimpse into their future career. Yet, a concerning reality currently exists: the presence of a significant "cognitive gap". Freshmen frequently find themselves "overwhelmed" by the massive volume of specialized knowledge and complex technical terminology presented in in-depth lectures (Nguyen, 2026). The transition from high school to a university learning environment leaves many feeling disoriented, as academic theory seems disconnected from the practical responsibilities of an on-site engineer. The lack of a connective system among technical thinking, active learning methods, and professional ethical foundations is the barrier that makes it difficult for students to cultivate passion and professional pride right from the initial stage.

Stemming from the aforementioned challenges, this paper proposes the "Triple-Helix Framework" model to build an integrated educational pathway, helping students not only grasp general industry knowledge but also develop precise thinking methods and ethical value systems by clarifying the mutual relationship among new-era challenges, effective self-study tools, and social responsibility.

1. Literature Review

The Evolution and Macro-challenges of The Industry

The history of the construction industry is not simply a process of accumulating physical assembly techniques, but essentially a long process demonstrating the evolution of intellect and humanity's aspiration to conquer space across eras. From the dawn of civilization, humans have known how to utilize raw natural materials such as clay, natural stone, and wood to create enduring symbolic structures. The massive stone blocks of the Giza Pyramids, the eternal solidity of the Great Wall, or the sophisticated arch bridge systems of the Roman Empire not only exhibit master mechanical capabilities but also reflect the tight social organization and timeless vision of ancient generations of engineers. During this period, the core objective of civil engineering was solidity and the ability to withstand harsh natural conditions, where natural materials played a dominant role and human labor was the primary driving force in altering geographic landscapes.

A breakthrough shift only truly occurred when humanity entered the Industrial Revolution, marking the advent of steel and Portland cement- two materials that completely redefined the limits of artificial structures. The emergence of the era of steel and high-strength concrete allowed engineers to break free from the span and weight limitations of traditional materials, paving the way for the boom of megacities with skyscrapers and long-span suspension bridges across seas. Contemporary structures such as the Burj Khalifa or Landmark 81 are no longer merely symbols of physical height but are the results of a synthesis among precise structural calculations, advanced material technology, and complex construction processes (Nguyen, 2026).

However, as humanity advances deep into the 21st century, the value system of the construction industry once again faces a fundamental shift. The greatest challenge today no longer centers on the question of "how to build taller or on a larger scale" but has profoundly shifted to the problem of "how to build more sustainably" to respond to the global climate crisis. Under a modern lens, issues such as integrating renewable energy into building structures, carbon sequestration technology starting from concrete production, and the thorough treatment of construction waste through a circular economy model have become central technical problems demanding decisive solutions (Kumar & Bhunia, 2019). Today's engineers must not only master formulas for the strength of materials but also become social problem solvers, ensuring that every structure created has the lowest carbon footprint and the highest adaptability to environmental changes. This evolution indicates that the construction industry has transformed from solely focusing on the sturdiness of physical entities to ensuring ecological balance for future generations (Nguyen, 2026). This affirms the position of civil engineers as coordinators of harmony between artificial infrastructure and the natural environment, requiring freshmen to early access ethical codes and social responsibilities to protect public interests (ASCE, 2017).

Figure 1. Modern Civil Engineering - Landmark 81, Ho Chi Minh City

(Source: (Hoang, 2018))

Pedagogical Engineering Method: SQ3R and Active Learning

Learning in engineering disciplines requires precise information processing capabilities. The SQ3R model [Survey - Question - Read - Recite - Review] has been proven to help students grasp the complex structure of building standards and design codes more effectively than passive reading methods. The integration of active thinking helps students overcome the pressure of heavy calculation and technical training programs (Robinson, 1946).

Professional Ethics and Community Responsibility

Ethics in construction is not an abstract concept. It is the safety of thousands of people moving on a bridge or living in a building. Historical engineering disasters (such as bridge collapses or dam failures) often stem from minor flaws in professional ethics rather than simple calculation errors (ASCE, 2017).

2. Proposed Methodology: The Triple-helix Framework

This study proposes an integrated model where three main elements intertwine like a double-helix structure, creating a solid foundation for students.

Pillar 1: Contextual Awareness and Professional Processes

The first pillar in the integrated approach framework plays a role in orienting the student's mindset. Before delving into complex calculation formulas, students need to be equipped with a proper worldview regarding the role of the Civil Engineering industry in historical currents and the stringent demands of the new era.

Engineering Vision in the Context of 21st-Century Challenges

The 21st century marks a turning point when the Construction industry is no longer simply about conquering records in height or span, but about solving humanity's existential problems. Nguyen's (2026) lecture points out the challenges that the new generation of engineers must face: rising sea levels threatening coastal cities, the need for smart transport infrastructure, and the integration of renewable energy into buildings (Net Zero Energy Buildings). Recognizing these "macro-challenges" helps freshmen overcome conventional thinking, forming a sense of responsibility toward the environment and society right from the first lessons. This is the motivation for them to master new technologies such as energy performance simulation or sustainable building materials.

Systematizing the Engineering Design and Construction Process

To actualize solutions to modern challenges, students must master the "backbone" of the industry: the engineering design process and the construction cycle. The paper proposes structuring this process into two complementary phases:

- Design Process: Students are familiarized with the sequence from needs identification and feasibility studies to detailed design. In this phase, creativity must go hand in hand with safety and economic constraints. Understanding the process clearly helps students see the connection between foundational subjects (Math, Physics) and the final product.

- Construction & Management: According to Nguyen (2026), construction products are characterized by their immobility and uniqueness. Therefore, the construction process requires close coordination among geological surveying, material supply management, and technical supervision on the site.

Classification and Technical-Economic

Characteristics of the Industry

A key point in the awareness pillar is helping students classify construction works to shape their future specialization (civil, transport, irrigation, or technical infrastructure). The differences in scale, investment capital, and long production cycles of the Construction industry compared to light industries require students to possess risk management thinking and long-term planning. Mastering Pillar 1 not only helps students answer the question, "What is civil engineering?" but more importantly, "What must civil engineers do to adapt to a changing world?". This is the theoretical foundation for students to apply self-study tools in Pillar 2 and verify them through the ethical lens in Pillar 3.

Pillar 2: The SQ3R Self-Study System as a Catalyst

If Pillar 1 provides the "material" of knowledge, Pillar 2 is the "catalyst" that helps students transform those raw materials into genuine professional competence. In the university environment, particularly in engineering disciplines with a massive volume of calculations and standards, self-study skills are not merely an option but a vital requirement to avoid "cognitive overload"

Decoding the SQ3R Model in Approaching Technical Documents

The paper proposes standardizing the process of reading and understanding construction documents through the SQ3R model [Survey - Question - Read - Recite - Review]. This is a method that helps freshmen systematically approach complex chapters in specialized lectures:

- *Survey*: Instead of reading word by word, students are guided to observe diagrams, figures, and main headings to grasp the overall structure.

- *Question*: Converting headings into questions. For example: "Why do construction products have unique characteristics?" This stimulates curiosity and orients goals while reading.

- *Read*: Focused reading to find answers to the questions posed, making information assimilation more selective and profound.

- *Recite*: Re-expressing knowledge in one's own words. This is especially important when learning abstract concepts such as "Learning Outcomes" or "Credits".

- *Review*: Systematizing knowledge periodically to transfer information from short-term to long-term memory.

The Combination of Positive Thinking and Time Management

The SQ3R system will not maximize its effectiveness without the right mindset foundation. Nguyen's (2026) Introduction to Civil Engineering lecture emphasizes the role of Positive Thinking in facing difficult modules. Maintaining belief in problem-solving abilities helps engineering students become more resilient to errors or failures in their first projects. Furthermore, Time Management skills are considered a powerful support tool. Planning studies by semester and allocating time for general and specialized subjects based on the number of credits helps students maintain balance, avoiding accumulated pressure at the end of the term. This is the element that keeps the SQ3R "catalyst" operating stably and efficiently.

From Active Learning to Professional Awareness

By mastering self-study methods, students gradually transition from a passive state to Active Learning. Pillar 2 does not stop at helping students achieve high grades; it forms the habit of continuously updating knowledge-a mandatory quality of an engineer in the context of rapidly changing construction technologies (such as BIM or 3D concrete printing). In short, once students master Pillar 2, they possess the "key" to decode all professional challenges in Pillar 1 and have sufficient clarity to execute professional ethics in Pillar 3.

Pillar 3: The ethical decision matrix (The Moral Compass)

Within the structure of the Triple-Helix Framework, Professional Ethics is not just a dry set of codes of conduct but acts as "The Moral Compass" guiding all engineering behaviors. For freshmen, forming ethical thinking early is crucial, because any mistakes in civil engineering can lead to catastrophic disasters involving human lives and property.

The Importance of Ethics in the Project Lifecycle

The ethical behavior of an engineer spans from the geological survey and structural design phases to construction and acceptance. Nguyen's (2026) Introduction to Civil Engineering lecture emphasizes that civil engineers hold the safety and health of the community. A decision to "cut corners" on materials or ignore a design flaw to meet a schedule is not only a breach of contract but also a degradation of professional ethics. This study proposes teaching ethics through practical case studies so students can clearly see the causal relationship between ethics and social safety.

Application of the Engineering Ethical Decision Matrix

To help students avoid confusion when facing conflicts of interest (between the investor's profit and structural safety), the paper proposes applying an Ethical Decision Matrix. This is a multidimensional analysis tool based on the core values of the ASCE (2017) and the Vietnam Construction Law (2014):

(1) Beneficiary analysis: Who will be affected by this decision? (The community, the environment, the clients)

(2) Risk and legal assessment: Does the decision violate technical standards or current regulations?

(3) Choosing the optimal solution: The top priority is always human safety and environmental sustainability.

Practical Case Study Analysis from the Lecture

The highlight of this pillar is practicing through highly realistic hypothetical situations. Typical example: The cement plant construction problem. In this scenario, students are required to role-play as a chief engineer facing pressure from the investor to cut the dust filtration system to save costs. Through group discussions and the application of the decision matrix, students must learn to use technical arguments and legal risks to persuade the partner, or in the worst case, exercise their right to refuse committing ethical violations to protect the local environment. This practice helps freshmen understand that: "Professional ethics is the courage to do the right thing even under pressure" (Nguyen, 2026). This is the final pillar but also the foundation to maintain the sustainability of the entire engineering career.

3. Experiment and Results

Experimental Setup and Data Description

To verify the effectiveness of the "Triple-Helix Framework," the study conducted a controlled pedagogical experiment in the first semester of the 2025-2026 academic year at the Faculty of Engineering-Technology, Mekong University.

Research subjects: The experimental group consisted of 20 freshmen majoring in Civil Engineering Technology. This group of subjects had just transitioned from high school to university, possessed a relatively uniform foundational awareness of the industry, but had never been exposed to in-depth study methods or engineering professional ethics.

Experimental method: The study used a one-group experimental design with pre-test and post-test methods.

- Stage 1 (Pre-test): Students took a survey assessing three indicators: (1) Understanding of industry processes, (2) Skills in processing technical documents, and (3) Decision-making ability in ethical conflict situations.

- Stage 2 (Intervention): Over the 6 weeks of the Introduction to Civil Engineering course, the Triple-Helix framework was thoroughly integrated. Students not only learned theory but also had to practice SQ3R on chapters 4 and 5 of the lecture, while participating in group discussions on 21st-century challenges and resolving situations using the ethical matrix.

- Stage 3 (Post-test): After completing the course, the group of 20 students retook the test with equivalent difficulty but requiring deeper analysis.

Measurement tools: Data was collected through multiple-choice tests combined with situational essays, a quantitative questionnaire (5-point Likert scale), and personal feedback reports from students regarding changes in their study methods. The purpose of this experimental setup is to collect quantitative and qualitative data to demonstrate that: The organic combination of professional knowledge, self-study tools, and ethical foundations will create a "cognitive breakthrough" for students right from the initial stage.

Achieved Results

Based on data collected from the 20 experimental students (shown in Figure 2, Table 1), the study draws three key academic observations on the superiority of the Triple-Helix model:

First: Breakthrough in ethical awareness and decision-making (Pillar 3). The results from Figure 2 show that before applying the model, only 65% of students correctly identified and handled conflicts of interest. However, after being equipped with the "Ethical Decision Matrix," this rate skyrocketed to 88%. This proves that: Professional ethics is not an innate trait but can be completely quantified and trained through simulated situations (case studies) right from the first year of university.

Second: The strong catalytic effect of the SQ3R method (Pillar 2). Analysis of the improvement margin from Table 1 and Figure 2 indicates a clear disparity between the control group and the experimental group. While traditional learning methods left students struggling with specialized terminology (reaching the baseline of 100%), the group applying SQ3R achieved an acquisition speed of up to 130% and a knowledge retention rate after one week that was 23% higher (85% vs. 62%). This observation affirms that SQ3R is not just a reading comprehension tool, but truly acts as a "filter" helping engineering students convert raw information into long-term knowledge.

Third: Comprehensive development from the Integrated 3-Pillar Framework. Unlike isolated educational methods, the simultaneous increase in the "Confidence" (8.8/10) and "Synthesis Ability" (8.2/10) indicators reflects the success of Pillar 1. Once students understand the historical context and macro-challenges of the 21st century, they no longer view general and foundational courses as grade "hurdles". Instead, student confidence is bolstered by clearly recognizing their development roadmap and career goals.

Preliminary Conclusion: The organic combination of the three pillars has thoroughly resolved the "Research Gap" raised at the beginning of the paper. Instead of producing students who "only know how to calculate" but are weak in ethics and skills, the Triple-Helix Framework has successfully outlined the competency profile of a global civil engineer.

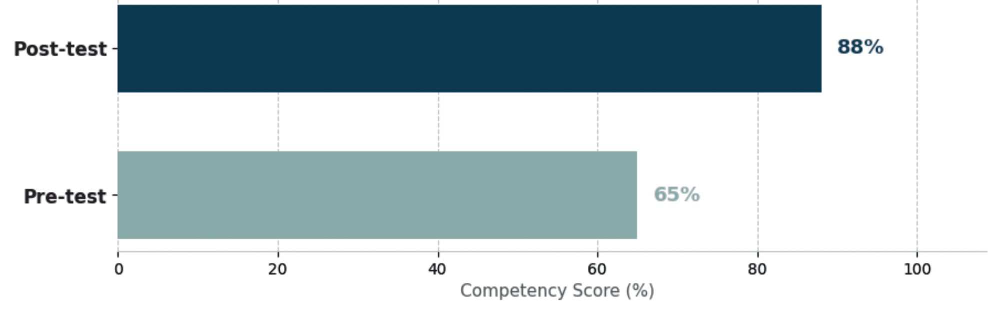

Figure 2. Effectiveness of ethical capacity development - evaluation of situation resolution capability through the experimental model

Table 1. Learning Performance Indicators (KPIs)

Measurement Indicators (KPIs)	Control Group	SQ3R Group (Experimental)
Terminology acquisition speed (%)	100% (baseline)	130% (+30%)
Knowledge retention rate (after 1 week) (%)	62%	85%
Confidence level in discussions (1-10)	6.5	8.8
Information synthesis capability (1-10)	5.8	8.2

Discussion and Conclusion

The experimental results on the group of 20 Civil Engineering students at Mekong University have clearly demonstrated the hypothesis that fragmentation in introductory education is a major barrier to the formation of engineering competence. The core of the "Triple-Helix Framework" does not lie in adding a volume of knowledge, but in establishing an organic connective network. When students comprehend the macro-challenges of the 21st century such as climate change or sustainable development (Pillar 1), an intrinsic need arises to acquire knowledge. At this point, the SQ3R method (Pillar 2) is no longer a dry mandatory skill but becomes a powerful tool to decode practical problems. The outstanding growth in terminology acquisition speed (130%) and knowledge retention rate (85%) is the result of a learning process with clear objectives.

Furthermore, professional ethics (Pillar 3) excellently performed its role as a "filter" orienting the other two pillars. Professional knowledge and self-study skills without an ethical foundation easily lead to wrong decisions, causing harm to the community. The fact that students' ethical awareness and situational handling scores surged from 65% to 88% shows: ethics can be fully quantified and trained through case studies, helping students form a sense of responsibility even before they become practicing engineers.

This study has contributed a reference framework for innovating the "Introduction to Civil Engineering" curriculum and other modules. Instead of the one-way transmission method, instructors can use this model to personalize the learning pathway and link theory with social responsibility. Although the study still has certain limitations regarding sample size (n=20) and tracking duration (one semester), these promising initial data open up new directions for engineering education research in the future.

In conclusion, the paper has successfully systematized Nguyen's (2026) lecture into a modern educational model. Transitioning to the integrated 3-Pillar framework not only helps freshmen overcome initial confusions but also lays a solid foundation for cultivating the next generation of global civil engineers. These will be engineers who are not only excellent at structural calculations and technology mastery but also steadfast in professional ethics and carry within themselves the mission to protect the sustainable development of society.

REFERENCES

American Society of Civil Engineers-ASCE. (2017). *Code of Ethics*. Accessed April 24, 2026, Retrieved from: https://www.asce.org/career-growth/ethics/code-of-ethics

Ministry of Construction of Vietnam. (2014). *Construction Law No. 50/2014/QH13*. Hanoi: National Political Publishing House.

Ching, F. D. K., & Winkel, S. R. (2018). *Building Codes Illustrated: A Guide to Understanding the 2018 International Building Code* (5th ed.). Wiley.

Hoang, D. (2018). *Toan canh toa nha cao nhat Viet Nam-Landmark 81 [Panoramic view of the tallest building in Vietnam-Landmark 81]*. VietnamFinance. Retrieved April 24, 2026, from https://vietnamfinance.vn/toan-canh-toa-nha-cao-nhat-viet-nam-landmark-81-d22367.html

Nguyen, D. K. (2026). *Introduction to Civil Engineering Lecture*. Vinh Long: Mekong University.

Kumar, S., & Bhunia, P. (2019). *Sustainable Construction Materials: Recycled Aggregates*. Woodhead Publishing.

Robinson, F. P. (1946). *Effective study*. Harper & Brothers.