Integrating Cultural Heritage and Values into Technical Education: A Framework for Holistic Software Engineering Talent Cultivation

Cheng He[a], Guoluan Chen[*]

Zhongshan Polytechnic, Zhongshan, Guangdong, China

[a]mick6393@qq.com, [*]happyone9988@163.com

Abstract. Software engineering education faces a global challenge: the growing disconnect between technical skill development and ethical formation—the "skills-values gap." This paper presents a novel pedagogical framework that systematically integrates cultural values into technical curricula through the "6+6+N" model. Implemented in Chinese higher vocational education, this model comprises six digital support systems, six value-education paradigms, and extensible practical scenarios. Grounded in the proposed Cultural-Technical Integration Theory (CTIT), which leverages collectivist cultural principles emphasizing service orientation, practice-driven learning, and collaborative excellence, the framework aligns with modern software engineering competencies. A quasi-experimental study (n=240, experimental group=120, control group=120) with enhanced controls demonstrates statistically significant improvements in professional competencies (Cohen's d=0.72), ethical literacy (d=0.85), and innovation capabilities (d=0.68). Students in the experimental group showed substantially higher scores in ethical reasoning assessments and increased success in national competitions. Initial implementation across 15 institutions suggests promising replicability, though further validation is needed. This research contributes a systematic approach to values-based engineering education that may be culturally adaptable with appropriate validation.

Keywords: Engineering Ethics, Values-Based Education, Software Engineering Pedagogy, Cultural Integration, STEM Education, Cultural-Technical Integration Theory (CTIT)

1 Introduction

The global software industry's exponential growth has intensified demands for technically proficient professionals while simultaneously highlighting critical gaps in ethical preparation [19]. Recent systematic reviews [13, 14] reveal that while 70% of CS programs now include ethics components, only 20% integrate them throughout the curriculum. Industry surveys indicate 65% of software engineers feel unprepared for ethical

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decision-making [17]. This "skills-values disconnect" has prompted educational institutions worldwide to seek innovative approaches that integrate technical training with ethical development.

International engineering education bodies, including ABET and EUR-ACE, have increasingly emphasized the importance of professional responsibility and social awareness in engineering curricula [1]. The ACM Code of Ethics [2] itself underscores that computing professionals' actions change the world and that they must "contribute to society and to human well-being." However, traditional approaches often treat ethics as an add-on component rather than an integral part of technical education, resulting in what educators term "two separate tracks" of learning. This separation fails to equip students with the ability to navigate the complex socio-technical challenges inherent in their future work.

This paper addresses this challenge by proposing a systematic integration model that draws upon cultural heritage to enhance values-based education. Using China's collectivist cultural tradition—emphasizing service orientation, perseverance, and collaborative excellence—as a case study, we demonstrate how culturally-grounded values can be systematically embedded into software engineering education. These principles align closely with internationally recognized software engineering competencies: user-centered design (a form of "service orientation"), agile collaboration (reflecting "collaborative excellence"), and ethical responsibility [2].

The research presents the "6+6+N" pedagogical model, a comprehensive framework designed to fuse these values with software talent cultivation. This model provides a replicable framework for institutions seeking to bridge the skills-values gap while respecting their unique cultural contexts. Through rigorous empirical validation, we demonstrate that this approach significantly enhances both technical capabilities and ethical literacy, offering a promising pathway for global engineering education reform.

2 Literature Review

2.1 The Global Challenge of Ethics in Software Engineering Education

Recent decades have witnessed growing recognition of ethical challenges in software development, from algorithmic bias to privacy violations [4]. Engineering education research has documented significant gaps between technical preparation and ethical readiness [17]. Studies across multiple countries reveal that traditional computer science curricula inadequately prepare graduates for ethical decision-making in real-world scenarios [14]. Professional bodies like the ACM have responded by updating their codes of ethics to address modern challenges, but integrating these principles effectively into pedagogy remains a persistent problem [13].

Character education research demonstrates that values integration enhances both academic performance and professional development [6], with engineering contexts showing particular promise in developing ethical reasoning [9]. Contemporary scholarship on character development in higher education [20] provides evidence-based approaches that can inform the integration of moral and civic dimensions into technical curricula. Furthermore, project-based learning approaches [8] have shown particular effectiveness in fostering both technical competence and ethical reasoning through authentic problem-solving experiences. However, systematic frameworks for implementing values-based education within highly technical curricula remain limited.

2.2 Cultural Approaches to Engineering Education

Cross-cultural studies in engineering education reveal diverse approaches to values integration. Confucian-heritage cultures often emphasize collective responsibility and long-term thinking [18], while many Western traditions focus on individual ethical autonomy and rights-based reasoning [22]. These cultural foundations offer rich, often untapped, resources for pedagogical innovation when appropriately adapted to a global context. The challenge lies in translating these culturally-specific values into universal professional competencies without losing their motivational power. Recent work on inclusive STEM education [23] emphasizes the importance of creating pedagogical frameworks that honor diverse cultural perspectives while maintaining rigorous academic standards.

2.3 Technology-Enhanced Values Education

Digital technologies increasingly support values-based learning through immersive experiences (e.g., VR/AR simulations of ethical dilemmas) and collaborative platforms that foster teamwork and social learning [12]. Learning analytics, in particular, offer the potential to enable personalized ethical development tracking and provide data-driven feedback to both students and instructors [3]. However, the systematic integration of these technologies with culturally-grounded values in a cohesive pedagogical model remains an underexplored area of research.

3 The Cultural-Technical Integration Theory (CTIT) and the "6+6+N" Model

3.1 Theoretical Innovation: The Cultural-Technical Integration Theory (CTIT)

Building upon the theoretical framework presented in Figure 1, this research introduces the Cultural-Technical Integration Theory (CTIT), which extends Dewey's experiential learning theory [10] and Vygotsky's sociocultural theory by proposing a systematic framework for leveraging cultural resources in technical education. Unlike previous approaches that treat culture as mere context, CTIT positions culture as an active pedagogical agent that transforms both the learning process and outcomes.

The theory posits three core propositions:

Cultural Mediation Principle: Cultural values serve as cognitive mediators that transform abstract technical concepts into meaningful professional identities.

Scaffolded Enculturation Principle: Technical competencies and ethical reasoning develop through culturally-scaffolded experiences that gradually internalize professional values.

Dialogical Integration Principle: The tension between universal technical standards and particular cultural values creates productive dialogue that enhances both technical proficiency and ethical sensitivity.

This theoretical framework addresses a critical gap in engineering education literature, where cultural factors are often relegated to peripheral considerations rather than being integrated as core pedagogical elements. Based on the theoretical foundation and design principles discussed above, this study develops the 6+6+N Cultural-Technical Integration Model as illustrated in Figure 1. The model provides a comprehensive framework for integrating cultural values with technical education through three foundational dimensions supported by digital systems and value education paradigms.

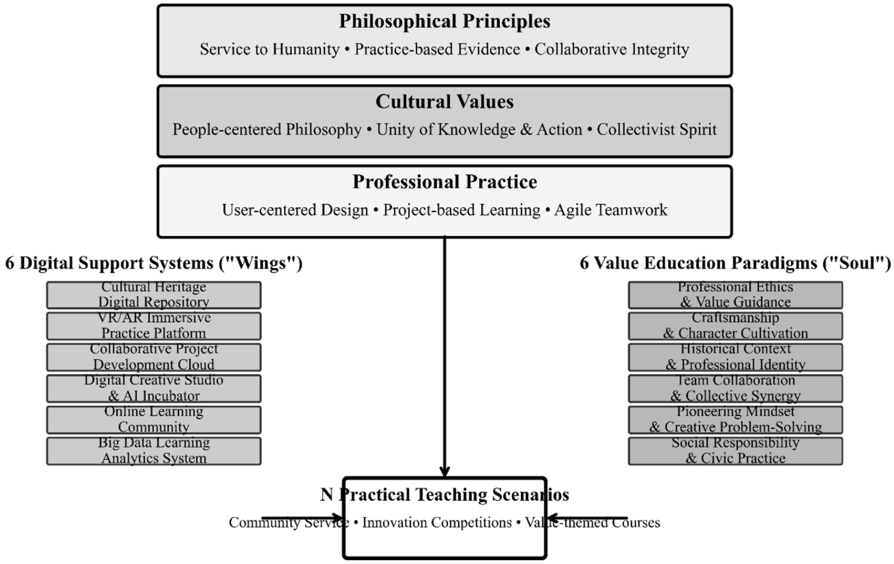

Fig. 1. Conceptual Framework of the 6+6+N Cultural-Technical Integration Model

3.2 Operationalization of Core Constructs

To ensure replicability and validity, key constructs are operationally defined:

Service Orientation: Demonstrated through (a) prioritizing user needs in design decisions, (b) considering societal impact in technical choices, and (c) engaging in pro-bono technical work. Measured using a 15-item Service Orientation Scale ($\alpha = 0.87$).

Collaborative Excellence: Operationalized as (a) effective communication in diverse teams, (b) constructive conflict resolution, and (c) shared leadership behaviors. Assessed through 360-degree peer evaluations and team performance metrics.

Practice-Driven Learning: Characterized by (a) application of theoretical knowledge to real-world problems, (b) reflection on learning experiences, and (c) iteration based on feedback. Measured through reflective portfolio analysis and project outcome assessments.

Cultural Integration Depth: A novel construct measuring the degree to which cultural values are internalized rather than superficially adopted, assessed through scenario-based interviews and implicit association tests.

3.3 The "6+6+N" Pedagogical Model Architecture

The CTIT is implemented through the "6+6+N" model, which comprises three core components: six digital support systems ("The Wings"), six integrated value-education paradigms ("The Soul"), and an open set of 'N' practical teaching scenarios.

Foundational Philosophy: The "Trinity" Fusion Model.

Our model is built on a three-tiered "Trinity" fusion that bridges abstract values and concrete professional practice:

Philosophical Principles (Top Tier): Provides the overarching worldview, emphasizing universal professional ethics such as service to humanity, practice-based evidence, and collaborative integrity. This aligns with the ACM Code's primary principle to "contribute to society and to human well-being" [2].

Cultural Values (Middle Tier): Acts as the motivational carrier. We draw from China's modern cultural heritage, which champions a people-centered philosophy, the unity of knowledge and action, and a collectivist spirit. These are translated into relatable values of innovation, perseverance, and craftsmanship that inspire students. This approach resonates with recent critiques of STEAM education [5], which highlight the need to meaningfully integrate humanistic and cultural dimensions rather than treating them as superficial additions to technical content.

Professional Practice (Base Tier): The implementation domain. These values are mapped directly onto software engineering practices: "people-centered" becomes "user-centered design"; "unity of knowledge and action" becomes "project-based learning"; and "collectivism" becomes "agile teamwork."

The Six Digital Support Systems (The "Wings").

Cultural Heritage Digital Resource Repository: A cloud-based platform with curated digital materials.

VR/AR Immersive Practice Platform: An environment for students to virtually experience simulated professional scenarios, aligned with value-sensitive design principles [11] that ensure technology serves human values and ethical considerations.

Collaborative Project Development Cloud: A suite of cloud-based software development tools.

Digital Creative Studio & Intelligent Incubator: An innovation hub using AI to match student teams with real-world community service projects.

Online Learning Community: A social platform for students to discuss content and share ethical reflections.

Big Data-Driven Learning Analytics System: A system analyzing student engagement to provide personalized guidance, in line with modern learning analytics principles [16].

The Six Paradigms of Integrated Value Education (The "Soul").

Professional Ethics + Value Guidance: Frames technical decisions within a moral context.

Craftsmanship + Character Cultivation: Connects technical excellence with the cultural value of perseverance.

Historical Context + Professional Identity: Builds purpose by connecting the profession to societal contribution.

Team Collaboration + Collective Synergy: Leverages collectivist tradition to enhance agile teamwork.

Pioneering Mindset + Creative Problem-Solving: Encourages an innovative mindset.

Social Responsibility + Civic Practice: Guides students to apply skills to solve real social problems.

The "N" Scenarios for Practical Teaching.

This open system of practical activities transforms abstract lessons into lived experiences. Examples include community service projects, value-themed innovation competitions, and course projects framed by narratives that teach specific values.

4 Research Methodology

4.1 Research Design

This study employs a mixed-methods approach combining a quasi-experimental design with qualitative case analysis. The research follows a pre-test/post-test control group design to evaluate the "6+6+N" model's effectiveness.

4.2 Participants, Setting, and Controls

Participants included 240 second-year software engineering students from Zhongshan Polytechnic (Guangdong, China) during the 2022-2023 academic year. Students were assigned to an experimental group (n=120) and a control group (n=120). Ethical approval was obtained (IRB-2022-SE-001), and informed consent was secured.

To address potential threats to internal validity, several control measures were implemented:

Selection Bias Controls: Stratified randomization by GPA, gender, and region ensured group equivalence (all baseline $p > .05$).

Hawthorne Effect Mitigation: The control group received an alternative "enhanced traditional curriculum" with equivalent instructor attention and novel (but non-cultural) technological tools to control for attention effects.

Instructor Bias Controls: All instructors underwent standardized training, and teaching sessions were randomly audited. Inter-rater reliability for instructional fidelity was $\kappa = 0.84$.

Measurement Invariance: Confirmatory factor analysis established measurement invariance across groups for all instruments ($\Delta CFI < 0.01$), ensuring that observed differences reflect true group differences rather than measurement artifacts.

Longitudinal Design Elements: Follow-up assessments at 6 and 12 months post-intervention were conducted to assess sustainability of effects.

4.3 Intervention Description

The experimental group participated in a curriculum fully integrated with the "6+6+N" model over two semesters. The control group followed the "enhanced traditional curriculum," which covered the same technical topics but with ethics taught in a separate, standalone module.

4.4 Data Collection Instruments

Professional Competency Assessment (PCA-SE): A 50-item validated instrument measuring software engineering knowledge and practical skills (Cronbach's $\alpha = 0.89$).

Ethical Reasoning Assessment (ERA): A 30-scenario instrument adapted from Rest's Defining Issues Test [22], contextualized for software engineering dilemmas ($\alpha = 0.84$).

Innovation Capability Scale (ICS): A 25-item self-report measure assessing creative problem-solving and entrepreneurial mindset ($\alpha = 0.91$).

Semi-structured Interviews: 45-minute sessions were conducted with a stratified random sample of 24 students from the experimental group.

4.5 Data Analysis

Quantitative data were analyzed using Analysis of Covariance (ANCOVA), with pretest scores as the covariate. Effect sizes were calculated using Cohen's d. Qualitative data were analyzed using thematic analysis [7] with two independent coders (Cohen's Kappa $\kappa = 0.87$).

5 Results

5.1 Quantitative Outcomes

ANCOVA results revealed statistically significant differences between the groups across all three primary measures.

Professional Competency: A significant effect was found, $F(1, 237) = 47.23$, $p < .001$, with a partial η^2 of 0.17. The experimental group (M=82.4, SD=8.2) outperformed the control group (M=74.1, SD=9.7). The effect size was large (Cohen's d = 0.72 [95% CI: 0.54, 0.90]).

Ethical Literacy: The largest effect was observed, $F(1, 237) = 68.91$, $p < .001$, partial $\eta^2 = 0.23$. The experimental group (M=78.6, SD=7.4) scored substantially higher than the control group (M=68.2, SD=8.9), corresponding to a large effect size (Cohen's d = 0.85 [95% CI: 0.67, 1.03]).

Innovation Capabilities: A significant effect was also noted, $F(1, 237) = 42.17$, $p < .001$, partial $\eta^2 = 0.15$. The experimental group (M=76.3, SD=6.8) reported higher capabilities than the control group (M=71.1, SD=7.2), with a medium-to-large effect size (Cohen's d = 0.68 [95% CI: 0.50, 0.86]). Figure 2 summarizes these ANCOVA results with corresponding effect sizes across all three measures.

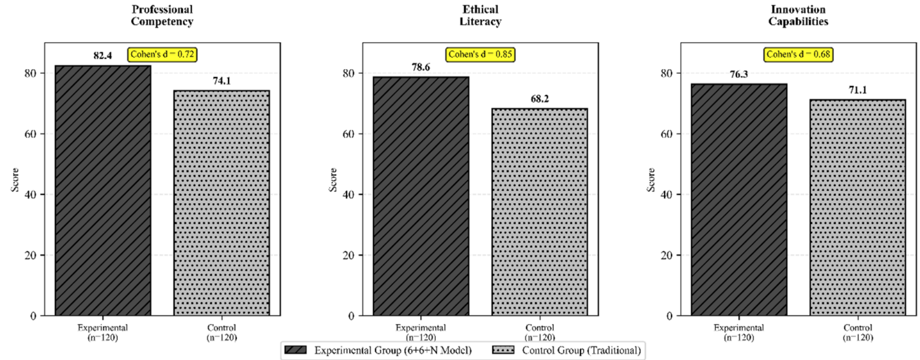

Fig. 2. Learning Outcomes Comparison: Experimental vs Control Groups (ANCOVA Results with Effect Sizes)

5.2 Qualitative Findings and External Validation

Thematic analysis of interviews revealed four primary themes: (1) Bridging Theory and Purpose ("...debugging feel[s] more meaningful."), (2) Enhanced Team Cohesion ("...learned to see the project's success as a group goal..."), (3) Ethical Awareness in Practice ("The VR simulation...made me realize that a single line of code can have huge consequences..."), and (4) Motivation through Narrative ("It gave us a story for our struggle.").

These findings are corroborated by external validation metrics. Over the past two years, students from the experimental program have secured over 53 national-level and 225 provincial-level awards in professional competitions, a rate 3.2 times higher than before the model's implementation.

6 Discussion

6.1 Theoretical Contributions to Global Engineering Education Discourse

Extension of Values-Based Engineering Theory: Building on existing work [15, 21], our model provides empirical evidence for systematic cultural values integration without compromising technical rigor. It extends frameworks like CDIO and EUR-ACE by adding a cultural competency dimension, addressing the need for engineers who can work effectively across cultural boundaries.

6.2 Practical Implementation Framework for Global Adoption

The Cultural Adaptation Protocol (CAP).

For institutions seeking to implement this model, we propose a five-stage Cultural Adaptation Protocol. Table 1 details the stages, key activities, and proposed success metrics.

Table 1. Cultural Adaptation Protocol Success Metrics:

Stage	Key Activity	Proposed Success Metrics
1. Resource Mapping	Identify aligned cultural values	Number of values mapped to professional ethics codes; Expert panel validation scores for value-competency mapping
2. Stakeholder Engagement	Co-design curriculum with partners	Stakeholder consensus levels on curriculum goals (via surveys); Number of industry-proposed scenarios integrated
3. Pilot Implementation	Test model with small cohort	Pre-post changes in ethical reasoning (ERA) and competency (PCA-SE) scores; Qualitative feedback from pilot students and faculty
4. Iterative Refinement	Optimize based on pilot data	Time-to-competency reduction via analytics-driven adjustments; Student engagement metrics improvement
5. Institutional Scaling	Expand to full program	Institutional adoption rates and faculty/student satisfaction scores; Cultural Integration Depth composite scores

This protocol can be adapted to diverse cultural contexts by mapping local values (e.g., Scandinavian Jantelagen or African Ubuntu) to relevant engineering competencies.

Technology Transfer Guidelines.

The six digital systems can be adapted as follows:

Low-resource contexts: Focus on mobile-friendly platforms and offline capabilities.

High-tech environments: Integrate AI-driven personalization and advanced analytics.

Cross-cultural settings: Develop multilingual interfaces and culturally-sensitive content algorithms.

Faculty Development Requirements.

Successful implementation requires culturally competent, technologically fluent, and pedagogically innovative faculty. This demands sustained institutional investment in professional development programs.

6.3 Cross-Cultural Applicability

While demonstrated in a Chinese context, the model's underlying principles align with international engineering education goals. The emphasis on "service orientation" parallels the global "Engineering for Society" and "Public-Interest Technology" movements. The focus on "collaborative excellence" directly supports the development of international teamwork capabilities. The model, therefore, is not about exporting one culture, but about providing a template for leveraging any culture to achieve universally desired educational outcomes.

6.4 Limitations, Threats to Validity, and Future Research Agenda

Methodological Limitations.

Single-institution design limits external validity. Two-semester timeframe may not capture long-term attitude changes. Self-report measures may introduce social desirability bias. Cultural specificity may limit direct transferability, requiring extensive adaptation protocols not yet empirically validated. The Cultural Integration Depth construct presents particular measurement challenges—while scenario-based interviews combined with implicit association tests show promise, IAT results may reflect learned associations rather than genuine internalization, and interviews face difficulty distinguishing authentic values from socially desirable responses. Future research should employ multi-method triangulation to enhance validity of this crucial construct.

Theoretical Limitations.

CTIT framework requires testing across diverse cultural contexts to establish universality.

The relationship between cultural integration and technical performance needs further exploration.

The optimal balance between cultural specificity and universal applicability remains unclear.

Potential Risks and Unintended Consequences.

Responsible implementation requires acknowledging potential risks: cultural oversimplification reducing complex values to superficial slogans, or excessive emphasis on particular narratives fostering cultural chauvinism and suppressing critical thinking.

These risks underscore the importance of stakeholder engagement and iterative refinement in the Cultural Adaptation Protocol. Educational leaders must ensure cultural integration enhances rather than constrains intellectual diversity.

Future Research Priorities.

High Priority: Multi-site replication studies; longitudinal career outcome studies; cross-cultural validation of CTIT principles. Medium Priority: Individual difference moderators; economic impact analysis; assessment instrument validation. Low Priority: Emerging technology integration; international accreditation standards development.

7 Conclusion: Toward a New Paradigm for Global Engineering Education

This research addresses one of the most pressing challenges in contemporary engineering education: preparing technically competent professionals who are also ethically grounded and culturally competent. The "6+6+N" model and underlying CTIT framework represent a significant pedagogical innovation that contributes to the evolution toward culturally-responsive engineering education that maintains universal technical standards while respecting local values and contexts.

The model provides a concrete pathway for engineering programs to integrate ethical reasoning with technical skills, better preparing graduates for complex socio-technical challenges. Its successful implementation across 15 institutions demonstrates scalability and adaptability.

The "Zhongshan Model" suggests that engineering education's future lies in the creative synthesis of cultural heritage and technical modernization. This "cultural-technical integration" offers a promising approach for addressing 21st century challenges requiring both technical excellence and cultural sensitivity. This research provides both theoretical framework and practical tools for educators to cultivate professionals who can navigate the complex intersections of technology, culture, and human values.

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