



Developing an Augmented Reality-Supported Training Model for Vocational Graduates to Enhance Learning Engagement and Cultural Literacy in China

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Abstract: This study aims to develop and evaluate the effectiveness of an Augmented Reality (AR)-supported graduate training model based on the ADDIE instructional design framework. The study involved 98 postgraduate students enrolled in vocational education programs in China. The validity of the research instruments and instructional module was evaluated using the Content Validity Index (CVI) by a panel of experts, while the effectiveness of the model was examined using descriptive statistics and multivariate analysis of variance (MANOVA). The expert validation results demonstrated high validity, with a Scale-Level Content Validity Index based on the average method (S-CVI/Ave) of 0.92 (92%). The mean scores increased from pretest to posttest for both knowledge acquisition (from 63.20 to 85.40; a 22.20-point increase) and practical skills (from 61.80 to 87.10; a 25.30-point increase). The MANOVA results indicated a statistically significant multivariate effect of the training model on the combined dependent variables, with an effect size of 0.416. Overall, the findings indicate that the developed AR-supported training model is effective in enhancing postgraduate students' knowledge acquisition and practical skills and provides a practical contribution to strengthening immersive technology-based vocational education at the postgraduate level.

Article History

Received: 09-07-2026

Revised: 15-08-2026

Accepted: 12-09-2026

Published: 20-10-2026

Key Words:

Vocational and Technical Education; Augmented Reality; Learning Engagement; Cultural Literacy.

How to Cite: ZhouFuXing, I Nyoman Jampel, & I Gde Wawan Sudatha. (2026). Developing an Augmented Reality-Supported Training Model for Vocational Graduates to Enhance Learning Engagement and Cultural Literacy in China. *Jurnal Paedagogy*, 13(4), 1373-1382. <https://doi.org/10.33394/jp.v13i4.21817>



<https://doi.org/10.33394/jp.v13i4.21817>

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Introduction

Vocational and Technical Education (VTE) has become a strategic pillar for preparing highly skilled human resources capable of responding to the rapid transformation of industry driven by digitalization, automation, and intelligent technologies. The emergence of Industry 4.0 and the transition toward Industry 5.0 require higher education institutions to cultivate graduates who not only possess advanced technical competencies but also demonstrate creativity, collaboration, ethical awareness, and cultural adaptability (OECD, 2021; UNESCO, 2021). Consequently, graduate education in vocational and technical fields is expected to adopt innovative training models that integrate digital technologies with learner-centered pedagogies to prepare students for increasingly complex professional environments.

In China, vocational education has undergone significant reforms to support the country's strategy of building a modern industrial system and promoting high-quality economic development. National policies such as the *National Vocational Education Reform Implementation Plan* emphasize the importance of strengthening postgraduate vocational education through industry–university collaboration, competency-based curricula, and digital transformation (Ministry of Education of the People's Republic of China, 2022). Despite these policy initiatives, many graduate training programs continue to rely on conventional instructional approaches that prioritize theoretical knowledge over authentic learning experiences. Such approaches often provide limited opportunities for students to actively



engage with real-world industrial contexts, resulting in insufficient development of higher-order thinking skills and professional competencies.

Learning engagement has been recognized as one of the strongest predictors of academic achievement, persistence, and professional competence in higher education. It encompasses behavioral, emotional, and cognitive dimensions that reflect students' active participation in meaningful learning activities (Fredricks et al., 2004; Partnership for 21st Century Learning, 2019). Students who demonstrate high levels of engagement are more likely to develop critical thinking, collaborative problem-solving abilities, and lifelong learning skills. However, previous studies have reported that learning engagement among graduate students in vocational education remains relatively low due to passive instructional methods, limited interaction, and insufficient integration of emerging educational technologies (Bond, 2020). Therefore, designing learning environments that encourage active participation has become an essential challenge for VTE institutions.

Alongside learning engagement, cultural literacy has emerged as another essential competency for graduates in the twenty-first century. Globalization, international industrial cooperation, and multicultural workplaces require vocational graduates to understand diverse cultural perspectives while maintaining their own cultural identity. Cultural literacy enables students to communicate effectively across cultural boundaries, demonstrate ethical responsibility, and appreciate cultural diversity in professional practice (UNESCO, 2021). Nevertheless, cultural literacy is frequently overlooked in vocational graduate training, where instructional emphasis remains focused primarily on technical and occupational competencies. This imbalance may reduce graduates' ability to work effectively in increasingly globalized and culturally diverse industrial settings.

Recent developments in educational technology provide new opportunities to address these challenges. Among various digital technologies, Augmented Reality (AR) has attracted considerable attention because of its ability to merge virtual information with real-world environments, enabling learners to visualize abstract concepts, simulate authentic workplace situations, and interact with digital objects in immersive learning contexts (Azuma, 1997; Ibáñez & Delgado-Kloos, 2018; Indrawan et al., 2026; Nugraha et al., 2025). Numerous studies have demonstrated that AR enhances students' motivation, conceptual understanding, learning performance, and collaborative learning experiences by providing contextualized and interactive learning environments (A.A. Komang Melia Sukmawati et al., 2025; Garzón et al., 2019). In vocational education, AR can facilitate practical training by allowing students to practice technical procedures safely, repeatedly, and efficiently before entering actual industrial workplaces. Augmented Reality (AR) facilitates cultural literacy by transforming abstract cultural learning into contextual, interactive, and experiential learning experiences (Anugerah & Chandra, 2023; Ningrum et al., 2022). Grounded in a constructivist perspective, AR enables learners to build a deep understanding of cultural awareness, professional identity, and cross-cultural communication as well as their application in the workplace through digital storytelling, interactive simulations of workplace ethics and situations, and the visualization of cultural heritage. The integration of contextual material and collaborative problem-solving within this AR-based model links cultural values with vocational competencies; thus, AR serves not merely as a visualization technology, but as an instructional tool that fosters authentic interaction, reflection, and comprehensive competency development (Mayer, 2021; Redecker, 2017; Supriyanto et al., 2023).

Despite the growing application of AR in education, its integration into graduate training models for Vocational and Technical Education remains limited. Existing studies



generally investigate AR as an instructional medium or learning application rather than as a comprehensive component of curriculum design, competency development, and graduate training systems. Furthermore, previous research has largely focused on cognitive learning outcomes, while relatively little attention has been given to the influence of AR-supported learning on learning engagement and cultural literacy. This indicates that current research has not fully explored the potential of AR to support holistic graduate education that combines technological competence with humanistic and cultural development.

Moreover, existing graduate training models in China's vocational education system have primarily emphasized curriculum reform, industry partnerships, and competency-based assessment without systematically incorporating immersive technologies into learning experiences. As a result, empirical evidence regarding the effectiveness of AR-supported graduate training models in improving student engagement and cultural literacy remains insufficient.

This gap suggests the need for a comprehensive instructional model that integrates advanced digital technology, learner-centered pedagogy, and competency-oriented graduate education. The current Vocational and Technical Education (VTE) framework in China suffers from structural shortcomings in fostering learning engagement and cultural literacy, stemming from a rigid, academic-oriented (discipline-centric) model that divorces theory from practice. Structurally, the curriculum is dominated by passive theoretical lectures and conventional printed materials, lacking a situational learning environment; meanwhile, cultural literacy development is relegated to a peripheral role within ideological-political courses rather than being infused throughout the professional training process. This situation is exacerbated by a singular evaluation system focused on academic performance and thesis completion, lacking measurable, standardized, and process-based assessment indicators. A fundamental research gap that this new model aims to address is the absence of immersive and interactive AR-based learning media for cultural literacy, the lack of evaluation indicators capable of quantitatively measuring improvements in learning engagement and cultural literacy, and the scarcity of empirical studies systematically integrating AR technology into all stages of VTE training in China.

To address these challenges, this study develops an Augmented Reality-supported Graduate Training Model specifically designed for Vocational and Technical Education in China. The proposed model integrates AR technology with competency-based learning principles to create authentic, interactive, and culturally responsive learning experiences. Beyond improving technical competencies, the model is intended to enhance students' learning engagement and strengthen their cultural literacy through collaborative, contextual, and reflective learning activities.

The novelty of this research lies in the integration of Augmented Reality into a comprehensive graduate training framework rather than treating AR merely as an instructional tool. In addition, the study simultaneously examines the effects of the developed model on learning engagement and cultural literacy, two competencies that are increasingly recognized as essential outcomes of graduate education but have rarely been investigated together in vocational education. Therefore, this study contributes to both theoretical and practical development of graduate education by proposing an innovative model that aligns technological advancement with human-centered educational values and the future competency demands of China's vocational and technical education system.



Research Method

This study employed a Research and Development (R&D) approach based on the ADDIE model (Analysis, Design, Development, Implementation, Evaluation) to develop and validate an Augmented Reality (AR)-supported graduate training model for Vocational and Technical Education (VTE) in China. Involving 98 participants as the research sample, this R&D approach systematically creates theoretically sound, empirically validated, and practical educational innovations (Branch, 2009). The Analysis phase aimed to identify the needs and challenges of graduate education in Vocational and Technical Education institutions in China. A comprehensive needs assessment was conducted through document analysis, semi-structured interviews, and questionnaire surveys involving graduate students, academic staff, university administrators, and industry representatives. Policy documents related to vocational education reform, Industry 4.0/5.0, and postgraduate education were also reviewed to identify competency requirements and existing gaps in graduate training. The results of this phase were used to establish learning objectives, competency indicators, and design requirements for the proposed AR-supported graduate training model. The activities conducted during each ADDIE phase are summarized in Table 1.

Table 1. Research Activities in Each ADDIE Phase

Phase	Activities	Expected Output
Analysis	Literature review, interviews, questionnaires, policy review	Needs assessment
Design	Learning objectives, AR scenario, instructional strategy	Initial model design
Development	Prototype development, expert validation, revision	Validated prototype
Implementation	Pilot implementation, pretest-posttest	Student performance data
Evaluation	Statistical analysis, revision	Final AR-supported graduate training model

During the Design phase, the conceptual framework of the graduate training model was formulated by integrating principles of competency-based education, constructivist learning theory, experiential learning, and Augmented Reality-supported instruction. Learning outcomes, instructional activities, AR learning scenarios, assessment strategies, and evaluation indicators were systematically organized into a training blueprint. Particular attention was given to incorporating activities that promote learning engagement through collaborative problem-solving and authentic learning experiences while simultaneously fostering cultural literacy through contextualized learning materials reflecting Chinese cultural values and global professional competencies (Fredricks et al., 2004; Ibáñez & Delgado-Kloos, 2018).

. To operationalize this AR intervention, the learning scenarios were developed using mainstream immersive development engines (such as Unity paired with the Vuforia AR SDK). The developed AR content encompassed interactive 3D models of industrial equipment, augmented cultural heritage maps, and simulated real-world workplace/ethical scenarios. Students accessed these AR resources seamlessly using mobile smart devices (smartphones/tablets) by scanning embedded physical markers/QR codes or accessing designated web-based AR platforms during instructional sessions.

The Development phase involved producing the prototype of the AR-supported graduate training model, including instructional guidelines, learning modules, AR-based



learning activities, lecturer manuals, and student learning resources. The AR learning environment was developed using commercially available AR development platforms that enable three-dimensional visualization, interactive simulations, and contextual learning experiences. Before implementation, the prototype underwent expert validation involving specialists in vocational education, instructional design, educational technology, and Augmented Reality. The content validity of each component was evaluated using a structured validation instrument, while suggestions from experts were incorporated into subsequent revisions to improve the quality and usability of the model. The research instruments employed during the development and implementation phases are presented in Table 2.

Table 2. Research Instruments

Variable	Instrument	Indicators	Scale
Learning Engagement	Student Engagement Questionnaire	Behavioral, Emotional, Cognitive	Likert (1–5)
Cultural Literacy	Cultural Literacy Questionnaire	Awareness, Identity, Communication, Appreciation	Likert (1–5)
Model Validity	Expert Validation Sheet	Content, Design, Media	Likert (1–5)
Practicality	Student Response Questionnaire	Ease of Use, Satisfaction	Likert (1–5)

The Implementation phase employed a quasi-experimental one-group pretest–posttest design to examine the effectiveness of the developed training model. The participants consisted of graduate students enrolled in Vocational and Technical Education programs at selected universities in China. Participants were selected using purposive sampling because they met the characteristics required for implementation of the developed model. Prior to the intervention, students completed questionnaires measuring learning engagement and cultural literacy. They then participated in the AR-supported graduate training program for one academic semester. Following completion of the program, the same instruments were administered as posttests to determine changes in both dependent variables.

Learning engagement was measured using an adapted version of the Student Engagement Scale, which evaluates behavioral, emotional, and cognitive engagement (Fredricks et al., 2004). Cultural literacy was measured through a questionnaire adapted from previous higher education studies focusing on cultural awareness, intercultural communication, cultural appreciation, and ethical responsibility. All instruments employed a five-point Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Prior to data collection, the questionnaires were examined for content validity by experts and pilot-tested to determine construct validity and internal consistency reliability. Instrument reliability was evaluated using Cronbach's alpha, with coefficients greater than 0.70 considered acceptable for educational research (Hair, 2022). The statistical procedures used to evaluate the developed model are summarized in Table 3.

Table 3. Data Analysis Techniques

Research Objective	Statistical Analysis
Content validity	Expert Judgment / CVI
Instrument reliability	Cronbach's Alpha
Normality	Shapiro–Wilk Test
Homogeneity	Levene's Test



Research Objective	Statistical Analysis
Effectiveness	Paired-samples t-test
Effect size	Cohen's <i>d</i>
Simultaneous effect	MANOVA
Software	IBM SPSS Statistics

The Evaluation phase consisted of formative and summative evaluations. Formative evaluation was conducted throughout every stage of ADDIE through expert reviews, pilot implementation, and participant feedback to continuously improve the model. Summative evaluation assessed the overall effectiveness of the AR-supported graduate training model after implementation. Descriptive statistics were used to summarize participant characteristics and variable distributions. Assumptions of normality and homogeneity were examined before hypothesis testing. Paired-sample *t*-tests were conducted to compare pretest and posttest scores for learning engagement and cultural literacy. Effect sizes were calculated using Cohen's *d* to determine the magnitude of improvement. Where appropriate, multivariate analysis was performed to evaluate the simultaneous influence of the developed model on both outcome variables. Statistical analyses were performed using IBM SPSS Statistics, with statistical significance established at $p < .05$.

Results and Discussion

Expert Validation Results

Prior to field testing, the Augmented Reality (AR)-supported graduate training model and its instructional instruments underwent expert evaluation. A panel of experts evaluated the content accuracy, instructional design, and AR technology integration.

Table 4. Summary of Expert Validation Results

Validation Aspect	Evaluation Focus	Mean Score (I-CVI)	Category
Content / Subject Matter	Theoretical soundness & accuracy	0.94	Highly Valid
Instructional Design	ADDIE model alignment & task clarity	0.91	Highly Valid
AR Media & Technology	Usability, interactivity & technical stability	0.90	Highly Valid
Overall Scale-Level CVI (S-CVI/Ave)		0.92	Highly Valid

As presented in Table 4, the overall Scale-Level Content Validity Index (S-CVI/Ave) achieved a score of 0.92, exceeding the standard threshold of 0.78. Based on expert feedback, minor revisions were implemented regarding 3D asset loading speed and terminology clarity before administering the model to the target sample.

Descriptive Statistics of Pre-Test and Post-Test

Data were collected from 98 postgraduate students ($N = 98$) across two primary evaluation metrics: Knowledge Acquisition and Practical Skill Competency.



Table 5. Descriptive Statistics for Pre-Test and Post-Test Scores (N = 98)

Metric	Assessment Phase	Minimum	Maximum	Mean	Std. Deviation
Knowledge Acquisition	Pre-Test	48	78	63.20	7.85
	Post-Test	72	96	85.40	6.12
Practical Skill Competency	Pre-Test	50	75	61.80	8.10
	Post-Test	75	98	87.10	5.95

The descriptive results in Table 5 show a substantial performance increase following the intervention. The mean score for Knowledge Acquisition rose from 63.20 ($SD = 7.85$) at pre-test to 85.40 ($SD = 6.12$) at post-test. Similarly, Practical Skill Competency improved from a pre-test mean of 61.80 ($SD = 8.10$) to a post-test mean of 87.10 ($SD = 5.95$).

Normality Test Results

To satisfy the assumptions for parametric multivariate statistical analysis, a normality test was conducted on the post-test residual scores of the 98 participants using the Shapiro–Wilk test.

Table 6. Shapiro–Wilk Test of Normality (N = 98)

Variable	Statistic (W)	df	Significance (p-value)	Conclusion
Knowledge Acquisition	0.981	98	0.165	Normally Distributed
Practical Skill Competency	0.978	98	0.112	Normally Distributed

As shown in Table 6, the significance values (p -values) for both Knowledge Acquisition ($p = 0.165$) and Practical Skill Competency ($p = 0.112$) were greater than the standard alpha level of 0.05 ($p > 0.05$). Thus, the assumption of bivariate normal distribution was fulfilled.

Multivariate Analysis of Variance (MANOVA)

A MANOVA was performed to determine whether the AR-supported graduate training model had a statistically significant effect on the combined dependent variables (Knowledge Acquisition and Practical Skill Competency) among postgraduate students compared to baseline expectations.

Table 7. Multivariate Tests Summary

Effect	Test Name	Value	F	Hypothesis df	Error df	Sig. (p)	Partial η^2
Model Intervention	Wilks' Lambda	0.584	33.85	2	95	< 0.001	0.416

Table 8. Tests of Between-Subjects Effects (Univariate Tests)

Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig. (p)	Partial η^2
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Knowledge Acquisition	2435.1	1	2435.1	45.2	< 0.001	0.32
Practical Skill Competency	3120.4	1	3120.4	58.65	< 0.001	0.379

As summarized in Table 7, the multivariate test yielded a statistically significant overall model effect across the combined dependent variables, Wilks' $\Lambda = 0.584$, $F(2,95) = 33.850$, $p < 0.001$, Partial $\eta^2 = 0.416$. The effect size indicates that 41.6% of the variance in postgraduate competencies is explained by the AR-supported training intervention. Follow-up univariate tests (Table 5) further confirmed significant gains for both individual outcome measures:

- 1) Knowledge Acquisition: $F(1,96) = 45.200$, $p < 0.001$, Partial $\eta^2 = 0.320$.
- 2) Practical Skill Competency: $F(1,96) = 58.650$, $p < 0.001$, Partial $\eta^2 = 0.379$.

The empirical findings ($N = 98$) confirm that the AR-Supported Graduate Training Model significantly enhances knowledge acquisition and practical skills, addressing the structural gap in China's conventional VTE framework. The high expert validity (S-CVI/Ave = 0.92) and substantial post-test gains align with (Azuma, 1997; Ibáñez & Delgado-Kloos, 2018; Nugraha et al., 2025), proving that immersive 3D visualizations bridge theoretical learning with authentic industrial practice. Furthermore, the significant MANOVA results (Wilks' $\Lambda = 0.584$, $p < 0.001$, Partial $\eta^2 = 0.416$) validate that embedding AR across the ADDIE framework activates multidimensional learning engagement a key predictor of academic achievement (Bond, 2020; Fredricks et al., 2004). Ultimately, this model provides an empirically validated, competency-based paradigm that fulfills global standards for Industry 4.0 and 5.0 graduate education (OECD, 2021; UNESCO, 2021).

Conclusion

In conclusion, the Augmented Reality (AR)-Supported Graduate Training Model is empirically validated and highly effective in enhancing postgraduate competencies in vocational and technical education ($N = 98$). Expert validation demonstrated high instructional and technical quality with an overall S-CVI/Ave score of 0.92 (92%). The implementation of the model generated substantial mean score increases in Knowledge Acquisition by 22.20 points (from 63.20 to 85.40; $d = 3.15$) and Practical Skill Competency by 25.30 points (from 61.80 to 87.10; $d = 3.55$). Furthermore, MANOVA results confirmed a statistically significant overall model effect (Wilks' $\Lambda = 0.584$, $F(2,95) = 33.850$, $p < 0.001$) with a large effect size (Partial $\eta^2 = 0.416$), indicating that 41.6% of the variance in student competencies is attributable to this AR-supported intervention. Consequently, this study provides concrete empirical evidence supporting the adoption of immersive, competency-based training models in advanced vocational education.

Recommendation

Based on the findings and the proposed AR-supported vocational graduate training model, this study recommends that higher education institutions, policymakers, and vocational education stakeholders in China systematically integrate Augmented Reality (AR) technologies into graduate training programs as part of a broader digital transformation strategy. Universities should redesign graduate curricula by combining competency-based education, experiential learning, and immersive AR applications to create authentic learning



environments that enhance students' learning engagement and cultural literacy while strengthening their professional competencies. Academic staff should be provided with continuous professional development programs focusing on AR-based instructional design, digital pedagogy, and learner-centered teaching strategies to ensure the effective implementation of innovative learning models. In addition, collaboration among universities, industries, technology developers, and government agencies should be strengthened to develop sustainable AR learning ecosystems that reflect current industrial practices and future workforce demands under the Industry 4.0 and Industry 5.0 paradigms. Educational policymakers are encouraged to formulate supportive policies, funding mechanisms, and quality assurance standards that facilitate the adoption of immersive technologies in vocational graduate education. Future research is recommended to validate the proposed model across different universities, vocational disciplines, and cultural contexts using larger and more diverse samples, as well as more rigorous research designs such as randomized controlled trials or longitudinal studies.

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