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Digital Teaching Competence and Student-Rated Teaching Effectiveness in Medical Education: Evidence from Qilu Medical University

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ABSTRACT

Digital tools now shape many parts of medical instruction, from virtual simulation and three-dimensional visualization to online clinical resources and artificial intelligence-supported learning. This study examined how medical educators' digital teaching competence relates to student-rated teaching effectiveness at Qilu Medical University. The study was guided by the Technological Pedagogical Content Knowledge (TPACK) framework, the European Framework for the Digital Competence of Educators (DigCompEdu), and the Technology Acceptance Model (TAM). Using a quantitative descriptive-correlational design, data were collected from 120 faculty members and 300 students through stratified random sampling. Faculty members assessed their competence in digital instructional design, digital resource utilization, digital classroom management, and digital assessment. Students rated teaching effectiveness in terms of teaching quality, engagement, learning outcomes, and satisfaction; these ratings were aggregated at the faculty level. Results showed high overall digital teaching competence (M = 3.92, SD = 0.68) and high student-rated teaching effectiveness (M = 4.07, SD = 0.63). Digital teaching competence was strongly associated with teaching effectiveness (r = .68, 95% CI [.57, .77], p < .001). Regression analysis showed that competence dimensions explained 51% of the variance in teaching effectiveness, with digital resource utilization (beta = .38) and digital instructional design (beta = .28) as the strongest predictors. The association was strongest among mid-career faculty with 6-10 years of teaching experience (r = .71). The findings suggest that effective digital teaching in medical education depends less on technology use itself than on educators' ability to select, design, and integrate digital resources for meaningful clinical learning. Implications are offered for staged faculty development, investment in medical digital resources, and evidence-informed digital education policies in private medical universities.

INTRODUCTION

Digital technology has changed the way higher education is designed, delivered, and evaluated. In medical education, the change is particularly visible. Virtual simulation systems, three-dimensional anatomy software, online clinical case repositories, surgical video libraries, and mixed-reality learning spaces now support learning experiences that were once limited to laboratories, hospitals, or rare clinical encounters. These tools do not simply add convenience; when used well, they can make difficult concepts visible, allow repeated practice, and help students connect theory with clinical reasoning (Zheng, 2024).

Digital teaching competence refers to educators' ability to use information and communication technologies in ways that are pedagogically sound and appropriate to context (Redecker, 2017). For medical educators, this means more than knowing how to operate a platform or display a digital resource. It involves selecting tools that match clinical learning outcomes, designing tasks around them, guiding students through simulations or cases, providing feedback, and using digital assessment to support learning. As artificial intelligence and digital platforms become more embedded in higher education, this competence has become central to teaching quality and institutional reform (The Nine Departments Including the Ministry of Education, 2025; Xu *et al.,* 2025).

Medical education also presents digital teaching demands that differ from those in many other disciplines. Medical learning often deals with invisible, complex, or high-risk phenomena that require visualization, interactivity, and safe repetition. Tools such as virtual anatomy platforms, patient simulation systems, and surgical video resources can make these experiences more accessible (Ergonul & Buyukcoban, 2026). At the same time, many medical educators balance teaching with clinical or professional duties, leaving limited time for lesson preparation and digital skill development. The benefit of digital tools therefore depends on how teachers design activities, scaffold participation, and offer feedback. Without such integration, technology may improve access to information without substantially improving learning (Liu *et al.,* 2025; Saad *et al.,* 2026).

Although digital teaching competence has been widely examined in general higher education (Fernández-Batanero *et al.,* 2021; Skantz-Åberg *et al.,* 2022), fewer studies focus on medical educators as a distinct group. Much of the medical education literature evaluates individual tools, such as virtual patients or online modules, rather than broader teacher competence.

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Few studies also connect faculty self-assessment with student-rated teaching outcomes. Evidence from private medical universities in China remains especially limited, despite the growing role of these institutions in medical workforce preparation and digital education reform.

Qilu Medical University offers a useful setting for this inquiry. As a private medical undergraduate institution, it faces the practical pressures of resource allocation, a relatively young teaching workforce, and students who increasingly expect technology-enhanced learning. The university has also invested in virtual simulation laboratories, online course development, and blended teaching. Studying this case can therefore provide evidence on how digital teaching competence is related to teaching effectiveness in a private medical education environment.

The study addressed five research questions: (1) What is the level of digital teaching competence among medical educators at Qilu Medical University? (2) What is the level of student-rated teaching effectiveness? (3) Is digital teaching competence significantly associated with student-rated teaching effectiveness? (4) Which dimensions of digital teaching competence best predict teaching effectiveness? and (5) Does teaching experience shape the relationship between digital teaching competence and teaching effectiveness?

LITERATURE REVIEW

Digital Teaching Competence and Teaching Effectiveness

Digital teaching competence includes the knowledge, skills, and professional dispositions that enable educators to use digital technologies to improve teaching and learning. It goes beyond basic technical ability and includes instructional design, resource selection, assessment, learner support, and the thoughtful integration of digital tools into pedagogy (Redecker, 2017). In medical education, it also includes the use of virtual simulations, digital clinical cases, online skills training, and technology-mediated feedback to develop clinical reasoning, procedural knowledge, and professional judgment.

Recent medical education technologies have made this competence more important. Virtual reality, augmented reality, generative AI-powered patient platforms, and online clinical simulations have been used to increase access to practice, support learner confidence, and strengthen clinical decision-making (Asadi & Karimian, 2025; Hassoulas *et al.,* 2025). Still, the tool alone does not teach. Educators must ensure that technology supports, rather than replaces, meaningful interaction, clinical reasoning, and human-centered care (Patil *et al.,* 2025; Younie *et al.,* 2024).

Teaching effectiveness refers to the extent to which instruction achieves intended learning outcomes. In medical education, this includes not only content mastery but also engagement, clinical reasoning, procedural skill development, and learner satisfaction (Bates, 2019). In this study, teaching effectiveness was measured through student ratings of teaching quality, student engagement, learning outcomes, and student satisfaction.

Theoretical Framework

The study drew on three theoretical perspectives. The first was the TPACK framework, which explains effective technology integration as the intersection of technological knowledge, pedagogical knowledge, and content knowledge (Koehler & Mishra, 2009). In a medical classroom, technological knowledge involves facility with tools such as simulation platforms and learning management systems; pedagogical knowledge includes approaches such as case-based learning, problem-based learning, and clinical skills instruction; and content knowledge refers to medical expertise. Digital teaching becomes effective when these forms of knowledge are brought together in actual teaching decisions.

The second framework was DigCompEdu, which organizes educators' digital competence across areas such as professional engagement, digital resources, teaching and learning, assessment, learner empowerment, and learners' digital competence (Redecker, 2017). Because this study focused on classroom-level teaching practice in medical education, DigCompEdu was adapted into four teaching-related dimensions: digital instructional design, digital resource utilization, digital classroom management, and digital assessment.

The third framework was TAM, which explains technology use through perceived usefulness and perceived ease of use (Davis, 1989). In medical education, TAM helps explain why technical skill may not automatically translate into better teaching. Teachers are more likely to use digital tools well when they believe those tools are useful for achieving specific medical learning goals and manageable within their actual teaching conditions (Lee *et al.,* 2025).

Empirical Evidence and Hypotheses

Systematic reviews in higher education suggest that teachers' digital competence is associated with instructional quality and learning outcomes (Fernández-Batanero *et al.,* 2021; Revuelta-Domínguez *et al.,* 2022). The strength of this association, however, may depend on institutional support, teacher beliefs, professional experience, student characteristics, and the fit between digital tools and learning objectives (Skantz-Åberg *et al.,* 2022; Tondeur *et al.,* 2017).

Medical education adds another layer of complexity. Ersoy *et al.* (2024) found that health sciences faculty reported intermediate to high digital competence, but many still struggled to decide how and when to use digital tools for specific educational purposes. This technology-teaching gap matters because operating a platform is different from designing a simulation, a case discussion, or a clinical skills activity that uses technology meaningfully. Other studies have also cautioned that excessive or poorly designed digital media use can distract learners and weaken deep learning (Smith *et al.,* 2025).

Based on the literature and the theoretical framework, the study tested the following hypotheses:

- H1. Medical educators at Qilu Medical University demonstrate moderate to high levels of digital teaching competence, with differences across competence dimensions.
- H2. Student-rated teaching effectiveness is at a moderate to high level, with differences across outcome dimensions.
- H3. Digital teaching competence is positively associated with student-rated teaching effectiveness.
- H4. The dimensions of digital teaching competence significantly predict student-rated teaching effectiveness, with digital resource utilization and digital instructional design expected to be the strongest predictors.
- H5. Teaching experience is associated with differences in digital teaching competence and shapes the relationship between digital teaching competence and teaching effectiveness.

MATERIALS AND METHODS

Research Design

A quantitative descriptive-correlational design was used to examine digital teaching competence, student-rated teaching effectiveness, the relationship between the two constructs, and the predictive contribution of specific competence dimensions. This design was appropriate because the study described existing conditions and tested associations rather than making causal claims.

Participants and Sampling

The study was conducted at Qilu Medical University. Stratified random sampling was used to include faculty from Basic Medicine, Clinical Medicine, Nursing, and Medical Technology, as well as from three experience groups: 5 years or fewer, 6-10 years, and more than 10 years. Student strata were based on year level and department, aligned with the distribution of participating faculty.

Faculty members were eligible if they were full-time educators with at least one year of experience using digital tools in teaching. Students were eligible if they were enrolled in at least one course that used digital tools such as a learning management system, simulation platform, or online instructional resource. Of the 140 teachers and 350 students invited, 120 teachers and 300 students returned valid responses, giving response rates of 85.7% for both groups. A G*Power calculation showed that at least 92 faculty-level cases were needed for regression analysis using a medium effect size ($f2 = .15$), alpha = .05, and power = .80. The final faculty sample therefore met the minimum power requirement.

Analytical Unit and Student Ratings

Faculty members completed the Digital Teaching Competence Scale, while students completed the Teaching Effectiveness Scale for their instructors. Student responses were aggregated at the faculty level so that each teacher's self-assessed digital teaching competence could be paired with the average student evaluation score for that teacher. The final analysis used 120 faculty-level cases. To protect anonymity and reduce the influence of individual student ratings, a faculty member was included only when at least five student evaluations were available.

Research Instruments

The questionnaire had three parts. The first gathered demographic information, including gender, teaching experience, academic title, and department. The second measured digital teaching competence using an adapted scale based on DigCompEdu (Redecker, 2017) and informed by TPACK. It contained four dimensions: digital instructional design (5 items), digital resource utilization (5 items), digital classroom management (4 items), and digital assessment (4 items). Responses used a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree. Mean scores were interpreted as follows: 1.00-2.33 = low, 2.34-3.67 = moderate, and 3.68-5.00 = high.

The third part was the student version of the Teaching Effectiveness Scale, adapted from Bates (2019) and Hizam *et al.* (2021). It measured teaching quality (4 items), student engagement (4 items), learning outcomes (4 items), and student satisfaction (3 items), using the same 5-point Likert response format.

Validity and Reliability

Three experts in educational technology and medical education reviewed the questionnaire for content validity. All items obtained content validity index values above .85. Exploratory factor analysis supported the expected four-factor structure of the Digital Teaching Competence Scale, explaining 73.2% of cumulative variance, with item loadings from .62 to .85. The Teaching Effectiveness Scale also produced a four-factor structure, explaining 75.6% of cumulative variance, with factor loadings from .65 to .88. Internal consistency was excellent, with Cronbach's alpha of .91 for the Digital Teaching Competence Scale and .93 for the Teaching Effectiveness Scale. Subscale alpha values ranged from .84 to .89 for digital competence and from .86 to .90 for teaching effectiveness.

Data Collection and Ethical Considerations

Institutional authorization and ethical approval were obtained before data collection. Questionnaires were distributed over four weeks through the university learning management system and printed forms for participants who preferred offline completion. Student evaluations were completed anonymously during class sessions. All participants provided informed consent, and all data were processed confidentially.

Data Analysis

Data were analyzed using SPSS 26.0. Descriptive statistics summarized means, standard deviations, and confidence intervals. Normality was assessed using the Shapiro-Wilk test, skewness, and kurtosis. Pearson correlation analysis with 95% confidence intervals examined relationships between digital teaching competence and teaching effectiveness. Multiple regression analysis determined the predictive contribution of the four digital competence dimensions. Variance Inflation Factor values were used to assess multicollinearity. One-way ANOVA and Tukey HSD post hoc tests compared digital teaching competence across teaching experience groups. The significance level was set at alpha = .05.

RESULTS AND DISCUSSION

Preliminary Data Quality Assessment

The Shapiro-Wilk test showed no significant deviation from normality for the primary variables ($p > .05$). Skewness coefficients ranged from -0.32 to -0.28, while kurtosis coefficients ranged from 0.18 to 0.22, indicating acceptable distributional properties for parametric analysis. Variance Inflation Factor values ranged from 1.7 to 2.1, below the common threshold of 5, suggesting that multicollinearity was not a concern.

Levels of Digital Teaching Competence and Teaching Effectiveness

As shown in Table 1, medical educators reported a high overall level of digital teaching competence (M = 3.92, SD = 0.68). Digital resource utilization received the highest score (M = 4.25, SD = 0.58), while digital classroom management was the only dimension in the moderate range (M = 3.52, SD = 0.79).

Table 1: Levels of Digital Teaching Competence (N = 120)

Dimension	Mean	SD	95% CI	Level
Digital instructional design	3.87	0.71	[3.74, 4.00]	High
Digital resource utilization	4.25	0.58	[4.15, 4.35]	High
Digital classroom management	3.52	0.79	[3.38, 3.66]	Moderate
Digital assessment	4.05	0.62	[3.94, 4.16]	High
Overall	3.92	0.68	[3.80, 4.04]	High

Note. Level based on tertile classification: 1.00-2.33 = Low; 2.34-3.67 = Moderate; 3.68-5.00 = High.

Table 2 shows that student-rated teaching effectiveness was also high overall (M = 4.07, SD = 0.63). Student satisfaction (M = 4.20, SD = 0.59) and teaching quality (M = 4.18, SD = 0.60) received the highest ratings. Student engagement had the lowest mean score (M = 3.78, SD = 0.74), although it remained within the high range.

Table 2: Levels of Student-Rated Teaching Effectiveness (300 student ratings aggregated for 120 teachers)

Dimension	Mean	SD	95% CI	Level
Teaching quality	4.18	0.60	[4.08, 4.28]	High
Student engagement	3.78	0.74	[3.65, 3.91]	High
Learning outcomes	4.11	0.58	[4.02, 4.20]	High
Student satisfaction	4.20	0.59	[4.11, 4.29]	High
Overall	4.07	0.63	[3.96, 4.18]	High

Correlations between Digital Teaching Competence and Teaching Effectiveness

A strong positive correlation was found between overall digital teaching competence and overall teaching effectiveness ($r = .68$, 95% CI [.57, .77], $p < .001$). At the dimensional level, digital resource utilization had the strongest correlation with teaching effectiveness ($r = .65$), followed by digital instructional design ($r = .58$), digital assessment ($r = .55$), and digital classroom management ($r = .42$).

Table 3: Pearson Correlations Between Digital Teaching Competence Dimensions and Overall Teaching Effectiveness

Dimension	r with Teaching Effectiveness	95% CI	p
Digital instructional design	.58	[.44, .70]	< .001
Digital resource utilization	.65	[.53, .75]	< .001
Digital classroom management	.42	[.26, .56]	< .001
Digital assessment	.55	[.41, .67]	< .001

Subgroup Analysis by Teaching Experience

A one-way ANOVA indicated significant differences in digital teaching competence across teaching experience groups, $F(2, 117) = 4.21$, $p = .017$. Tukey HSD comparisons showed that mid-career faculty (6-10 years) and late-career faculty (more than 10 years) had significantly higher digital teaching competence than early-career faculty (5 years or fewer). The difference between the mid-career and late-career groups was not significant. The relationship between digital competence and teaching effectiveness was strongest among mid-career faculty ($r = .71$).

Table 4: Subgroup Analysis by Teaching Experience

Teaching Experience	N	DTC (M +/- SD)	Teaching Effectiveness (M +/- SD)	r (95% CI)
<= 5 years	38	3.75 +/- 0.62	3.88 +/- 0.65	.52 [.27, .71]
6-10 years	52	4.02 +/- 0.64	4.15 +/- 0.60	.71 [.56, .82]
> 10 years	30	3.96 +/- 0.67	4.12 +/- 0.63	.68 [.44, .83]

Regression Analysis

Multiple regression analysis was conducted to determine the predictive contribution of the four digital teaching competence dimensions. The model was statistically significant, $F(4, 115) = 29.87$, $p < .001$, and explained 51% of the variance in teaching effectiveness ($R2 = .51$, adjusted $R2 = .49$). Using Cohen's (1988) criteria, the effect size was large ($f2 = 1.04$). Digital resource utilization was the strongest unique predictor (beta = .38, $p < .001$), followed by digital instructional design (beta = .28, $p = .003$), digital assessment (beta = .22, $p = .012$), and digital classroom management (beta = .15, $p = .048$).

Table 5: Multiple Regression Analysis Predicting Teaching Effectiveness

Predictor	beta	p	95% CI for beta	VIF
Digital instructional design	.28	.003	[.13, .43]	1.9
Digital resource utilization	.38	< .001	[.24, .52]	1.8
Digital classroom management	.15	.048	[.01, .29]	2.1
Digital assessment	.22	.012	[.07, .37]	1.7

Note. Model summary: R2 = .51; adjusted R2 = .49; F(4, 115) = 29.87, p < .001.

Discussion

The findings show a clear relationship between medical educators' digital teaching competence and student-rated teaching effectiveness. Beyond confirming the overall association, the results point to a more practical issue: not all digital skills carry equal weight in medical education. Competence in selecting and using digital resources, together with the ability to design instruction around those resources, appears especially important.

Digital resource utilization emerged as the strongest predictor of teaching effectiveness. This result is plausible because medical education often asks students to understand structures, procedures, and clinical situations that are difficult to observe directly. A well-chosen 3D anatomy model, virtual patient case, surgical video, or simulation platform can make an abstract concept concrete and repeatable. From the perspective of TAM, these resources likely have high perceived usefulness because they solve a real teaching problem. From the perspective of TPACK, the finding suggests that technology-content knowledge may be especially important in medical settings: teachers need to know which digital resource can best represent a specific clinical or biomedical concept.

Digital classroom management also mattered, but its contribution was smaller. This result should not be read as evidence that classroom management is unimportant. Rather, it may function as a baseline condition. Once teachers can prevent major disruptions, guide students through digital tasks, and keep learning activities organized, further improvements in classroom management may offer fewer gains than improvements in resource selection or instructional design. Medical teaching often occurs in structured settings such as simulation rooms, laboratories, skills stations, or case-based discussions, where management demands are closely tied to the design of the learning activity itself.

The role of teaching experience also deserves attention. The strongest relationship between digital competence and teaching effectiveness appeared among mid-career faculty. This challenges the common assumption that younger teachers are automatically better digital educators. Early-career faculty may be comfortable with devices and applications, but digital fluency is not the same as digital pedagogy. Effective technology integration also requires content knowledge, teaching judgment, and familiarity with students' learning difficulties. Mid-career faculty may have enough classroom and disciplinary experience to use digital tools with greater purpose, while still being open to innovation.

The descriptive results also reveal an engagement gap. Students rated teaching quality and satisfaction highly, but engagement received the lowest mean. This suggests that digital teaching may be improving access to content more effectively than it is creating active learning. Students can appreciate clear materials, organized online resources, and useful visual tools while still having limited opportunities to participate, question, solve problems, or receive immediate feedback. For medical education, the next stage of digital reform should therefore focus less on adding more resources and more on designing interactive uses of those resources.

For private medical universities, the implication is direct. Faculty development should move beyond basic technical training. Teachers need support in choosing digital resources, aligning them with learning outcomes, designing active learning tasks, facilitating simulation debriefings, and assessing student performance in digital environments. Investment in digital resource banks remains valuable, but resources have limited effect if teachers are not prepared to use them in ways that support clinical reasoning and engagement. Career-stage-sensitive training may also be useful: early-career faculty may need mentoring in digital pedagogy, mid-career faculty may serve as peer leaders, and senior faculty may benefit from targeted support that reduces barriers to adopting newer tools.

CONCLUSION

This study found that medical educators' digital teaching competence is strongly and positively associated with student-rated teaching effectiveness. Among the competence dimensions, digital resource utilization and digital instructional design were the strongest predictors, while digital classroom management made a smaller but still significant contribution. Teaching experience also shaped the relationship, with mid-career faculty showing the strongest association between digital competence and teaching effectiveness.

The findings extend TPACK, DigCompEdu, and TAM into the context of medical education. They show that effective digital teaching depends on the integration of technical knowledge, pedagogical design, and medical content expertise. For private medical universities, the results highlight the need for targeted digital faculty development, investment in high-quality medical digital resources, active learning design, and differentiated training across career stages.

Limitations and Future Research

Several limitations should be acknowledged. First, the cross-sectional correlational design identifies associations but cannot establish causality. Second, although teacher and student data were collected from different respondent groups, both relied on perceptual questionnaires, which may involve self-report and evaluation biases. Third, the sample came from a single private medical university, limiting generalizability to other institutional types and regions. Fourth, the study examined teaching experience as the main moderating variable but did not include course type, digital tool type, student digital literacy, class size, or institutional support.

Future research should include multi-center studies across public and private medical universities, use longitudinal or quasi-experimental designs to examine causal effects, and add qualitative data to explore how teachers actually integrate digital tools into classroom and clinical instruction. Intervention studies would also be useful for testing whether targeted faculty development in digital resource utilization, instructional design, and active learning improves student engagement and learning outcomes.

Declarations

• Funding: The authors received no external funding for this study.

• Conflict of Interest: The authors declare no conflict of interest.

• Ethical Considerations: Participation was voluntary, and informed consent was secured from all participants.

• Use of Generative AI: Generative AI tools were used only for language refinement and editorial support. The authors reviewed and approved the final manuscript and remain fully responsible for its content.

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