



From Supporting Students to Designing Learning: Digital Pedagogy among Chemistry Pre-Service Teachers

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Abstract

This study examines digital pedagogy among Indonesian pre-service chemistry teachers, with particular attention to patterns across pedagogical orientation, pedagogical practices, and digital pedagogical competence. A descriptive-comparative quantitative survey design was employed, involving 158 respondents from seven Islamic teacher education institutions in Indonesia. Data were collected using a self-assessment instrument and analysed through descriptive statistics and independent-samples t-tests. The findings revealed a generally positive profile of digital pedagogy. Pedagogical orientation received the highest mean score ($M = 3.59$), followed by pedagogical practices ($M = 3.58$), while digital pedagogical competence recorded the lowest score ($M = 3.53$). Item-level analysis showed that respondents were more confident in supporting students through communication, participation, and positive classroom relationships than in designing learning through inclusive planning, assessment design, educational data use, and technology-supported evaluation. No statistically significant differences were found by gender or number of digital tools used ($p > .05$). The study suggests that digital pedagogy develops unevenly across domains. While pre-service teachers appear relatively well prepared to support students, they may be less prepared to design learning experiences that are inclusive, assessment-informed, and pedagogically purposeful. These findings highlight the need for chemistry teacher education programs to move beyond generic technology training and provide more structured opportunities for design-oriented, discipline-specific, and inclusive digital pedagogy development.

Keywords: Digital competence; digital pedagogy; educational technology; inclusive pedagogy; pre-service teachers

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INTRODUCTION

The rapid digital transformation of education has fundamentally reshaped expectations of teacher professionalism worldwide. Teachers are no longer expected merely to operate digital devices or online platforms, but to integrate technology pedagogically in ways that enhance student engagement, disciplinary understanding, assessment quality, and inclusive participation (Asmayawati et al., 2024; Chattopadhyay, 2025; Saravanakumar et al., 2023). As a result, digital pedagogy has become a central dimension of teacher readiness in the twenty-first century (Brussino, 2021; Redecker, 2017). In Indonesia, however, the development of technology-enhanced and inclusive learning environments continues to face structural constraints, including infrastructure disparities, uneven access to digital resources, and variations in teacher preparation quality (Astari & Yulianto, 2025; Raharjo & Rohmadi, 2025). These conditions make teachers' digital pedagogical competence increasingly important, particularly their ability to design, implement, and reflect on learning experiences that respond to diverse student needs.

Despite growing access to technology, the transition from technological familiarity to pedagogically meaningful use remains uneven. In many teacher education programs, pre-service teachers are introduced to presentation tools, learning management systems, and online resources,

yet they often receive limited preparation for aligning these tools with curriculum goals, learner diversity, and subject-specific instructional demands (Cheek et al., 2019; Wang, 2023). However, digital pedagogy does not necessarily develop evenly across all areas of teaching. Pre-service teachers may feel confident in supporting students, fostering participation, and maintaining positive classroom relationships, but less prepared to design learning activities, assessments, and technology-supported instruction that respond to diverse learner needs. This uneven development suggests that digital pedagogy involves multiple dimensions that may mature at different rates during teacher preparation (Scherer et al., 2019; Tondeur et al., 2017).

This issue is particularly relevant among pre-service teachers belonging to Generation Z. Having grown up in digitally mediated environments, this generation is frequently described as “digital natives” and is often assumed to possess natural technological fluency (Bourke, 2019; Febliza et al., 2025; Prensky, 2001). However, increasing evidence suggests that everyday digital familiarity does not automatically develop into professional or pedagogical competence (Blyznyuk & Hotsaniuk, 2024; Didmanidze et al., 2023; Giunta, 2017). The ability to use social media, communication applications, or general-purpose technologies differs substantially from the capacity to design instruction, facilitate learning, and evaluate student understanding through digital means (Ngongpah & Oni, 2025). For this reason, Generation Z pre-service teachers represent an important population for examining whether personal digital confidence can be transformed into pedagogically meaningful competence.

The context of chemistry education makes this issue even more consequential. Chemistry learning frequently requires students to understand abstract, microscopic, symbolic, and multi-representational concepts that are difficult to grasp through conventional explanation alone. Effective digital pedagogy in chemistry often depends on simulations, molecular visualisation tools, virtual laboratories, animations, graphing software, and interactive models that help learners connect macroscopic observations, submicroscopic particle processes, and symbolic chemical representations (Gilbert & Treagust, 2009; Jones & Kelly, 2015). Therefore, chemistry teacher preparation requires not only general digital literacy but also subject-specific pedagogical integration of technology that makes complex concepts accessible to diverse learners.

Digital pedagogy is commonly understood as the pedagogically meaningful use of digital technologies to support learning. Rather than focusing solely on technical proficiency, contemporary perspectives emphasise how teachers use technology to facilitate participation, interaction, assessment, and knowledge construction. Väättäjä and Ruokamo (2021) Conceptualise digital pedagogy as consisting of three interconnected dimensions: pedagogical orientation, pedagogical practices, and digital pedagogical competence. Together, these dimensions provide a useful framework for understanding how teachers think about teaching, enact instruction, and integrate digital technologies in learning environments.

Although these dimensions are closely related, they may not develop uniformly. Teachers may demonstrate strengths in supporting students through positive relationships, communication, and participation, while experiencing greater challenges in instructional planning, assessment design, and technology-supported decision-making. Examining these patterns is particularly important in chemistry education, where effective teaching requires not only supportive learning environments but also carefully designed learning experiences that help students engage with complex and abstract scientific concepts.

Previous studies have examined digital competence, technology integration, and teacher readiness in a variety of educational contexts (Chai et al., 2011; Scherer et al., 2019; Teo, 2011). However, less attention has been paid to how different dimensions of digital pedagogy develop among pre-service teachers and whether some aspects are more developed than others. In particular, limited research has explored the distinction between supporting students through positive relationships and participation, and designing learning through planning, assessment, and instructional decision-making. Understanding this distinction is important because effective digital pedagogy requires both relational and instructional capacities, especially in disciplines such as chemistry that involve complex conceptual learning.

In Indonesia, teacher education institutions are increasingly expected to prepare future teachers who are digitally literate, pedagogically responsive, and inclusive. However, curriculum delivery often prioritises operational technology skills over pedagogical integration and reflective use. Many pre-service teachers learn how to use educational software but receive insufficient guidance on when, why, and for whom to use such tools. This situation risks creating a technical bias, in which digital fluency is mistaken for digital pedagogy (Scherer et al., 2019).

This study addresses these gaps in three ways. *First*, it provides a multidimensional profile of digital pedagogy among chemistry pre-service teachers. *Second*, it identifies areas of relative strength and areas requiring further development across pedagogical orientation, pedagogical practices, and digital pedagogical competence. *Third*, it contributes contextual evidence from Indonesian Islamic teacher education institutions, a setting that remains underrepresented in the digital pedagogy literature.

Self-assessment is particularly relevant in this context because it functions as a metacognitive tool that encourages reflective awareness of strengths, limitations, and professional learning needs (Andrade & Valtcheva, 2009). Prior studies have shown that self-assessment can support professional growth, strengthen self-efficacy, and provide meaningful evidence of developing teacher competence (Kilic & Saglam, 2023; Quddus et al., 2019). Thus, examining how pre-service teachers assess their own readiness offers both diagnostic and developmental value for teacher education programs.

Accordingly, this study addresses the following research questions:

- (1) How do Indonesian chemistry pre-service teachers perceive their pedagogical orientation, pedagogical practices, and digital pedagogical competence?
- (2) Are there statistically significant differences based on gender and level of digital tool use?
- (3) What do the observed patterns reveal about strengths and developmental needs in digital pedagogy among chemistry pre-service teachers?

METHODS

Research Design

This study employed a cross-sectional, descriptive-comparative quantitative survey design to examine the self-assessed digital pedagogical competence of Indonesian pre-service chemistry teachers. The descriptive component was used to identify response patterns across three core competence dimensions, whereas the comparative component was used to examine whether statistically significant differences existed across selected demographic groups. A survey design was considered appropriate because the study aimed to capture participants' perceptions of different dimensions of digital pedagogy, including pedagogical orientation, pedagogical practices, and digital pedagogical competence, at a single point in time.

Participants and Sampling Procedure

The participants were 158 chemistry pre-service teachers enrolled in Islamic teacher education institutions (*Perguruan Tinggi Keagamaan Islam Negeri/PTKI*) in Indonesia. Respondents were drawn from seven participating universities: UIN Sunan Kalijaga Yogyakarta (n = 26), UIN Walisongo Semarang (n = 35), UIN Syarif Hidayatullah Jakarta (n = 10), UIN Sultan Syarif Kasim Riau (n = 34), UIN Sunan Gunung Djati Bandung (n = 26), UIN Ar-Raniry Banda Aceh (n = 13), and UIN Mahmud Yunus Batusangkar (n = 14).

A total sampling strategy was applied within the participating programs, meaning that all eligible students in the targeted cohorts were invited to participate during the data collection period. Across the seven institutions, the accessible population consisted of approximately 184 eligible students, of whom 158 submitted valid responses.

Eligibility criteria required participants to: (1) be enrolled in a chemistry education or chemistry teacher preparation program; (2) be in the third year or above; and (3) have completed courses related to pedagogy and/or ICT-supported learning. Accordingly, the sample reflects students from participating institutions rather than all PTKI institutions nationally. These

institutions were selected based on program accessibility and willingness to participate during the data collection period.

Of the respondents (Table 1), 24 (15.19%) identified as male and 134 (84.81%) as female. In terms of digital tool exposure, 44 respondents (27.85%) reported using more than six educational software applications, 60 (37.97%) reported using four to six applications, and 54 (34.18%) reported using fewer than four.

Table 1. Respondents' characteristics (N = 158)

Variable	Category	n	%
Gender	Male	24	15.19
	Female	134	84.81
Educational software used	>6	44	27.85
	4-6	60	37.97
	<4	54	34.18

Instrument Development

Data were collected using a structured self-assessment questionnaire based on the digital pedagogy framework proposed by Väättäjä and Ruokamo (2021). The instrument was designed to capture three interrelated dimensions of digital pedagogy: pedagogical orientation, pedagogical practices, and digital pedagogical competence.

The initial item pool was generated to reflect three interrelated dimensions of digital pedagogy:

- (1) Pedagogical Orientation (5 items): measuring perceptions of supporting student participation, engagement, responsiveness, and learning design.
Example item: *Technology can help address diverse learner needs in chemistry classrooms.*
- (2) Pedagogical Practices (10 items): measuring self-reported implementation of student-centred and digitally supported instructional strategies.
Example item: *I use digital tools to facilitate collaboration, discussion, or formative feedback.*
- (3) Digital Pedagogical Competence (15 items): measuring confidence in selecting, adapting, evaluating, and integrating digital tools for instructional purposes, including assessment, communication, classroom management, and technology-supported instructional decision-making.
Example item: *I can determine whether a digital tool is suitable for specific chemistry learning objectives.*

All items were rated using a five-point Likert scale ranging from 1 (*strongly disagree*) to 5 (*strongly agree*).

Validity and Reliability

The instrument was reviewed by two experts in science education and educational technology to assess content relevance, construct alignment, clarity of wording, and redundancy across items. Subsequent revisions were made to improve item precision and conceptual fit.

A pilot test was then conducted with 30 chemistry pre-service teachers who were not included in the final sample. Internal consistency analysis showed satisfactory reliability. The overall Cronbach's alpha coefficient was 0.88, while subscale reliability coefficients ranged from 0.85 to 0.91, indicating high internal consistency.

Data Collection Procedure

Data were collected over a two-month period using an online questionnaire distributed through an official student WhatsApp Group coordinated by designated program representatives at each participating institution. This distribution channel was selected because it was the most widely used and accessible communication medium among the target population.

To ensure participant eligibility, the survey link was shared only within identified cohorts of chemistry education students who met the inclusion criteria. The introductory page of the

questionnaire required respondents to confirm that they were currently enrolled in a chemistry teacher education program, were in the third year or above, and had completed pedagogy and/or ICT-related coursework before proceeding to the main survey. Responses not meeting these criteria were excluded.

Duplicate responses were minimised through survey settings restricting multiple submissions from the same account and through post-collection screening of timestamps, identical demographic profiles, and highly repetitive response patterns. Where duplicate entries were suspected, only the most complete submission was retained. Incomplete responses were also removed prior to analysis.

Participation was voluntary. Respondents were informed of the study's purpose, confidentiality procedures, and their right to withdraw at any stage without consequences. Digital informed consent was obtained prior to completing the questionnaire. The study procedures were conducted in accordance with general ethical standards for voluntary educational research.

Data Analysis

Data were analysed using SPSS version 26. Descriptive statistics, including means, standard deviations, and response distributions, were used to summarise participants' self-assessments across the three dimensions. To examine group differences, independent-samples t-tests were conducted based on gender and level of digital tool use. For comparative analysis, respondents were grouped into two categories of tool use: (1) six or fewer tools and (2) more than six tools.

In addition to dimension-level analysis, item-level means were examined to identify specific strengths and challenges within each dimension. This approach enabled a more nuanced understanding of digital pedagogy beyond overall average scores and supported the identification of patterns in supporting students and in designing learning.

Prior to inferential testing, statistical assumptions were examined. Normality was assessed through Shapiro–Wilk tests and inspection of skewness and kurtosis values, while homogeneity of variance was assessed using Levene's test. The data met the assumptions required for parametric testing. Statistical significance was set at $p < .05$. Where relevant, effect sizes were considered to interpret the practical magnitude of observed differences.

Finally, item-level patterns were examined to identify areas of relative strength and areas requiring further development across the three dimensions of digital pedagogy. Particular attention was given to distinctions between student-support-oriented and instructional design-oriented aspects of digital pedagogy, as these patterns provided insights into the developmental profile of chemistry pre-service teachers.

RESULTS & DISCUSSION

Result

The findings are organised into four parts. *First*, overall scores across the three dimensions of digital pedagogical competence are presented. *Second*, item-level analysis identifies the strongest and weakest indicators reported by respondents. *Third*, comparative analyses examine whether scores differed by gender and level of digital tool use. *Finally*, the section concludes with an integrated summary of the main empirical patterns.

Perceptions Across Digital Pedagogical Dimensions

The self-assessment results indicate generally moderate-to-positive perceptions across all three measured dimensions of digital pedagogy (Table 2). Among the dimensions, Pedagogical Orientation recorded the highest mean score ($M = 3.594$, $SD = 0.536$), followed closely by Pedagogical Practices ($M = 3.585$, $SD = 0.523$). Digital Pedagogical Competence showed the lowest mean score ($M = 3.528$, $SD = 0.511$).

Although the differences among the three dimension-level means were relatively small (range = 0.066), the results suggest a generally positive profile of digital pedagogy across the

sample. Respondents reported the highest confidence in pedagogical orientation and the lowest confidence in digital pedagogical competence. However, the modest differences indicate that overall dimension-level scores alone provide only a partial picture of respondents' strengths and developmental needs. More nuanced insights emerge from the item-level analysis presented below.

Table 2. Descriptive statistics of digital pedagogical competence (n = 158)

Dimension	Mean (M)	Standard Deviation (SD)
Pedagogical Orientation (PO)	3.594	0.536
Pedagogical Practices (PP)	3.585	0.523
Digital Pedagogical Competence (DPC)	3.528	0.511

Supporting Students and Designing Learning: Item-Level Patterns of Digital Pedagogy

To provide a more detailed understanding of respondents' perceptions, item-level analysis was conducted across the full instrument. The five highest-rated and five lowest-rated indicators are presented in Table 3.

Table 3. Highest- and Lowest-Rated Survey Indicators

Category	Item Code	Indicator	Mean (M)
Highest	PO5	Providing opportunities for students to express learning difficulties or personal conditions	3.75
	PO4	Creating a friendly and supportive classroom climate	3.70
	PO3	Encouraging student attention and active participation	3.61
	DPC24	Using chat applications to improve communication with students	3.60
	PP8	Applying various online learning methods	3.58
Lowest	PO2	Designing objectives that consider diverse learners, including disabilities	3.40
	DPC30	Developing tools to evaluate technology-based student projects	3.41
	DPC28	Managing student data efficiently using digital tools	3.43
	DPC29	Using technology to collect and report student performance data	3.44
	DPC21	Helping students solve technical problems with devices	3.45

The highest-rated indicators were concentrated in pedagogical aspects related to relationships, communication, and participation. Respondents reported the strongest confidence in creating supportive learning environments, giving students space to communicate difficulties, encouraging engagement, and maintaining communication through familiar digital platforms. By contrast, the lowest-rated indicators were concentrated in inclusive instructional planning, assessment design, educational data use, and technical troubleshooting. These Competence involve more advanced pedagogical judgment and managerial decision-making.

The item-level pattern suggests a distinction between supporting students and designing learning. Respondents expressed greater confidence in relational aspects of teaching, such as creating supportive environments, maintaining communication, and encouraging participation. In contrast, lower confidence was reported in competence associated with instructional design, assessment, data-informed decision-making, and technology-supported evaluation. This pattern indicates that different dimensions of digital pedagogy may develop unevenly during teacher preparation.

A particularly noteworthy finding is that the lowest score within the Pedagogical Orientation dimension concerned designing learning objectives that explicitly account for diverse learners, including students with disabilities (PO2, M = 3.40). This suggests that respondents may feel more confident in relational inclusivity than in translating inclusion into formal instructional planning.

Overall, the item-level findings reinforce the broader pattern observed at the dimension level: respondents appeared more confident in visible and interactional aspects of teaching than in higher-order planning, evaluation, and adaptive digital pedagogy.

Gender-Based Comparisons

No statistically significant gender differences were identified across pedagogical orientation, pedagogical practices, or digital pedagogical competence (Table 4). Effect sizes were trivial to small, indicating negligible practical differences between male and female respondents.

Table 4. Independent-Samples t-Test by Gender

Dimension	<i>t</i>	<i>df</i>	<i>p</i>	Effect Size (<i>r</i>)
Pedagogical Orientation (PO)	1.016	146	.311	.084
Pedagogical Practices (PP)	0.892	146	.374	.074
Digital Pedagogical Competence (DPC)	0.781	146	.436	.065

Comparisons by Level of Digital Tool Use

Similarly, no statistically significant differences were observed based on the number of educational software applications used (Table 5). Although respondents reporting greater software use showed slightly higher scores, effect sizes remained small, suggesting that broader exposure to digital tools does not necessarily correspond to stronger digital pedagogical confidence.

Table 5. Independent-Samples t-Test by Number of Tools Used

Dimension	<i>t</i>	<i>df</i>	<i>p</i>	Effect Size (<i>r</i>)
Pedagogical Orientation	1.482	156	.141	.118
Pedagogical Practices	1.265	156	.208	.101
Digital Pedagogical Competence	1.701	156	.091	.135

Integrated Interpretation of the Findings

Across all analyses, the most consistent empirical pattern was not demographic variation but the contrast between relational and instructional aspects of digital pedagogy. Respondents expressed relatively strong confidence in supporting students through communication, participation, and positive classroom relationships, while reporting lower confidence in instructional tasks such as inclusive planning, assessment design, data management, and technology-supported evaluation.

The absence of statistically significant differences based on gender or software use further suggests that these patterns are not primarily explained by demographic characteristics or simple exposure to technology. Instead, the findings point to developmental challenges in transforming supportive teaching dispositions into more sophisticated forms of instructional design and digital pedagogical decision-making.

Overall, the results suggest that chemistry pre-service teachers may be better prepared to support students than to design inclusive, assessment-informed, and pedagogically complex learning experiences.

Discussion

This study provides a clearer picture of the digital pedagogical readiness of Indonesian pre-service chemistry teachers. The main finding was not only the overall score levels, but also the pattern across the three dimensions of digital pedagogy. Respondents reported the highest scores for pedagogical orientation, followed by pedagogical practices, while digital pedagogical competence received the lowest scores. More importantly, item-level analysis revealed a consistent distinction between relational and instructional aspects of digital pedagogy. Respondents expressed greater confidence in creating supportive learning environments, encouraging participation, and maintaining communication with students, whereas lower scores

were observed in inclusive planning, assessment design, educational data use, and technology-supported evaluation. These findings suggest that digital pedagogical readiness does not develop evenly across all domains. Rather, some aspects appear to develop earlier than others during teacher preparation.

This pattern is theoretically important because it suggests that different dimensions of digital pedagogy may follow different developmental trajectories. Educational technology research often assumes that confidence, positive attitudes, or familiarity with technology will naturally translate into effective pedagogical use. However, the present findings point to a more differentiated process. Respondents appeared relatively confident in supporting students through communication and participation, yet reported lower confidence in designing, assessing, and adapting technology-supported learning experiences. The key challenge for teacher education, therefore, may not be fostering positive orientations toward technology, but helping future teachers develop the instructional expertise required to use technology in pedagogically meaningful ways.

A useful interpretation is that the three dimensions reflect different forms of professional learning. Pedagogical orientation captures commitments to student-centred and technology-supportive values. Pedagogical practices reflect the enactment of these values in routine teaching activities. Digital pedagogical competence, however, requires more sophisticated forms of professional judgment, including selecting appropriate digital tools, aligning technology with learning objectives, adapting instruction to learner needs, and evaluating learning outcomes. These activities involve instructional reasoning that extends beyond positive attitudes or routine technology use. Consequently, the findings suggest that digital pedagogy should be understood not as a single competence that develops uniformly, but as a multidimensional capacity in which relational support, instructional design, assessment, and technology integration may develop at different rates during teacher preparation.

Why Supportive Dispositions Do Not Automatically Lead to Instructional Expertise

A central finding of this study is that respondents expressed relatively strong confidence in supporting students through communication, participation, and positive classroom relationships, while reporting lower confidence in instructional tasks such as inclusive planning, assessment design, educational data use, and technology-supported evaluation. This pattern suggests that supportive dispositions and instructional expertise may develop differently during teacher preparation. Although both are important components of effective teaching, the ability to create a welcoming learning environment does not automatically translate into the capacity to design, implement, and evaluate learning experiences that respond to diverse learner needs (Bondie et al., 2019).

One possible explanation is that teacher education programs often place considerable emphasis on student-centred values, classroom interaction, and positive teacher–student relationships. These experiences help future teachers develop awareness of learners’ needs and the importance of participation and inclusion. However, opportunities to engage in more complex pedagogical tasks, such as designing differentiated learning objectives, constructing assessment systems, interpreting learning evidence, or selecting technology for specific instructional purposes, may be less frequent (Ntuli & Nyarambi, 2018; Oigara, 2013; Tondeur et al., 2017). As a result, pre-service teachers may leave teacher preparation programs with strong supportive dispositions but less confidence in the design-oriented aspects of teaching.

The item-level findings support this interpretation. Respondents reported high confidence in creating supportive classroom environments, encouraging participation, and maintaining communication with students. In contrast, lower scores were observed for designing learning objectives that account for diverse learners, developing technology-based assessment tools, managing student performance data, and using digital evidence to inform instructional decisions. These activities require pedagogical judgment that extends beyond interpersonal relationships. Teachers must determine what students need to learn, how learning should be assessed, what evidence should be collected, and how instructional decisions should be adapted in response to

that evidence. Such decision-making processes have long been recognized as central components of professional teaching expertise (Shulman, 1987).

This distinction is particularly important because effective digital pedagogy depends not only on the willingness to use technology but also on the ability to make informed instructional decisions. Digital tools can support learning in many ways, yet their educational value depends on how they are selected, structured, and integrated into learning activities (Redecker, 2017; Schmidt et al., 2009). Creating opportunities for interaction or communication does not guarantee meaningful learning outcomes. Teachers must also be able to align digital resources with learning objectives, assessment processes, and the needs of diverse learners (Scherer et al., 2019).

The findings, therefore, suggest that the challenge facing teacher education may not primarily be motivational. Respondents generally demonstrated positive orientations toward teaching and technology-supported learning. Instead, the more significant challenge appears to be developing instructional expertise. This interpretation extends previous research that has identified barriers related to confidence, infrastructure, and institutional support (Collins, 2024; Reddy & Bubonia, 2020). While such factors remain important, the present study indicates that readiness may also be constrained by limited opportunities to develop higher-order pedagogical capabilities, including planning, assessment, adaptation, and evidence-informed teaching. Similar concerns have been raised in studies showing that exposure to digital technologies alone does not necessarily promote deeper pedagogical competence (Hatlevik & Hatlevik, 2018; Tondeur et al., 2017).

From a teacher education perspective, these findings highlight the importance of moving beyond technology exposure and positive attitudes toward more deliberate engagement with instructional design. Pre-service teachers need opportunities not only to use digital tools, but also to justify their selection, evaluate their effectiveness, adapt them for different learners, and connect them to disciplinary learning goals. Strengthening these experiences may help future teachers move from supporting students effectively to designing learning experiences that are pedagogically purposeful, inclusive, and responsive to learner diversity.

Relational Inclusivity Is Stronger Than Instructional Inclusivity

Beyond general instructional expertise, the findings also reveal important implications for inclusive education. One of the more notable findings was that the lowest-rated item within pedagogical orientation concerned designing learning objectives that explicitly consider diverse learners, including students with disabilities. In contrast, several of the highest-rated items focused on interpersonal practices, such as listening to students' concerns and creating a welcoming classroom environment.

This pattern suggests a difference between relational inclusivity and instructional inclusivity. Respondents appeared more confident in supporting students socially and emotionally than in translating inclusive principles into curriculum planning. However, inclusive education depends not only on positive attitudes or caring relationships. It also requires differentiated objectives, accessible learning materials, flexible assessment, anticipatory planning, and appropriate scaffolding (Adebisi, 2024; Bondie et al., 2019; Dhakal, 2024; Suprihatiningrum et al., 2025; Wulayalin & Suprihatiningrum, 2024).

This finding is consistent with previous studies showing that positive attitudes toward inclusion often exceed teachers' confidence in their ability to implement it (Abellán & Fernández-Bustos, 2024; Baglieri, 2024; Beltran et al., 2022; Charitaki et al., 2022; Coelho et al., 2017). Many teachers support inclusive education in principle but feel less prepared to adapt curriculum or assessment in practice. The present study adds to this discussion by indicating that the same pattern may already be present during pre-service preparation.

This issue is also relevant to digital pedagogy. If inclusion is weakly considered during planning, technology may reproduce existing barriers rather than reduce them. Digital tools can improve access, but only when selected and organised with learner diversity in mind.

Challenging the “Digital Native” Thesis

The findings also question the common assumption that members of Generation Z will naturally become digitally competent teachers because they grew up with technology. Although respondents reported generally positive orientations toward digital pedagogy, this did not correspond to equally strong confidence in design-oriented, evaluative, and reflective aspects of teaching with technology.

This suggests that everyday digital familiarity should not be equated with professional pedagogical competence. Being comfortable with messaging applications, social media, or entertainment technologies is different from being able to design learning activities, represent disciplinary concepts, assess student understanding, and respond to learner diversity through technology. These are professional skills developed through training and practice rather than solely through age or generational identity.

For this reason, the explanatory value of the “digital native” concept may be limited in teacher education. Familiarity with technology may reduce anxiety or increase willingness to experiment, but it cannot replace systematic pedagogical preparation. This supports more recent critiques arguing that age-based stereotypes often overlook the more important roles of training quality, learning opportunities, and teaching experience (Giunta, 2017; Howard et al., 2022). The present findings therefore qualify Prensky (2001) earlier claims by suggesting that digital familiarity may support confidence but does not necessarily guarantee pedagogical competence.

Why Tool Exposure Did Not Produce Stronger Competence

No statistically significant differences were found based on the number of digital tools used, and the effect sizes were small. This finding is important because it challenges a common assumption in teacher education that using more tools automatically indicates higher competence.

Using many applications may reflect experimentation, convenience, or institutional demands, but not necessarily pedagogical reasoning. A pre-service teacher may use multiple tools for communication, presentations, or file sharing, yet still lack confidence in selecting an appropriate simulation, designing a valid formative assessment, or adapting digital tasks for learners with different needs.

This result is in line with previous studies warning that participation or frequency measures may overestimate deeper forms of digital capability (Hatlevik & Hatlevik, 2018; Ntuli & Nyarambi, 2018). The present study extends this concern to teacher education by showing that future teachers may use technology frequently without developing stronger pedagogical competence. Institutions should therefore be cautious about assuming that technology-rich environments automatically produce competence-rich outcomes.

Implications for Chemistry Teacher Education

These issues are especially relevant in chemistry education, where technology often helps students understand phenomena that cannot be directly observed. Simulations, molecular visualisations, graphing tools, animations, and virtual laboratories can support connections between macroscopic observations, submicroscopic processes, and symbolic representations. However, these tools are effective only when linked to misconceptions, representational transitions, inquiry goals, and feedback processes.

Previous studies on chemistry education have shown that visual technologies can improve conceptual understanding when properly scaffolded, but may have a limited impact when used superficially (Gilbert & Treagust, 2009; Jones & Kelly, 2015). The present findings suggest that pre-service teachers may value these tools, yet still feel underprepared to use them strategically.

More importantly, the findings indicate that the primary challenge may not be encouraging pre-service teachers to use technology but helping them develop the instructional expertise required to design learning with technology. Respondents expressed relatively strong confidence in supporting students through communication and participation, yet lower confidence in assessment design, educational data use, and planning for diverse learners. This pattern

suggests that chemistry teacher education may be more successful in developing supportive teaching dispositions than in cultivating design-oriented pedagogical capabilities.

Accordingly, chemistry teacher education should provide more structured opportunities for pre-service teachers to engage in design-oriented pedagogical work. Such opportunities may include designing technology-supported lessons, developing formative assessments, interpreting student learning evidence, adapting instruction for diverse learners, and justifying the selection of digital tools for specific learning goals. Particular attention should be given to inclusive instructional design, as respondents reported lower confidence in planning learning objectives that explicitly consider learner diversity. In chemistry education, these experiences should be embedded within authentic disciplinary challenges, such as addressing misconceptions, connecting multiple representations, and supporting conceptual understanding through simulations and visualisations. These experiences may help future teachers move beyond supporting students toward designing learning experiences that are pedagogically purposeful, inclusive, and responsive to learner needs.

CONCLUSION

This study examined the digital pedagogy of Indonesian pre-service chemistry teachers across three dimensions: pedagogical orientation, pedagogical practices, and digital pedagogical competence. The findings revealed a generally positive profile of digital pedagogy but also highlighted important differences across dimensions and indicators. While respondents reported relatively strong confidence in supporting students through communication, participation, and positive learning environments, they expressed lower confidence in inclusive planning, assessment design, educational data use, and technology-supported evaluation.

The most significant contribution of this study is the distinction between supporting students and designing learning. The findings suggest that pre-service teachers may be more prepared to foster supportive and participatory learning environments than to design learning experiences that are pedagogically purposeful, assessment-informed, and responsive to learner diversity. This pattern indicates that digital pedagogy develops unevenly and that different dimensions of professional competence may require different forms of preparation and support.

No statistically significant differences were found based on gender or level of digital tool use. These findings challenge assumptions that demographic characteristics or greater exposure to digital tools necessarily translate into stronger digital pedagogical readiness. Instead, the results point to the importance of pedagogical preparation and instructional design expertise in shaping meaningful technology use.

From a practical perspective, chemistry teacher education should move beyond generic technology training toward opportunities that strengthen design-oriented pedagogical capabilities. Pre-service teachers need structured experiences in designing technology-supported lessons, developing formative assessments, interpreting learning evidence, adapting instruction for diverse learners, and connecting digital tools to disciplinary learning goals. Such experiences may help future teachers move beyond supporting students toward designing learning experiences that are inclusive, reflective, and instructionally effective.

This study has several limitations. It relied on self-assessment data that reflect perceived rather than observed competence, used a cross-sectional design that cannot capture developmental change, and involved participants from selected Islamic teacher education institutions only. Future research should therefore employ longitudinal, observational, and mixed-method approaches to examine how digital pedagogical competence develops over time and how perceived readiness is translated into actual teaching practice.

Overall, the findings suggest that the central challenge in preparing future chemistry teachers may not be encouraging technology use, but developing the pedagogical expertise required to use technology in ways that support meaningful, inclusive, and discipline-specific learning.

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