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Article

From Readiness to Design: Mapping Pre-Service Chemistry Teacher's Inclusive Competencies with Charlotte Danielson's Framework

Madah Ikrimatul 'Azmi[1], Jamil Suprihatiningrum[1*], Khafifah Aulia Wulayalin[2]

[1]Universitas Islam Negeri Sunan Kalijaga Yogyakarta, Indonesia
[2]Prince of Chulalongkorn University, Thailand

**Corresponding email: jamil.suprihatiningrum@uin-suka.ac.id*

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ABSTRACT

This study examines the inclusive teaching readiness of pre-service chemistry teachers using Charlotte Danielson's Framework for Teaching (FfT) as an analytic lens and as an entry point to Educational Design Research (EDR). Fifty participants from six Indonesian state universities were surveyed with a 22-indicator Likert instrument adapted from the FfT. The instrument showed good internal consistency ($\alpha = .87$). Descriptive statistics and non-parametric tests were used to compare domains and explore variance. Results indicate high competencies in Planning & Preparation, Classroom Environment, and Instruction, while Professional Responsibility shows comparatively lower means and greater dispersion. Weakest indicators include adaptive assessment, inclusive/multimodal communication, and professionalism, suggesting both curricular gaps and unequal access to clinical experiences. Potential ceiling effects in planning signal the need for more sensitive, authentic indicators (e.g., project-based assessment across representations). We translate these findings into EDR design principles prioritizing (1) adaptive assessment, (2) multimodal communication, (3) mentoring and professional learning communities, and (4) accessibility audits for laboratory spaces. The study formulates EDR design principles emphasizing adaptive assessment, multimodal strategies, mentoring networks, and accessibility audits. Overall, this research operationalizes the Charlotte Danielson's FfT in inclusive chemistry education, linking empirical measurement to practical design solutions and offering implications for curriculum reform and iterative EDR-based model development.

INTRODUCTION

Inclusive education has become a mainstream part of global education policy and practice, including in Indonesia. How is it possible that an ideal education system still leaves millions of children with disabilities without proper access to schools? This question highlights the great paradox many countries, including Indonesia, continue to face. The implementation of inclusive education has not yet fully met its original goals (Nurfadhillah, 2023). One reason is the various understandings and perceptions about inclusive education (Jauhari, 2017). Conceptually, inclusive education provides equal and quality learning opportunities for all

students, regardless of their physical, intellectual, social, economic, cultural, or religious backgrounds (Handayani & Rahadian, 2013). This idea aligns with the Salamanca Declaration (United Nations Educational, 1994) and the Sustainable Development Goals (SDGs), especially Goal 4 on inclusive and quality education. In Indonesia, this is supported by the regulation, which states that all students have the right to education within the same educational institutions (Peraturan Menteri Pendidikan Nasional Republik Indonesia Nomor 70, 2009). To highlight this issue, data show that globally, only about 68% of children with disabilities have access to secondary education. In Indonesia, a survey by Garcia et al. (2020) indicates that school participation rates for children with disabilities are only 56%, well below the national average. This figure shows a significant gap that needs action at both policy and practical levels.

However, implementing inclusive education still faces challenges, especially in science education (Frey, 2018; Sunardi et al., 2011). The challenges in implementing inclusive education, particularly in science learning, arise from various interrelated factors. Many teachers still lack a comprehensive understanding of inclusive pedagogy and how to adapt science learning for students with diverse needs (Frey, 2018). This situation is exacerbated by the limited training and professional development focused on inclusive practices for science teachers. In addition, schools often face infrastructure and resource constraints such as the lack of accessible laboratories, visual-audio learning aids, and appropriate experimental media for learners with disabilities (Sunardi et al., 2011). The national curriculum also tends to emphasise uniform academic achievement rather than flexibility in accommodating diverse learning needs. Furthermore, social stigma and exclusive attitudes from teachers, students, and parents remain barriers to the full participation of students with disabilities in science class. These various issues indicate that the implementation of inclusive education requires not only policy commitment but also concrete actions in teacher preparation, curriculum design, and school culture transformation.

As a branch of science, chemistry is abstract, conceptual, and experimental, requiring a high level of understanding from students. This challenges teachers to adapt materials and methods to be accessible to all students, including those with special needs (Ainscow, 2005; Zulfah & Yodi, 2021).Previous research (Kamaludin, 2015; Rosa, 2015; Sholahudin et al., 2024) shows a lack of adaptation of chemistry materials in an inclusive context. Teachers tend to use a homogeneous and results-oriented approach, which indirectly excludes students with diverse learning needs (Plomp & Nieveen, 2013; Rambuda, 2017). In fact, the national curriculum used in inclusive schools is the same as that used in regular schools (Dumbuya, 2024). Therefore, adapting the curriculum and learning strategies to become more responsive is an important step (Sharma et al., 2012). An ideal inclusive curriculum emphasizes flexibility in objectives, material presentation, and evaluation methods, while reducing barriers to participation (Florian & Black-Hawkins, 2011; Trisnani et al., 2024). Principles like *Universal Design for Learning* (UDL) and *Differentiated Instruction* (Tomlinson, 2001) serve as relevant guidelines, although the development of chemistry curricula specifically for students with disabilities remains very limited. This highlights an important research gap that design-based research needs to address. In practice, chemistry teachers in inclusive schools often modify laboratory experiments using simple household materials or incorporate visual aids, but documentation of these effective practices is still very limited. Moreover, limited professional development opportunities in inclusive pedagogy for science teachers further exacerbate the gap (Sharma & Loreman, 2019).

Pre-service chemistry teachers play a crucial role in addressing these challenges. They must master chemistry content and develop flexible, reflective, and inclusive teaching skills. However, studies reveal that teacher education programs mainly focus on general learning without adequately integrating inclusivity in science (Florian & Beaton, 2018). As a result, pre-service chemistry teachers are not yet fully prepared to create and implement inclusive learning

environments. This underscores the urgent need to incorporate an inclusive perspective into the curriculum systematically. Teacher competencies in pedagogical, professional, social, and personal areas are essential (Peraturan Pemerintah Nomor 19, 2005). In an inclusive classroom, pedagogical competence involves recognizing learning needs, designing differentiated instruction, and conducting adaptive assessments (Hattie, 2008). Meanwhile, professional competence includes mastering chemistry content, laboratory techniques, and visual representations (Farida, 2018). Without coordinated development in these areas, it will be challenging for all students to access chemistry education. At this point, the Educational Design Research (EDR) approach is particularly relevant as a framework for understanding conditions and developing practical solutions. In EDR, the exploration stage identifies the actual needs of pre-service teachers, the design stage creates prototypes of inclusive learning models, and the evaluation stage assesses the model's effectiveness using specific indicators. This cyclical process ensures that innovations are both theoretically sound and practically viable (McKenney & Reeves, 2012).

In this context, Charlotte Danielson's Framework for Teaching is a crucial tool for analyzing and designing solutions. It categorizes teacher competencies into four main domains: planning and preparation, classroom environment, instruction, and professional responsibility (Danielson et al., 2010). This framework is widely adopted internationally for teacher evaluation and professional development (Danielson, 2007a; Little, 2009). Compared to other frameworks like TPACK and DigCompEdu, the Danielson Framework is more comprehensive because it evaluates not only technological or digital skills but also the learning environment and professional responsibilities (Tomczyk & Fedeli, 2021). Therefore, this framework is relevant to the context of inclusive education in Indonesia because it addresses adaptive, social-emotional, interactive, and reflective dimensions (McGreal, 1983). In the EDR exploration phase, the Danielson Framework acts as a lens to identify the strengths and weaknesses of pre-service teachers; during the design phase, it guides the development of modules or strategies; and in the evaluation phase, indicators within the four domains are used to assess the success of the intervention.

Furthermore, the Danielson Framework can also serve as a foundation for developing teacher education curricula (Danielson, 2007b, 2008, 2013). Within the EDR framework, it functions as a lens for analysis during the exploration stage, a reference for design in the planning stage, and as evaluation criteria in the solution testing stage. However, research focused specifically on its application in inclusive chemistry education in Indonesia remains limited. Studies Lalupanda et al., (2019) and Iriani & Lelatobur, (2024) demonstrate the framework's effectiveness with active teachers but have not addressed the readiness of pre-service teachers. This readiness is crucial to integrating inclusive practices from the professional education stage. Therefore, this study aims to analyze pre-service chemistry teachers' needs and readiness and develop a foundation for an inclusive learning model based on the Danielson Framework. As a result, this research fills a gap in the literature and makes practical contributions to developing EDR-based models. The policy implications of this study include the need to adjust the chemistry Preservice Teacher Education Program (PPG) curriculum to emphasize inclusive skills, such as strengthening reflective practices, differentiated learning, and the integration of adaptive assessments. Additionally, the findings hold significant theoretical value by confirming the role of EDR in linking pedagogical theory with actual practice in inclusive classrooms, and practical importance by providing policy recommendations for teacher training programs in Indonesia and for international comparisons, such as with more advanced inclusion programs in Finland and Japan.

Based on the above background, the research problem is to identify the challenges faced by pre-service chemistry teachers in designing and implementing inclusive learning. It also aims to analyze their strengths and weaknesses in the four domains of Charlotte Danielson's

Framework for Teaching and to explain how these findings can serve as a basis for developing a model to enhance the competencies of prospective inclusive chemistry teachers through the EDR approach. The objectives of this study are to understand the actual challenges faced by pre-service chemistry teachers, explore their strengths and weaknesses within the four domains of the Danielson Framework, and develop a conceptual framework for an inclusive chemistry learning model. Therefore, this study not only describes the current conditions but also offers practical and relevant solutions for the chemistry teacher education curriculum. Theoretically, this research adds to the literature on applying EDR in inclusive chemistry education. Practically, it provides policy insights and recommendations for strengthening the Pendidikan Profesi Guru (PPG) curriculum and teacher training programs in Indonesia.

Based on the above background, the research centers on integrating Charlotte Danielson's Framework for Teaching (CDFT) within the Educational Design Research (EDR) approach to analyze and develop the competencies of pre-service chemistry teachers in inclusive education. Unlike previous studies that mainly used the Danielson Framework to evaluate in-service teachers, this study employs it as both an analytical tool and a design foundation during the exploration phase of EDR. It specifically emphasizes inclusive chemistry education, a field rarely examined, by addressing how the abstract and experimental nature of chemistry requires differentiated strategies and adaptive assessments. Additionally, this study offers empirical evidence through a validated FfT-based instrument and advanced statistical analyses to identify gaps in planning, instruction, and professional responsibility. Another key aspect of its systemic perspective reveals how structural limitations within Indonesia's *Pendidikan Profesi Guru* (PPG) curriculum hinder reflective and inclusive practices. Therefore, this research not only bridges a conceptual and empirical gap but also establishes a theoretical and policy foundation for designing future EDR cycles aimed at improving inclusive chemistry teacher education.

METHODS

This study employs an Educational Design Research (EDR) approach, positioned at the exploration phase, to investigate the needs and readiness of pre-service chemistry teachers in implementing inclusive learning. The EDR approach is appropriate because it bridges theory and practice by systematically identifying problems, designing solutions, and testing their feasibility in real contexts (McKenney & Reeves, 2012; Plomp & Nieveen, 2013).

Participants

The participants were 50 students from six state universities in Indonesia, recruited through convenience sampling. They were enrolled in chemistry education programs and represented diverse backgrounds in terms of gender, semester level, and prior experience with inclusive teaching. Participation was voluntary, and informed consent was obtained prior to data collection.

Instrument

Data were gathered using a Likert-scale questionnaire consisting of 22 items adapted from Charlotte Danielson's Framework for Teaching (FfT), covering four domains, namely planning and preparation, classroom environment, instruction, and professional responsibility. Each item was rated on a 5-point scale (1 = strongly disagree to 5 = strongly agree). The questionnaire was validated through expert judgment with senior chemistry education lecturers and inclusive education specialists, and further tested for content validity using the Content Validity Index (CVI). Reliability was measured using Cronbach's Alpha ($\alpha = 0.87$), and ordinal alpha was also calculated to account for the Likert scale's ordinal nature.

Data collection

Data were collected online from November 2024 to April 2025 through Google Forms (https://bit.ly/Mahasiswa_PPGKimia). The process adhered to research ethics principles,

including voluntary participation, confidentiality, and institutional ethical clearance obtained from the authors' university ethics board.

Data analysis

Data analysis involved several steps. *First*, descriptive statistics (mean, median, standard deviation, and interquartile range) were used to provide an overview of teacher readiness across domains and indicators. *Second*, normality tests (Shapiro–Wilk) were conducted to determine the distribution of responses. *Third*, non-parametric Mann–Whitney U tests were used to examine potential differences across groups (e.g., teaching experience and experience with students with disabilities). *Fourth*, ceiling and floor effects were analyzed by calculating the proportion of maximum and minimum scores per item. *Finally*, domain-level reliability indices were reported, and results were interpreted in relation to the Danielson Framework and the exploration stage of EDR. All data analysis were operationalized using JASP 0.19.3 software.

The findings from this methodological process were not only intended to describe the competencies of pre-service chemistry teachers but also to serve as a systematic needs assessment. This assessment provides a foundation for designing inclusive learning prototypes in the subsequent design phase of EDR, ensuring that any interventions are directly responsive to the strengths and weaknesses identified in this study.

RESULTS AND DISCUSSION

This section presents the results and critical discussion based on Charlotte Danielson's Framework for Teaching (CDFT) within the context of Educational Design Research (EDR). Instead of stopping at numerical descriptions, the analysis focuses on (i) interpreting data patterns (averages, distributions, and potential ceiling/floor effects), (ii) comparing domains to identify competency gaps, (iii) examining alternative explanations and measurement biases, and (iv) deriving design principles and policy implications that highlight the novelty of this study.

Descriptive statistics

Table 1 summarizes the descriptive statistics of the 22 indicators across the four domains. Overall, the highest mean scores were found in the domain of *Planning and Preparation* (M = 4.21, SD = 0.56), followed by *Classroom Environment* (M = 4.05, SD = 0.61), and *Instruction* (M = 3.98, SD = 0.67). The lowest scores appeared in *Professional Responsibility* (M = 3.52, SD = 0.84), with relatively higher dispersion compared to the other domains. Median and interquartile range (IQR) values confirmed these trends, showing consistency in central tendencies with variations in the PR domain.

Table 1. Descriptive Statistical Analysis Results

	Mean	Std. Deviation	Minimum	Maximum
PP1	4.200	0.990	1.000	5.000
PP2	4.420	0.810	1.000	5.000
PP3	4.380	0.901	1.000	5.000
PP4	4.520	0.814	1.000	5.000
PP5	4.160	0.792	2.000	5.000
PP6	4.060	0.913	2.000	5.000
CE1	3.960	0.856	2.000	5.000
CE2	3.820	0.873	2.000	5.000
CE3	4.180	0.850	1.000	5.000
CE4	4.280	0.834	1.000	5.000
CE5	3.700	0.789	2.000	5.000
I1	3.880	0.849	1.000	5.000
I2	3.960	0.856	1.000	5.000
I3	4.160	0.866	1.000	5.000

	Mean	Std. Deviation	Minimum	Maximum
I4	3.980	0.892	2.000	5.000
I5	3.940	0.793	2.000	5.000
PR1	4.100	0.886	1.000	5.000
PR2	3.720	0.809	1.000	5.000
PR3	3.580	0.810	2.000	5.000
PR4	3.580	1.214	1.000	5.000
PR5	3.680	0.891	1.000	5.000
PR6	3.380	1.028	1.000	5.000

Table 2. Descriptive Statistics of Pre-service Chemistry Teachers' Competencies Across Domains

Domain	Mean	Median	SD	IQR
Planning & Preparation (PP)	4.21	4.20	0.56	0.70
Classroom Environment (CE)	4.05	4.00	0.61	0.80
Instruction (I)	3.98	4.00	0.67	0.85
Professional Responsibility (PR)	3.52	3.50	0.84	1.05

Score Categories (Pimentel, 2010) are 1.00–1.50 very low; 1.51–2.50 low; 2.51–3.50 moderate; 3.51–4.50 high; 4.51–5.00 very high. Generally, the first three domains fall into the high category, while the Professional Responsibility domain is relatively lower and more varied (SD ≥ 1.0 in PR4 and PR6).

The results indicate that pre-service chemistry teachers demonstrate strong competencies in lesson planning and classroom management but face challenges in professional responsibility, particularly in reflective practices, collaboration, and ongoing professional development. These results provide critical input for the EDR process, especially in formulating design principles for inclusive teacher training modules.

Distribution tests

Normality testing using the Shapiro–Wilk test indicated that the data for most items were not normally distributed ($p < .05$), supporting the use of non-parametric statistics for further analysis.

Group comparisons

Table 3. Mann-Whitney Test Based on Teaching Experience

Independent Samples T-Test

	U	df	p
Domain 1	63.500		0.041
Domain 2	56.000		0.023
Domain 3	64.500		0.043
Domain 4	87.500		0.186

Note. Mann-Whitney U test.

Table 4. Mann-Whitney Test Based on Disability Interaction Experience

Independent Samples T-Test

	U	df	p
Domain 1	82.500		< .001
Domain 2	148.500		0.042
Domain 3	138.000		0.022
Domain 4	162.500		0.085

Note. Mann-Whitney U test.

The Mann–Whitney U test was applied to examine differences based on teaching experience and disability interaction experience. As shown in Table 3, significant differences were found across three domains when grouped by teaching experience: Planning and Preparation ($U = 63.50$, $p = .041$), Classroom Environment ($U = 56.00$, $p = .023$), and

Instruction (U = 64.50, p = .043). Only the Professional Responsibility domain did not show a significant difference (U = 87.50, p = .186). These results suggest that prior teaching experience is associated with higher readiness in lesson planning, classroom management, and instructional delivery, but not necessarily in professional responsibilities.

Similarly, Table 4 shows differences based on disability interaction experience. Significant differences were observed in Planning and Preparation (U = 82.50, p < .001), Classroom Environment (U = 148.50, p = .042), and Instruction (U = 138.00, p = .022), whereas Professional Responsibility was not significantly different (U = 162.50, p = .085). This pattern indicates that students with prior interaction with peers or learners with disabilities demonstrate stronger competencies in planning, managing inclusive environments, and delivering instruction. However, professional responsibility skills appear to require more structured institutional support rather than relying solely on individual experiences.

The Mann–Whitney U test, complemented with Cliff's δ effect sizes, revealed notable patterns across teaching experience and disability interaction experience.

Teaching experience (n = 44 with teaching experience; n = 6 without):

- Domain 1 (Planning & Preparation): δ = -0.52 (large effect)
- Domain 2 (Classroom Environment): δ = -0.58 (large effect)
- Domain 3 (Instruction): δ = -0.51 (large effect)
- Domain 4 (Professional Responsibility): δ = -0.34 (moderate effect)

Disability interaction experience (n = 13 with interaction; n = 37 without):

- Domain 1 (Planning & Preparation): δ = -0.66 (large effect)
- Domain 2 (Classroom Environment): δ = -0.38 (moderate effect)
- Domain 3 (Instruction): δ = -0.43 (moderate effect)
- Domain 4 (Professional Responsibility): δ = -0.32 (moderate effect)

For teaching experience, large negative effect sizes were observed in three domains, Planning and Preparation, Classroom Environment, and Instruction, while Professional Responsibility showed a moderate effect. The negative direction indicates that participants with no prior teaching experience reported higher self-perceived competencies in these domains compared to those with teaching experience. This paradoxical result may be explained by the tendency of inexperienced individuals to overestimate their abilities, while those with real classroom exposure may rate themselves more critically due to increased awareness of teaching challenges (Kruger & Dunning, 1999).

For disability interaction experience, a large negative effect was found in Planning and Preparation, with moderate effects in Classroom Environment, Instruction, and Professional Responsibility. Again, the negative direction suggests that participants without prior disability interaction perceived themselves as more competent than those with such experience. This counterintuitive finding supports previous studies showing that experiential exposure to disability contexts often lowers self-ratings, as students become more aware of the complexities of inclusive practice (Florian & Beaton, 2018; Sharma & Loreman, 2019).

These findings emphasize that group differences are not only statistically significant but also practically meaningful. The direction of effects underscores the importance of interpreting self-report data cautiously, higher self-perceived scores may not always reflect higher competence but can instead signal limited exposure and less calibrated self-awareness. For Educational Design Research (EDR), this highlights the need for interventions that simultaneously strengthen inclusive teaching skills and scaffold reflective calibration, enabling teacher candidates to develop both competence and accurate self-perceptions.

Ceiling and Floor Effects

Ceiling effects were detected in several items within the *Planning and Preparation* domain, where over 35% of participants selected the highest rating. This suggests limited discriminatory power of certain items in capturing higher-order planning competencies. In

contrast, floor effects were negligible, with less than 5% of participants consistently choosing the lowest response options. These findings are not just statistical artefacts but offer vital input for the EDR process. The presence of ceiling effects in Planning and Preparation underscores the need to refine measurement tools to better assess higher-order skills, while the lack of significant floor effects confirms that the tool remains appropriate for identifying baseline readiness. Therefore, analysing ceiling and floor effects directly guides both instrument improvement and curriculum development for inclusive chemistry teacher education.

Critical Analysis per Domain

Planning and Preparation (PP)

The high scores in this domain indicate that pre-service chemistry teachers are adept at resource utilization, but the relatively lower score in assessment design (PP6) signals a gap in adaptive assessment skills. Inclusive chemistry requires assessments that accommodate portfolios, demonstrations, and varied performance tasks. This aligns with Hattie (2023), who emphasizes evidence-based strategies and regular monitoring of progress. The potential ceiling effect in PP2–PP4 indicates that while basic competencies are achieved, advanced skills such as project-based and multirepresentational assessments remain underdeveloped. Prior research also notes that uniform assessment practices often mask disparities in higher-order skills (Järvelä & Hadwin, 2024; Taruna et al., 2025). For EDR, this highlights the need to design authentic assessment prototypes embedded within Pendidikan Profesi Guru (PPG) modules, such as collaborative performance-based tasks and differentiated rubrics. Without these, inclusive readiness in chemistry remains superficial.

Classroom Environment (CE)

The strengths in behavior management (CE4) contrast with the weakness in designing inclusive physical spaces (CE5). This gap suggests that while classroom management practices are established, accessibility issues in physical and laboratory spaces are still neglected. Literature (Jeannis et al., 2020; OECD, 2014) confirms that accessibility is central to science inclusion, while Florian & Black-Hawkins (2011) argue that environmental affordances significantly mediate participation. In the Indonesian context, studies Trisnani et al. (2024) highlight how limited infrastructural investment constrains the implementation of inclusive pedagogy. From an EDR lens, this implies that training modules should pair micro-level classroom management practices with macro-level accessibility audits, including laboratory SOPs and physical environment redesign. This dual strategy ensures that inclusive practice is not only behavioral but also structurally supported.

Instruction (I)

While engagement (I3) scored relatively high, instructional communication (I1) lags behind. Effective inclusive communication requires multimodal strategies (verbal, visual, kinesthetic) and scaffolded talk, supported by assistive technologies. Recent studies in inclusive science pedagogy emphasize multimodal explanations and scaffolded dialogue as essential for student participation with special needs (Hyytinen et al., 2023; Tan et al., 2024). Similarly, Florian & and Beaton (2018) argue that communication strategies are central to sustaining inclusive classrooms. For EDR, intervention designs should integrate structured multimodal communication practices, such as dual coding, guided notes, and simplified chemical representations, rather than mere pedagogical variation. Without embedding communication as a design principle, inclusive instruction risks becoming fragmented and inconsistent.

Professional Responsibility (PR)

This domain emerged as the gap, particularly in professionalism (PR6) and relationships with parents and community (PR4). The relatively low mean coupled with high variance suggests structural inequities in access to professional ecosystems such as mentoring, peer learning communities (PLCs), and opportunities for clinical reflection. Prior studies affirm that

reflective and professional dimensions are among the most underdeveloped in teacher preparation programs (UNESCO, 2024; Vangrieken et al., 2023). OECD (2014) emphasizes that collaborative professional learning is a strong predictor of long-term teacher effectiveness, while Ambarini et al. (2024) highlight the contribution of peer coaching in reducing competency gaps among pre-service teachers. Furthermore, Hyytinen et al. (2023) and Suriyanisa et al. (2024) found that unequal access to field practice and reflective mentoring significantly widens disparities in professional competence. These findings suggest that interventions should move beyond delivering content knowledge to embedding systemic support structures such as mentoring schemes, structured peer observation, reflective journals, and cross-campus PLCs, so that reflective and professional growth becomes a sustained and equitable component of pre-service teacher education.

Teacher Activity Implications

Building on the critical analysis per domain, several teaching activities can be proposed as prototypes within the EDR framework. In the *Planning and Preparation* domain, teacher candidates can be trained to design adaptive performance-based assessments, such as portfolio tasks from laboratory projects that allow multiple modes of expression (written reports, visual models, or oral presentations). For the *Classroom Environment* domain, activities can include accessibility audits of laboratory and classroom spaces, where students evaluate seating arrangements, laboratory benches, and safety procedures for learners with physical disabilities. Within the *Instruction* domain, candidates can practice multimodal communication strategies, for instance by delivering microteaching that combines dual coding (visual and verbal explanations), simplified chemical symbols, tactile molecular kits, and sign-supported video materials. Finally, for the *Professional Responsibility* domain, candidates can engage in peer-coaching lesson studies and maintain reflective journals documenting interactions with parents, mentors, and peers, thus embedding professional growth as a continuous practice. These activities exemplify how statistical findings can be translated into concrete learning designs that enhance inclusive readiness in pre-service chemistry teacher education.

Cross-domain analysis

The imbalance between strong technical domains (PP, CE, I) and weak reflective or professional domains (PR) reflects the current structure of PPG curricula in Indonesia, which emphasizes technical delivery while marginalising reflective practices. (UNESCO, 2024), Hyytinen et al. (2023), and Khairi & Nofrion (2024) similarly note gaps in reflective capacities across teacher education. These findings are in line with the research by Sumantri & Wibowo, (2023) which found that achievement motivation and learning activities contribute positively to the science learning outcomes of prospective primary school teachers. In the context of chemistry education, these results reinforce the importance of fostering intrinsic motivation and positive attitudes towards science as the basis for developing professional and inclusive competencies. The considerable variation in PR suggests systemic inequalities in access to field experiences and professional mentoring, consistent with Bland (2015) and Suriyanisa et al. (2024). Ceiling effects in PP further indicate the need for more sophisticated and authentic assessment items, as emphasised by Taruna et al. (2025) and Järvelä & Hadwin (2024). Finally, low CE5 scores are linked not only to teacher competence but also to infrastructural inequalities in partner schools, reaffirming OECD (2014) and Jeannis et al. (2020).

These findings illustrate how the PPG curriculum structurally privileges mastery of technical skills while offering minimal scaffolding for reflective practice and professional ecosystems. This imbalance not only limits teacher candidates' preparedness for inclusive classrooms but also perpetuates systemic inequities between institutions with strong mentoring cultures and those without. Reform efforts, therefore, need to move beyond isolated workshops and integrate reflective practice as a core curricular strand, supported by institutionalized PLCs, mentoring networks, and accessibility audits. Such systemic reforms would align PPG with

international best practices in inclusive teacher preparation (OECD, 2014; Vangrieken et al., 2023) and respond directly to Indonesia's policy agenda on strengthening teacher professionalism. Within the EDR framework, the cross-domain synthesis informs design principles that balance technical competence with reflective, collaborative, and infrastructural support, ensuring that future interventions are both contextually grounded and policy-relevant.

Synthesis and critique of the Danielson Framework

While the FfT provides comprehensive coverage of teaching competencies across four domains, its Western origins pose contextual challenges that require critical adaptation. Indicators such as community engagement are less congruent with Pendidikan Profesi Guru (PPG) realities in Indonesia, where institutional support and parental involvement differ significantly from Western contexts. Moreover, its reliance on observable behavior tends to overlook deeper teacher dispositions, critical reflection, and socio-cultural responsiveness, which are crucial for inclusive pedagogy (Florian & Beaton, 2018; Sharma et al., 2012). The ceiling effect in PP further exposes limitations, as generic indicators are less sensitive to advanced competencies needed in authentic, project-based chemistry instruction.

When compared with alternative frameworks, the differences become clearer. For example, TPACK focuses strongly on the integration of technological knowledge with pedagogy and content, yet it does not systematically address inclusive practices or professional responsibility. Similarly, DigCompEdu highlights digital competence but remains limited in evaluating classroom environment and reflective professionalism (Tomczyk & Fedeli, 2021). By contrast, FfT encompasses broader pedagogical, environmental, and professional domains, making it more holistic but also less attuned to local socio-cultural variations.

A critical stance therefore positions the Danielson Framework not as a prescriptive tool, but as an analytical lens that must be recalibrated through contextual validation and iterative refinement. Within EDR, combining FfT's structural clarity with the flexibility of design-based iteration allows the development of hybrid frameworks that incorporate insights from TPACK and DigCompEdu while remaining sensitive to inclusive priorities. In this way, teacher education research can generate design principles that are empirically grounded, locally responsive, and simultaneously contribute to international comparative discourse.

CONCLUSION

This study reveals that while pre-service chemistry teachers in Indonesia exhibit strong technical readiness in lesson planning, classroom management, and instructional delivery, their skills in adaptive assessment, multimodal communication, and professional responsibility remain underdeveloped. These gaps stem not only from individual limitations but also from structural imbalances within the *Pendidikan Profesi Guru* (PPG) curriculum, which emphasizes technical proficiency over reflective and inclusive practice. Through Charlotte Danielson's Framework for Teaching within the EDR approach, the study demonstrates the fragility of professional ecosystems and reflective capacity amid institutional inequalities.

To address these issues, PPG programs should embed reflective journals, mentoring-based supervision, adaptive assessments, and accessibility audits as integral components. Building sustainable professional learning communities, peer observation systems, and cross-campus mentoring networks is essential for equitable professional growth. Strengthening inclusive infrastructure and refining measurement instruments will further enhance readiness evaluation. Aligning these reforms with SDG 4 and global best practices ensures that future chemistry teachers become reflective, adaptive, and inclusive professionals.

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