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Development of A Science Education Program Framework Anchored on The Teaching Readiness of Pre-Service Teachers

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Abstract

This study developed a Science Education Program Framework anchored on the teaching readiness of Bachelor of Secondary Education major in Science pre-service teachers at North Eastern Mindanao State University. Using a quantitative descriptive-correlational design, the study surveyed 263 third year and fourth-year pre-service science teachers and analyzed the data through descriptive statistics and Partial Least Squares Structural Equation Modeling. Teaching readiness was examined across six domains: Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation. Results showed that the respondents were highly ready across all six domains, with Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Pedagogical Content Knowledge obtaining the highest mean scores. The measurement model demonstrated acceptable reliability and convergent validity, while discriminant validity results indicated empirical overlap among several pedagogical domains, supporting the treatment of teaching readiness as an integrated higher-order construct. Structural model results revealed that all six domains significantly contributed to Overall Teaching Readiness, with Pedagogical Content Knowledge and Ethical, Social-Responsive, and Community Collaboration emerging as the strongest contributors. The model also demonstrated acceptable fit, as indicated by SRMR = 0.06. Based on these findings, the proposed Science Education Program Framework positions science content application as the foundation, core pedagogy and ethical responsiveness as the central instructional engine, and inquiry, research, technology, and innovation as advanced professional catalysts. The study provides an empirical basis for strengthening curriculum design, practicum preparation, mentoring, and quality assurance in pre-service science teacher education.

Keywords: PLS-SEM, Pre-Service Teachers, Program Framework, Science Education, Science Teaching Readiness, Teacher Education

1. Introduction

Science teacher education continues to face intensified expectations as schools respond to rapid curricular reforms, technological transformation, learner diversity, and the growing demand for inquiry-based and evidence-informed science instruction. Contemporary science teachers are expected not only to possess adequate content knowledge but also to translate scientific concepts into meaningful learning experiences, design assessment-responsive instruction, facilitate inquiry, integrate digital technologies, and engage learners ethically and inclusively. Recent scholarship affirms that pre-service teacher preparation must move beyond knowledge transmission toward integrated professional competence, where content, pedagogy, assessment, technology, research orientation, and socio-emotional responsiveness function together in classroom practice (Backfisch et al., 2024; Gotwals & Cisterna, 2022; Großmann & Krüger, 2024). This is particularly relevant in science education, where teachers must help learners understand abstract concepts, conduct evidence-based reasoning, apply scientific inquiry, and connect science learning to real-world problems.

Teaching readiness is therefore best understood as a multidimensional construct. It includes mastery of science content, the ability to apply content to authentic teaching contexts, readiness to facilitate scientific inquiry, competence in lesson design and assessment, pedagogical content knowledge, ethical and community-responsive engagement, and purposeful technology integration. Studies on pre-service science teachers show that pedagogical content knowledge remains central to effective teaching because it allows teachers to anticipate student misconceptions, select appropriate representations, and transform subject matter into learnable classroom experiences (Koberstein-Schwarz & Meisert, 2022; Oztay & Boz, 2022). Similarly, lesson planning and assessment competence are strongly associated with instructional quality because effective teachers must align objectives, learning activities, assessment evidence, and feedback mechanisms in coherent ways (Gotwals & Cisterna, 2022; Großmann & Krüger, 2024). These findings indicate that readiness cannot be reduced to content mastery alone; rather, it requires the coordinated development of professional capabilities that enable pre-service teachers to plan, teach, assess, and adapt instruction.

The increasing emphasis on inquiry-based science education further strengthens the need to examine teaching readiness among pre-service science teachers. Inquiry-based science teaching requires teachers to guide learners in asking questions, investigating phenomena, interpreting evidence, and constructing explanations. However, recent research indicates that inquiry teaching readiness depends not only on confidence in conducting classroom inquiry but also on teachers' understanding of the nature of scientific inquiry and their ability to facilitate inquiry processes in authentic learning environments (Toma et al., 2025). Related studies also show that pre-service teachers benefit when they engage in inquiry-oriented school placements, practitioner research, and reflective teaching communities because these experiences help them connect theory, assessment, and classroom decision-making (Moura et al., 2024). This suggests that teacher education programs must provide deliberate preparation in inquiry facilitation and research-based teaching rather than assuming that pre-service teachers will automatically acquire such competence during practicum exposure.

Technology integration has also become a central component of science teaching readiness. The post-digital classroom requires teachers to use technology not merely as presentation support but as a tool for simulation, visualization, collaboration, assessment, experimentation, and differentiated learning. Recent evidence shows that targeted interventions can strengthen pre-service teachers' technological pedagogical content knowledge, particularly when technology use is connected to pedagogical purpose and subject-matter learning (Backfisch et al., 2024). Studies on pedagogical makerspaces and virtual reality acceptance similarly indicate that pre-service science teachers become more ready to use digital tools when they experience hands-on, design-oriented, and well-supported learning environments (Max et al., 2023; Thohir et al., 2023). These findings are important because technology readiness does not automatically emerge from general digital familiarity. Pre-service teachers may be personally comfortable with digital tools but still lack the professional capacity to integrate them meaningfully into science instruction.

Another important dimension of teaching readiness involves ethical, social-responsive, and community collaboration competence. Current international education discourse emphasizes that teachers must support not only cognitive learning but also learners' social, emotional, ethical, and civic development. UNESCO (2024) describes social and emotional learning as a process through which learners acquire competencies for managing emotions, building positive relationships, making responsible decisions, and responding constructively to challenging situations. The OECD likewise links social and emotional skills to academic success, well-being, employability, active citizenship, and healthier life outcomes (OECD, 2024a, 2024b). In teacher education, this implies that readiness must include the capacity to build inclusive classroom environments, collaborate with communities, respond to diverse learner needs, and exercise professional responsibility. Research on pre-service teachers supports this view, showing that university climate, preparation programs, and practicum experiences influence student teachers' social-emotional competence and professional development (Tsybulsky & Muchnik-Rozanov, 2021; Wu et al., 2023).

Despite the expanding body of literature on teacher readiness, several gaps remain. First, many studies examine only one dimension of readiness, such as pedagogical content knowledge, assessment literacy, inquiry teaching, technology integration, or social-emotional competence. While these studies provide valuable insights, they often treat readiness domains as separate competencies rather than as interrelated components of an integrated professional readiness system. Second, there is limited empirical work that validates teaching readiness as a higher-order construct using structural equation modeling, particularly in science teacher education. This is a methodological gap because teacher education programs need evidence not only on whether pre-service teachers are "ready" in a descriptive sense, but also on which domains most strongly define or predict overall teaching readiness. Third, there remains a contextual gap in the Philippine higher education setting, particularly in state universities preparing Bachelor of Secondary Education major in Science students for classroom practice. Local program improvement requires institution-specific evidence that can guide curriculum strengthening, practicum support, mentoring, and assessment systems.

Addressing these gaps is necessary because science teacher education programs must produce graduates who can perform in complex, technology-mediated, inquiry-oriented, and socially diverse classrooms. A validated readiness model can help teacher education institutions identify strengths and developmental needs across essential readiness domains. It can also provide empirical justification for designing a program framework that is not based merely on assumptions or isolated competency standards but on the actual readiness profile of pre-service science teachers. In the context of North Eastern Mindanao State University, such evidence is particularly useful for strengthening the Bachelor of Secondary Education major in Science program by identifying which competencies should serve as foundational, which should be reinforced as core pedagogical capacities, and which should be advanced as professional catalysts for 21st-century science teaching.

Hence, this study aimed to develop a Science Education Program Framework anchored on the teaching readiness of BSEd Science pre-service teachers. Specifically, it examined teaching readiness across six domains: Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation. Using Partial Least Squares Structural Equation Modeling, the study sought to validate whether these domains operate as interrelated components of Overall Teaching Readiness and to determine their contribution to the proposed framework.

Through this approach, the study contributes to science teacher education by providing an empirically grounded framework that can inform curriculum enhancement, practicum design, faculty mentoring, and institutional quality assurance in pre-service science teacher preparation.

Theoretical Framework

This study is anchored on Shulman's Pedagogical Content Knowledge theory and the Technological Pedagogical Content Knowledge framework. Shulman's theory explains that effective teaching depends not only on mastery of subject matter but also on the teacher's ability to transform content into forms that learners can understand. This supports the inclusion of Science Content and Application, Pedagogical Content Knowledge, and Learning Design and Assessment as core dimensions of teaching readiness. Meanwhile, the TPACK framework extends this view by emphasizing the integrated use of content, pedagogy, and technology in meaningful instruction, thereby supporting the inclusion of Technology and Innovation as a readiness domain (Mishra & Koehler, 2006; Shulman, 1986). The study is also informed by inquiry-based science education and teacher competence perspectives, which view teaching readiness as a developmental and multidimensional construct. Inquiry-based science education emphasizes teachers' capacity to guide learners in questioning, investigating, interpreting evidence, and constructing scientific explanations. Teacher competence models further suggest that professional readiness includes knowledge, skills, beliefs, judgment, and context-responsive action. Thus, in this study, teaching readiness is conceptualized as an integrated higher-order construct composed of six interrelated domains: Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation.

Conceptual Framework

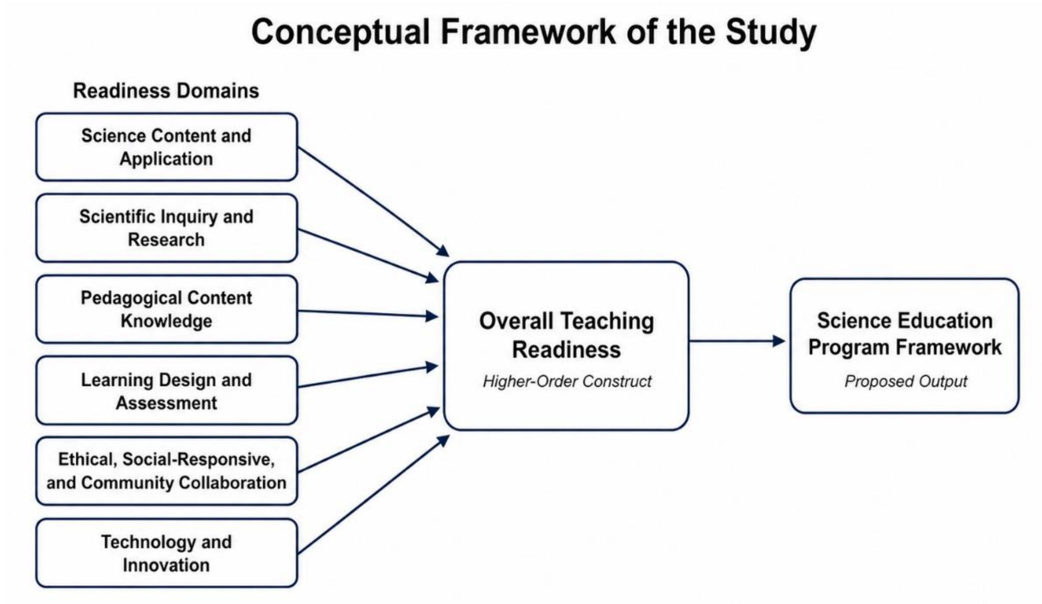

Figure 1. Conceptual Framework of the Study

Figure 1 presents the conceptual framework of the study, showing how the six readiness domains serve as predictors of Overall Teaching Readiness among BSEd Science pre-service teachers. These domains include Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation. Overall Teaching Readiness is treated as a higher-order construct that integrates these six domains. The framework further shows that the validated readiness structure serves as the empirical basis for developing the proposed Science Education Program Framework.

Aim of the Study

This study aimed to develop a Science Education Program Framework anchored on the teaching readiness of Bachelor of Secondary Education major in Science pre-service teachers at North Eastern Mindanao State University.

Statement of the Problem

This study sought to develop a Science Education Program Framework anchored on the teaching readiness of pre-service science teachers. Specifically, it answered the following questions:

1. What is the level of teaching readiness of BSEd Science pre-service teachers in terms of:

1.1. Science Content and Application;
1.2. Scientific Inquiry and Research;
1.3. Pedagogical Content Knowledge;
1.4. Learning Design and Assessment;
1.5. Ethical, Social-Responsive, and Community Collaboration; and
1.6. Technology and Innovation?

2. What is the reliability and validity of the teaching readiness measurement model in terms of:

2.1. indicator reliability;
2.2. internal consistency reliability;
2.3. convergent validity; and
2.4. discriminant validity?

3. What are the structural relationships between the six readiness domains and Overall Teaching Readiness?
4. Which readiness domains significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers?
5. What Science Education Program Framework may be developed based on the empirical findings of the study?

Hypotheses of the Study

The following null hypotheses were tested in the study:

H_{01}: Science Content and Application Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.
H_{02}: Scientific Inquiry and Research Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.
H_{03}: Pedagogical Content Knowledge Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.
H_{04}: Learning Design and Assessment Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.
H_{05}: Ethical, Social-Responsive, and Community Collaboration Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.
H_{06}: Technology and Innovation Readiness does not significantly contribute to Overall Teaching Readiness among BSEd Science pre-service teachers.

2. Literature Review

Teaching readiness in science education has increasingly been conceptualized as an integrated professional capability rather than a single measure of subject-matter knowledge or practicum exposure. Contemporary studies show that pre-service science teachers need to demonstrate competence in content application, inquiry facilitation, pedagogical decision-making, lesson design, assessment, ethical responsiveness, collaboration, and technology integration. These domains do not operate independently in actual classroom practice. Instead, they interact as mutually reinforcing components of professional readiness. This synthesis is directly relevant to the present study, which examines whether six readiness domains collectively define Overall Teaching Readiness among BSEd Science pre-service teachers and whether these domains can serve as the empirical basis for a Science Education Program Framework.

Science Content and Application Readiness

Science content knowledge remains a necessary foundation of teaching readiness because teachers cannot design meaningful learning experiences without an adequate grasp of the concepts, processes, and applications of science. However, recent literature suggests that content knowledge becomes educationally useful only when pre-service teachers can translate it into teachable representations, activities, explanations, and classroom tasks. Whittington and Tekkumru-Kisa (2020) found that pre-service science teachers' task selection often reflects the depth of their understanding of science content and their ability to recognize learning opportunities within instructional materials. Their findings imply that readiness is not simply demonstrated by knowing scientific facts but by choosing and adapting tasks that can promote conceptual understanding and higher-order thinking.

This position is reinforced by studies that connect content knowledge with teaching application. Oztay and Boz (2022) showed that pre-service chemistry teachers' pedagogical content knowledge interacted with their content knowledge when teaching electrochemistry, suggesting that the ability to teach complex science concepts depends on both conceptual mastery and pedagogical transformation. Similarly, Mataka and Taibu (2025) reported that pre-service teachers became more prepared to teach science through blended experiences that integrated science content with inquiry-oriented methods. These findings support the present study's inclusion of Science Content and Application Readiness as a distinct domain. In the current framework, content readiness is treated not as an isolated academic variable but as the foundational substrate from which inquiry, pedagogy, assessment, and technology-supported instruction can develop.

Scientific Inquiry and Research Readiness

Scientific inquiry and research readiness is central to science teacher preparation because science teaching requires learners to ask questions, examine evidence, construct explanations, and apply reasoning to natural phenomena. Inquiry-based science teaching therefore demands more than general teaching confidence. It requires teachers to understand the nature of scientific inquiry and to manage classroom experiences where learners engage in investigation, interpretation, and evidence-based argumentation. Toma et al. (2025) emphasized that inquiry teaching self-efficacy must include both confidence in inquiry facilitation and epistemological understanding of scientific inquiry. This is significant because pre-service teachers may express confidence in using inquiry-based activities while still lacking the deeper capacity to guide students through authentic scientific reasoning.

Empirical work on school placement and practitioner research further shows that inquiry readiness develops through structured professional experience. Moura et al. (2024) found that when pre-service teachers engaged in practitioner research during school placement, they strengthened their enactment of assessment-for-learning principles and became more capable of connecting classroom evidence with instructional decisions. Pondee et al. (2021) similarly demonstrated that mobile game-based inquiry learning supported pre-service science teachers' technological pedagogical content knowledge, showing that inquiry readiness can be enhanced when investigation, pedagogy, and technology are integrated. These studies are directly linked to the present investigation because Scientific Inquiry and Research Readiness is one of the six domains tested as a contributor to Overall Teaching Readiness. The literature suggests that this domain should not be treated as a peripheral skill but as a specialized competence that enables pre-service science teachers to move from content delivery toward evidence-based and student-centered science teaching.

Pedagogical Content Knowledge Readiness

Pedagogical Content Knowledge remains one of the strongest theoretical and empirical anchors of science teaching readiness. PCK refers to the teacher's capacity to transform subject matter into forms that are understandable to learners, including the use of representations, examples, analogies, questions, explanations, and strategies responsive to student misconceptions. Recent studies indicate that PCK is especially important in science education because science concepts are often abstract, cumulative, and prone to misunderstanding. Oztay and Boz (2022) showed that pre-service chemistry teachers' PCK was deeply connected to how they understood and taught electrochemistry, indicating that content knowledge alone was insufficient for effective instructional enactment. Koberstein-Schwarz and Meisert (2022) similarly found that material-based lesson planning can reveal and support the development of pre-service biology teachers' PCK, particularly when teachers are required to connect topic-specific content with instructional decisions.

The relevance of PCK to the present study is substantial. Since the study aims to determine how readiness domains predict Overall Teaching Readiness, PCK serves as the conceptual bridge between knowing science and teaching science. It links Science Content and Application with Learning Design and Assessment because teachers must select content, anticipate learning barriers, design activities, and assess student understanding. Hartmuth et al. (2025) further emphasized that science teachers' enacted PCK can be strengthened through the integration of student feedback, suggesting that PCK develops when pre-service teachers learn to interpret student responses and refine instructional decisions. Thus, the present study's treatment of Pedagogical Content Knowledge Readiness as a major domain is consistent with the broader literature that positions PCK as a central determinant of science teaching competence.

Learning Design and Assessment Readiness

Learning design and assessment readiness concerns the capacity of pre-service teachers to plan coherent lessons, align objectives with learning activities, select appropriate materials, and use assessment evidence to improve instruction. Recent research suggests that lesson planning and assessment should not be treated as mechanical procedures but as reflective, adaptive, and evidence-informed professional practices. Karlström and Hamza (2021) argued that pre-service teachers need to understand planning as a complex and iterative process rather than a fixed sequence of steps. This means that readiness in lesson design involves professional judgment, responsiveness to learners, and the ability to modify instruction based on classroom evidence.

Assessment literacy is similarly important because science teachers must determine whether students understand concepts, can apply inquiry skills, and can explain scientific relationships. Gotwals and Cisterna (2022) proposed formative assessment practice progressions for teacher preparation, arguing that formative assessment should be developed as an integral part of teaching practice rather than as a separate technical skill. Großmann and Krüger (2024) also developed and validated a rubric for assessing science lesson-plan quality, emphasizing the need for transparent criteria when evaluating teachers' planning competence. These studies support the present study's inclusion of Learning Design and Assessment Readiness as a core domain. In the current framework, this domain is expected to connect strongly with PCK and content application because effective lesson design requires teachers to transform science content into assessable and learner-centered experiences.

Ethical, Social-Responsive, and Community Collaboration Readiness

The literature on teacher readiness increasingly recognizes that effective teaching requires ethical judgment, social responsiveness, and collaborative competence. Science teachers work with learners from diverse backgrounds and must create inclusive learning environments where students feel respected, supported, and able to participate in scientific learning. Wu et al. (2023) found that university climate and pre-service preparation influence student teachers' social-emotional competence, indicating that teacher readiness is shaped by the broader preparation environment and not only by coursework. Tsybulsky and Muchnik-Rozanov (2021) also showed that emotional experiences during project-based pedagogical practicum contributed to the development of pre-service science teachers' competencies, suggesting that emotional and relational dimensions are embedded in professional learning.

This body of literature supports the present study's inclusion of Ethical, Social-Responsive, and Community Collaboration Readiness. In science education, ethical and collaborative competence is relevant not only to classroom management but also to the social purposes of science teaching. Teachers must help learners engage with environmental issues, health concerns, technological risks, sustainability problems, and community-based applications of science. Therefore, social-responsive readiness broadens the meaning of science teaching from content delivery to responsible participation in society. In the present study, this domain is treated as part of

Overall Teaching Readiness because pre-service science teachers must be prepared to connect science learning with learners' lived contexts, institutional expectations, and community needs.

Technology and Innovation Readiness

Technology and innovation readiness has become indispensable in science teacher education because digital tools now support simulation, visualization, data collection, collaborative learning, formative assessment, and inquiry-based experimentation. However, the literature consistently cautions that digital familiarity does not automatically produce pedagogically effective technology integration. Backfisch et al. (2024) showed that utility-value interventions can support pre-service teachers' technological pedagogical content knowledge, particularly when technology use is connected to meaningful instructional purposes. This finding suggests that readiness for technology integration requires the coordination of technological, pedagogical, and content knowledge rather than isolated tool competence.

Other studies reinforce the same argument. Max et al. (2023) found that pedagogical makerspaces can support the development of pre-service science teachers' TPACK by giving them opportunities to design, test, and reflect on technology-supported learning experiences. Thohir et al. (2023) demonstrated that pre-service teachers' acceptance of virtual reality in science education was influenced by TPACK and facility conditions, showing that readiness depends on both individual competence and institutional support. Pondee et al. (2021) also found that mobile game-based inquiry learning contributed to pre-service science teachers' emerging pedagogy of technology integration. These findings justify the present study's Technology and Innovation Readiness domain. Within the proposed framework, technology readiness functions not as a substitute for content or pedagogy but as an advanced professional catalyst that can strengthen inquiry, visualization, assessment, and learner engagement when properly integrated.

Interrelationships Among Readiness Domains

A major implication of the reviewed literature is that the domains of teaching readiness are conceptually distinct but practically interconnected. Content knowledge influences PCK because teachers need to understand science before they can transform it pedagogically. PCK influences lesson design because teachers must select representations, tasks, and assessments that fit the content and the learners. Inquiry readiness depends on content, pedagogy, assessment, and classroom facilitation. Technology readiness becomes meaningful only when digital tools are aligned with pedagogical intentions and science learning goals. Ethical and community-responsive readiness shapes the way teachers design inclusive tasks, interact with learners, and connect science to social contexts. Thus, the literature supports the present study's assumption that readiness domains should be examined together rather than separately.

This integrated view is consistent with the methodological direction of the present study. By using Partial Least Squares Structural Equation Modeling, the study moves beyond descriptive assessment and examines how six readiness domains collectively contribute to Overall Teaching Readiness. This is important because previous studies often focus on one domain at a time, such as inquiry self-efficacy, PCK, lesson planning, assessment literacy, technology readiness, or social-emotional competence. Although such studies are valuable, they provide limited evidence for program-level decision-making because they do not show how multiple domains operate simultaneously within a coherent readiness structure. The present study addresses this limitation by testing teaching readiness as a higher-order construct and by using the results as the empirical basis for developing a Science Education Program Framework.

Synthesis and Research Gap

The reviewed studies collectively establish that science teaching readiness is multidimensional, developmental, and context-dependent. Science Content and Application provides the conceptual foundation for teaching.

Scientific Inquiry and Research enables teachers to facilitate evidence-based learning. Pedagogical Content Knowledge transforms content into teachable forms. Learning Design and Assessment structures instruction and monitors learning. Ethical, Social-Responsive, and Community Collaboration Readiness situates teaching within inclusive and socially meaningful contexts. Technology and Innovation Readiness supports 21st-century science instruction through digital and design-based tools. Taken together, these domains form a coherent professional readiness system.

However, the literature also reveals important gaps. First, many studies examine readiness domains separately, which limits understanding of how these competencies interact within the overall professional preparation of pre-service science teachers. Second, there is limited use of higher-order structural models to validate teaching readiness as an integrated construct in science teacher education. Third, there remains a need for context-specific evidence from Philippine teacher education institutions, particularly state universities preparing BSEd Science students for classroom practice. The present study responds to these gaps by examining six readiness domains among pre-service science teachers and by using PLS-SEM to determine their contribution to Overall Teaching Readiness. In doing so, the study provides a data-driven basis for a Science Education Program Framework that can guide curriculum enhancement, practicum design, mentoring, and institutional quality assurance.

3. Methodology

Research Design

This study employed a quantitative descriptive-correlational research design using Partial Least Squares Structural Equation Modeling (PLS-SEM). The descriptive component was used to determine the level of teaching readiness of pre-service science teachers across the six identified domains: Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation. The correlational and structural modeling components were used to examine the relationships among these domains and determine their contribution to Overall Teaching Readiness as a higher-order construct.

A cross-sectional survey approach was also used because data were collected from the respondents at a single point in time during the academic year 2025–2026. This design was appropriate for the study because the primary objective was to describe the readiness profile of Bachelor of Secondary Education major in Science pre-service teachers and empirically validate a proposed readiness structure that could serve as the basis for developing a Science Education Program Framework. The use of PLS-SEM was appropriate because the study aimed to assess both the measurement properties of the readiness constructs and the predictive relationships among latent variables within the proposed model.

Research Locale

The study was conducted at selected campuses of North Eastern Mindanao State University. The locale was appropriate because the university offers Bachelor of Secondary Education major in Science and prepares pre-service teachers for future teaching practice in basic education. The institutional setting provided a relevant context for examining science teaching readiness because the respondents had been exposed to science content courses, professional education courses, research-related subjects, assessment training, technology-supported instruction, and field-based learning experiences.

Participants of the Study

The respondents of the study were officially enrolled third-year and fourth-year Bachelor of Secondary Education major in Science students from the selected campuses of North Eastern Mindanao State University during the academic year 2025–2026. These year levels were selected because the students had already completed substantial coursework in science content, pedagogy, assessment, research, and professional education. Their academic progression made them suitable respondents for assessing perceived teaching readiness before full professional entry into classroom teaching.

The study initially targeted all 275 eligible third-year and fourth-year BSEd Science students through total enumeration. Total enumeration was used because the target population was manageable and because the study sought to obtain a comprehensive readiness profile of the accessible population. However, due to non-response, schedule constraints, and respondent availability, 263 students participated as actual respondents. Thus, the final sample consisted of the accessible and consenting members of the target population.

Research Instrument

The primary data-gathering instrument was a researcher-made survey questionnaire designed to measure the teaching readiness of BSEd Science pre-service teachers. The instrument was structured according to the six domains of the study: Science Content and Application Readiness, Scientific Inquiry and Research Readiness, Pedagogical Content Knowledge Readiness, Learning Design and Assessment Readiness, Ethical, Social-Responsive, and Community Collaboration Readiness, and Technology and Innovation Readiness.

The items were developed based on relevant literature, the objectives of the study, national competency expectations for teacher education, and institutional directions for science teacher preparation. The items were written as behavioral capability statements to capture respondents' self-perceived readiness in relation to science teaching. Each domain contained indicators that reflected the knowledge, skills, dispositions, and professional capacities expected of pre-service science teachers.

The questionnaire used a five-point Likert scale. Responses were interpreted using the following scale: 4.21–5.00, Strongly Agree or Highly Ready; 3.41–4.20, Agree or Ready; 2.61–3.40, Neutral or Moderately Ready; 1.81–2.60, Disagree or Slightly Ready; and 1.00–1.80, Strongly Disagree or Not Ready. This scale was appropriate because the items were framed as self-perceived capability statements, where higher agreement indicated higher perceived teaching readiness.

Validity and Reliability of the Instrument

To establish content validity, the initial version of the questionnaire was reviewed by experts in science education, teacher education, and research. The validators examined the clarity, relevance, construct alignment, and appropriateness of the items in relation to the six readiness domains. Their comments and recommendations were incorporated to improve the wording, coverage, and coherence of the instrument.

A pilot test was conducted among respondents who were not included in the actual study. The pilot testing helped determine whether the items were understandable, relevant, and appropriate for the target respondents. Internal consistency reliability was assessed using Cronbach's alpha and composite reliability. In the PLS-SEM measurement model, indicator reliability was examined through standardized outer loadings, convergent validity was assessed using Average Variance Extracted, and discriminant validity was examined using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio. These procedures ensured that the instrument demonstrated acceptable reliability and validity before its results were used as the basis for the proposed framework.

Data Collection Procedure

The data collection procedure was conducted in several stages to ensure proper coordination, methodological rigor, and ethical compliance.

First, the researcher developed the survey questionnaire based on the identified readiness domains, relevant literature, competency expectations, and the objectives of the study. The draft instrument was submitted for expert validation, and the comments of the validators were used to refine the items. A pilot test was then conducted to determine the clarity and reliability of the instrument before actual administration.

Second, the researcher secured the necessary institutional permissions. A formal request was submitted to the university administration to obtain approval to conduct the study. Coordination was also made with the concerned campus administrators, college deans, program chairs, and faculty members to access the target respondents and determine the appropriate schedule and mode of survey administration.

Third, the finalized questionnaire was administered to the respondents using a hybrid approach. Some questionnaires were administered face-to-face, while others were distributed online through Google Forms. This approach allowed the researcher to accommodate the availability of respondents across selected campuses and improve participation.

Fourth, before answering the questionnaire, the respondents were informed of the purpose of the study, the voluntary nature of their participation, the confidentiality of their responses, and their right to withdraw at any point without penalty. Informed consent was obtained before respondents proceeded with the survey.
Finally, the completed questionnaires were collected, encoded, and consolidated into a single dataset. The data were screened for missing values, inconsistent responses, and possible outliers. Data-cleaning procedures were conducted before the final dataset was subjected to descriptive analysis and PLS-SEM.

Data Analysis

The quantitative data were analyzed using descriptive statistics and Partial Least Squares Structural Equation Modeling through SmartPLS.

For the descriptive analysis, means and standard deviations were computed to determine the level of teaching readiness of the respondents across the six domains. The mean scores were interpreted using the established five-point readiness scale. This analysis provided the baseline profile of the respondents' perceived readiness in science teaching.

For the measurement model assessment, the reliability and validity of the constructs were examined. Indicator reliability was assessed using standardized outer loadings. Internal consistency reliability was evaluated using Cronbach's alpha and composite reliability. Convergent validity was assessed using Average Variance Extracted, while discriminant validity was examined using the Fornell–Larcker criterion and the Heterotrait–Monotrait ratio. These procedures determined whether the indicators adequately measured their respective readiness domains.

For the structural model assessment, path coefficients, t-values, and p-values were examined to determine the direct contribution of each readiness domain to Overall Teaching Readiness. The analysis assessed the extent to which Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation predicted teaching readiness as a higher-order construct. The coefficient of determination was also considered to determine the explanatory power of the model. Model adequacy was assessed using the Standardized Root Mean Square Residual as a model-fit indicator within the PLS-SEM approach.

The findings from the descriptive analysis and the structural model served as the empirical basis for developing the proposed Science Education Program Framework anchored on the teaching readiness of pre-service science teachers.

Ethical Considerations

The study observed ethical research standards and complied with the principles of voluntary participation, informed consent, confidentiality, anonymity, and responsible data handling. The respondents were informed about the nature and purpose of the study before their participation. They were also informed that participation was voluntary and that they could decline or withdraw from the study at any time without penalty.

No personally identifying information, such as full names or student numbers, was reported in the study. The collected data were used solely for academic and institutional improvement purposes. Digital files were password-protected, while printed materials were kept in a secure location accessible only to the researcher. Results were reported in aggregate form to protect the identity and privacy of the respondents. The study also observed the provisions of the Philippine Data Privacy Act of 2012 in the handling, storage, and reporting of research data.

4. Results and Discussion

Table 1. Level of Teaching Readiness of BSEd Science Pre-Service Teachers

Readiness Domain	Mean	SD	Interpretation
Science Content and Application	4.480	0.600	Highly Ready
Scientific Inquiry and Research	4.354	0.618	Highly Ready
Pedagogical Content Knowledge	4.592	0.610	Highly Ready
Learning Design and Assessment	4.613	0.575	Highly Ready
Ethical, Social-Responsive, and Community Collaboration	4.612	0.578	Highly Ready
Technology and Innovation	4.452	0.591	Highly Ready

Legend: 4.21–5.00 = Highly Ready; 3.41–4.20 = Ready; 2.61–3.40 = Moderately Ready; 1.81–2.60 = Slightly Ready; 1.00–1.80 = Not Ready.

As shown in **Table 1**, the BSEd Science pre-service teachers reported a highly ready level of teaching readiness across all six domains. The highest mean was obtained by Learning Design and Assessment (M = 4.613, SD = 0.575), followed closely by Ethical, Social-Responsive, and Community Collaboration (M = 4.612, SD = 0.578) and Pedagogical Content Knowledge (M = 4.592, SD = 0.610). These results indicate that the respondents perceived themselves as particularly prepared in designing lessons, aligning learning objectives, planning assessment procedures, demonstrating pedagogical understanding, and responding to ethical and community-based teaching responsibilities.

Science Content and Application also obtained a high rating (M = 4.480, SD = 0.600), suggesting that respondents perceived themselves as capable of applying science concepts in teaching contexts. Technology and Innovation (M = 4.452, SD = 0.591) and Scientific Inquiry and Research (M = 4.354, SD = 0.618) also received highly ready interpretations, although these were the two lowest-rated domains. This pattern suggests that while respondents generally demonstrated strong perceived readiness, their confidence was relatively lower in areas requiring advanced inquiry facilitation, research-based teaching, and purposeful technology integration.

The findings imply that the respondents had a strong baseline of teaching readiness. However, the slight variation among domains shows that readiness is not uniform across all areas. The stronger ratings in learning design, assessment, ethical responsiveness, and pedagogical content knowledge suggest that the teacher education program has effectively developed core pedagogical competencies. Meanwhile, the relatively lower ratings in scientific inquiry and technology indicate areas that may require further strengthening, especially because contemporary science teaching increasingly requires evidence-based inquiry, research orientation, and technology-supported instruction.

Table 2. Measurement Model Results

Construct / Indicator	Outer Loading	AVE	CR	Cronbach's Alpha
Science Content and Application Readiness		0.63	0.91	0.88
SCA 1	0.81			
SCA 2	0.82			
SCA 3	0.75			
SCA 4	0.79			
SCA 5	0.87			
SCA 6	0.71			
Scientific Inquiry and Research Readiness		0.65	0.92	0.89
SIR 1	0.82			
SIR 2	0.80			
SIR 3	0.85			
SIR 4	0.78			
SIR 5	0.82			
SIR 6	0.76			
Pedagogical Content Knowledge Readiness		0.67	0.93	0.91
PCK 1	0.82			
PCK 2	0.80			
PCK 3	0.83			
PCK 4	0.77			
PCK 5	0.90			
PCK 6	0.83			
Learning Design and Assessment Readiness		0.79	0.95	0.93
LDA 1	0.91			
LDA 2	0.85			
LDA 3	0.91			
LDA 4	0.87			
LDA 5	0.90			
LDA 6	0.88			
Ethical, Social-Responsive, and Community Collaboration Readiness		0.56	0.86	0.80
ESC 1	0.71			
ESC 2	0.78			
ESC 3	0.62			
ESC 4	0.82			
ESC 5	0.79			
ESC 6	0.75			
Technology and Innovation Readiness		0.60	0.90	0.86
TIR 1	0.84			
TIR 2	0.82			
TIR 3	0.86			
TIR 4	0.87			
TIR 5	0.63			

Construct / Indicator	Outer Loading	AVE	CR	Cronbach's Alpha
TIR 6	0.58			

The measurement model results in **Table 2** show that the instrument demonstrated acceptable reliability and convergent validity. All constructs obtained Average Variance Extracted values above the minimum threshold of 0.50, indicating that the indicators adequately represented their respective latent constructs. Composite Reliability values ranged from 0.86 to 0.95, while Cronbach's alpha values ranged from 0.80 to 0.93. These results indicate strong internal consistency across the six readiness domains.

Among the six constructs, Learning Design and Assessment showed the strongest measurement performance, with an AVE of 0.79, CR of 0.95, and Cronbach's alpha of 0.93. This confirms that the indicators under this domain were highly consistent in measuring respondents' readiness in lesson planning, instructional alignment, and assessment-related tasks. Pedagogical Content Knowledge also showed strong reliability and validity, with an AVE of 0.67, CR of 0.93, and Cronbach's alpha of 0.91, suggesting that the indicators coherently captured the respondents' perceived ability to transform science content into teachable forms.

Ethical, Social-Responsive, and Community Collaboration had the lowest AVE among the six domains at 0.56, although it still met the acceptable criterion for convergent validity. Technology and Innovation also met the required standards, although two indicators, TIR 5 and TIR 6, had relatively lower loadings of 0.63 and 0.58. These values remain acceptable but suggest that some technology-related indicators may have been perceived with greater variation among respondents. Overall, the findings confirm that the readiness domains were measured reliably and could be used for further structural model testing.

Table 3. Discriminant Validity Using the Fornell–Larcker Criterion

Construct	SCA	SIR	PCK	LDA	ESC	TIR
SCA	0.79	0.61	0.81	0.78	0.76	0.50
SIR	0.61	0.81	0.67	0.64	0.59	0.73
PCK	0.81	0.67	0.82	0.86	0.77	0.57
LDA	0.78	0.64	0.86	0.89	0.84	0.61
ESC	0.76	0.59	0.77	0.84	0.75	0.61
TIR	0.50	0.73	0.57	0.61	0.61	0.77

The Fornell–Larcker results in **Table 3** show that some readiness domains had strong empirical overlap. Several inter-construct correlations were close to or higher than the square root of the AVE values on the diagonal. For instance, Pedagogical Content Knowledge was strongly correlated with Science Content and Application (r = 0.81) and Learning Design and Assessment (r = 0.86). Learning Design and Assessment was also strongly associated with Ethical, Social-Responsive, and Community Collaboration (r = 0.84). These results indicate that the six readiness domains were conceptually related and empirically interconnected. Rather than treating this overlap as a weakness of the study, the results support the assumption that teaching readiness is an integrated professional construct. In actual science teaching, content application, pedagogical judgment, learning design, assessment, ethical responsiveness, inquiry, and technology use are not performed as isolated skills. They operate together in the planning, delivery, and evaluation of instruction. Thus, the Fornell–Larcker results justify the study's higher-order modeling of Overall Teaching Readiness.

Table 4. Discriminant Validity Using the Heterotrait–Monotrait Ratio

Construct	SCA	SIR	PCK	LDA	ESC	TIR
SCA	—	0.70	0.92	0.87	0.91	0.58
SIR	0.70	—	0.74	0.71	0.70	0.83
PCK	0.92	0.74	—	0.93	0.90	0.65
LDA	0.87	0.71	0.93	—	0.97	0.68
ESC	0.91	0.70	0.90	0.97	—	0.73
TIR	0.58	0.83	0.65	0.68	0.73	—

The HTMT results in **Table 4** provide a more stringent assessment of discriminant validity. The results show that several constructs were highly associated, particularly Learning Design and Assessment with Ethical, Social-Responsive, and Community Collaboration (HTMT = 0.97), Learning Design and Assessment with Pedagogical Content Knowledge (HTMT = 0.93), Pedagogical Content Knowledge with Science Content and Application (HTMT = 0.92), and Science Content and Application with Ethical, Social-Responsive, and Community Collaboration (HTMT = 0.91).

These values indicate that complete empirical separation among all readiness constructs was not achieved. However, this result is consistent with the theoretical position of the study that teaching readiness functions as an integrated higher-order construct. The strong overlap among content application, PCK, learning design, assessment, and ethical responsiveness suggests that pre-service teachers perceive these domains as connected aspects of the same professional preparation process. In contrast, Technology and Innovation and Scientific Inquiry and Research showed clearer distinction from some domains, suggesting that these competencies may represent more specialized readiness areas requiring targeted development.

Table 5. Path Coefficients of the Readiness Domains Toward Overall Teaching Readiness

Structural Path	β	t-value	p-value	Decision
Science Content and Application → Overall Teaching Readiness	0.46	12.85	0.000	Significant
Scientific Inquiry and Research → Overall Teaching Readiness	0.24	6.92	0.000	Significant
Pedagogical Content Knowledge → Overall Teaching Readiness	0.50	14.33	0.000	Significant
Learning Design and Assessment → Overall Teaching Readiness	0.44	11.76	0.000	Significant
Ethical, Social-Responsive, and Community Collaboration → Overall Teaching Readiness	0.50	13.95	0.000	Significant
Technology and Innovation → Overall Teaching Readiness	0.34	9.28	0.000	Significant

The structural model results in **Table 5** show that all six readiness domains had positive and statistically significant effects on Overall Teaching Readiness. This means that Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation each contributed significantly to the overall teaching readiness of BSEd Science pre-service teachers.

Pedagogical Content Knowledge and Ethical, Social-Responsive, and Community Collaboration both obtained the highest path coefficient (β = 0.50). This indicates that the strongest contributors to Overall Teaching Readiness were the respondents' perceived ability to transform science content into teachable forms and their perceived capacity to engage ethically, socially, and collaboratively in educational contexts. Science Content and Application also showed a strong contribution (β = 0.46), confirming that content mastery and application remain foundational to science teaching readiness.

Learning Design and Assessment also made a substantial contribution (β = 0.44), indicating that lesson planning, instructional organization, and assessment competence are major components of readiness. Technology and Innovation showed a moderate but significant contribution (β = 0.34), suggesting that digital and innovative teaching capacities are important, although not as dominant as content, pedagogy, and ethical responsiveness. Scientific Inquiry and Research had the lowest path coefficient (β = 0.24), but it remained statistically significant. This implies that inquiry and research readiness contributed to overall readiness, although it may require further programmatic strengthening.

The results support the rejection of all null hypotheses. Each readiness domain significantly contributed to Overall Teaching Readiness. These findings confirm that teaching readiness among pre-service science teachers is multidimensional and that no single domain can fully represent readiness by itself. Instead, readiness is best understood as the combined effect of content competence, pedagogical transformation, instructional design, assessment, ethical responsiveness, inquiry, research orientation, and technological innovation.

Table 6. Model Fit Index

Index	Value	Threshold	Interpretation
SRMR	0.06	≤ 0.08	Good fit

The model fit result in **Table 6** shows that the Standardized Root Mean Square Residual was 0.06, which is below the commonly accepted threshold of 0.08. This indicates that the structural model demonstrated acceptable fit with the empirical data. The result supports the adequacy of the proposed model in representing the relationship between the six readiness domains and Overall Teaching Readiness.

The acceptable SRMR value strengthens the claim that the proposed readiness structure can serve as a valid empirical basis for framework development. Since the six readiness domains were shown to significantly contribute to Overall Teaching Readiness, the model provides statistical support for designing a Science Education Program Framework that is anchored on the actual readiness profile of pre-service science teachers.

Proposed Science Education Program Framework Based on the Findings

The results of the descriptive and structural analyses provide the empirical basis for the proposed Science Education Program Framework. The framework is organized around the idea that teaching readiness develops through interconnected readiness domains rather than through isolated competencies. Based on the findings, Science Content and Application serves as the foundational domain because science teachers must possess adequate content mastery before they can design meaningful instruction. Pedagogical Content Knowledge, Learning Design and Assessment, and Ethical, Social-Responsive, and Community Collaboration form the core pedagogical domains because they showed strong descriptive ratings and strong structural contributions to Overall Teaching Readiness.

Technology and Innovation and Scientific Inquiry and Research function as advanced professional catalysts. Although both domains were rated as highly ready and significantly contributed to Overall Teaching Readiness, they obtained relatively lower descriptive means and path coefficients compared with the other domains. This suggests that they should be strengthened through targeted program interventions, such as inquiry-based teaching laboratories, research-integrated practicum activities, action research capstones, technology-enhanced lesson simulations, and digital pedagogy workshops.

The results support a Science Education Program Framework that begins with strong science content preparation, develops core pedagogical and assessment competencies, and advances toward inquiry-based, research-oriented, ethical, collaborative, and technology-supported science teaching. This framework responds directly to the study's findings by preserving the domains where pre-service teachers already show strong readiness while strengthening the areas that require additional institutional support.

5. Conclusion and Recommendations

Conclusion

The study concludes that BSEd Science pre-service teachers demonstrated a high level of teaching readiness across the six domains of Science Content and Application, Scientific Inquiry and Research, Pedagogical Content Knowledge, Learning Design and Assessment, Ethical, Social-Responsive, and Community Collaboration, and Technology and Innovation. The results further confirm that teaching readiness is a multidimensional and integrated construct, as all six domains significantly contributed to Overall Teaching Readiness. Among these domains, Pedagogical Content Knowledge and Ethical, Social-Responsive, and Community Collaboration emerged as the strongest contributors, indicating that readiness for science teaching depends not only on content mastery but also on the ability to transform science concepts into teachable forms and respond professionally to learners and communities. The acceptable model fit supports the validity of using the findings as the empirical basis for developing a Science Education Program Framework for pre-service science teacher preparation.

Recommendations

Based on the findings, the study recommends that the Science Education program strengthen its existing preparation system by sustaining the domains where pre-service teachers already demonstrated high readiness, particularly Learning Design and Assessment, Pedagogical Content Knowledge, and Ethical, Social-Responsive, and Community Collaboration. At the same time, greater institutional attention should be given to Scientific Inquiry and Research and Technology and Innovation, as these domains recorded relatively lower mean scores and path coefficients despite remaining significant contributors to Overall Teaching Readiness. The program may therefore enhance practicum-based inquiry teaching, action research activities, technology-integrated lesson simulations, digital pedagogy workshops, and mentoring systems that allow pre-service teachers to apply science content, pedagogy, assessment, inquiry, and technology in authentic classroom contexts. Future studies may also validate the proposed framework using other teacher education institutions, larger samples, and additional evidence from classroom observation or practicum performance.

Declarations

Ethical Approval
The study observed ethical research procedures and complied with the principles of voluntary participation, informed consent, confidentiality, anonymity, and responsible data handling. Permission was secured from the concerned institutional authorities before data collection. The respondents were informed of the purpose of the study, their right to decline or withdraw from participation, and the confidentiality of their responses.

Informed Consent
Informed consent was obtained from all respondents before they participated in the study. Participation was voluntary, and no respondent was compelled to answer the survey instrument.

Data Privacy and Confidentiality
The study complied with the provisions of the Philippine Data Privacy Act of 2012. No personally identifying information was reported in the manuscript. All data were treated with strict confidentiality and were reported only in aggregate form.

Availability of Data
The data supporting the findings of this study may be made available from the corresponding author upon reasonable request and subject to institutional data privacy and research ethics restrictions.

Competing Interests

The authors declare that they have no competing interests.

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Authors' Contributions
Kyla Rita A. Mercado served as the principal author and was responsible for the conceptualization of the study, data gathering, statistical analysis, interpretation of findings, and preparation of the initial manuscript. Don Anton R. Balida contributed to manuscript development, academic writing refinement, methodological alignment, results presentation, and final editorial review. Both authors reviewed and approved the final version of the manuscript.

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During the preparation of this manuscript, the authors used ChatGPT as an AI-assisted writing tool to support language refinement, organization of ideas, grammar improvement, and formatting of selected sections. The authors manually reviewed, verified, revised, and approved all AI-assisted outputs. The authors retain full responsibility for the accuracy, integrity, originality, and final content of the manuscript.

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