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Intervention Model for Science Teachers Competencies and 21st Century Skills to Enhance Performance of Learners

Rowenalyn M. Fernandez
Nueva Vizcaya State University
Department of Education - Tuao High School, Bagabag, Nueva Vizcaya
rowenalyn.fernandez@deped.gov.ph

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ABSTRACT

This study examined the interrelationships among secondary science teachers' teaching competencies, 21st-century skills, and their students' academic performance in the Schools Division of Nueva Vizcaya, Philippines, and used the findings as the basis for an intervention plan. A quantitative descriptive-correlational design was employed. From a reported population of 264 science teachers, 47 secondary science teachers were randomly selected; 10 students were then systematically selected from each participating teacher's class, yielding 470 student respondents. A three-part questionnaire assessed teacher profile, pedagogical, professional, social, and personal competencies, and the 4Cs of critical thinking, collaboration, communication, and creativity. The instrument obtained a content-validation score of 1.00 and an overall Cronbach's alpha of approximately .83. Frequency, percentage, mean, standard deviation, and Structural Equation Modeling (SEM) using AMOS were applied. Most teachers were female (70.21%), bachelor's degree holders (78.72%), and had 15 years or less of teaching experience (76.60%). Pedagogical (M = 3.25), professional (M = 3.08), and social competence (M = 3.17) were highly proficient, while personal competence based on IPCR was outstanding (M = 4.79). Critical thinking (M = 3.18), collaboration (M = 3.20), communication (M = 3.21), and creativity (M = 3.23) were highly proficient. Students' science performance was satisfactory (M = 83.36). In the final model, pedagogical competence showed an indirect effect on academic performance (.41), while critical thinking (3.76) and creativity (2.54) showed direct positive effects. The findings support professional-development interventions that strengthen pedagogy and 21st-century skills in secondary science instruction.

Keywords: *teaching competencies, 21st-century skills, secondary science teachers, academic performance, structural equation modeling, professional development*

INTRODUCTION

Science education in the Philippines continues to confront persistent challenges in building scientific literacy and improving learner outcomes. National and international assessment results cited in the dissertation showed weak performance in science, including low TIMSS and PISA results and low mastery or proficiency in national assessments (Albano, 2019; Bernardo, 2020; De La Cruz, 2022). These conditions underscore the importance of strengthening the capacity of teachers who translate curriculum goals into classroom learning experiences.

Professional development is central to this effort because teachers are expected not only to possess strong disciplinary and pedagogical competence but also to cultivate competencies required for contemporary learning. Effective professional learning can strengthen instructional practice and student outcomes when it is sustained, content-focused, collaborative, and connected to classroom needs (Akiba & Liang, 2021; Darling-Hammond et

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al., 2017; El-Deghaidy et al., 2015). In science education, such professional growth is especially important because instruction requires accurate content knowledge, inquiry-based pedagogy, classroom management, and the capacity to connect scientific ideas to real-world contexts.

The 21st-century classroom also requires teachers to model and develop critical thinking, collaboration, communication, and creativity. These skills are widely treated as essential for learning, work, and participation in a rapidly changing society (Djudin, 2020; Trilling & Fadel, 2009). Science teachers are therefore expected to use teaching approaches that engage students in inquiry, teamwork, communication of evidence, and creative problem solving. The use of these competencies has been linked in the literature to stronger classroom engagement and more effective learning experiences (Parker et al., 2022; Sulaiman & Ismail, 2020).

Previous studies have examined science-teacher competence, 21st-century teaching skills, and professional performance, but the dissertation identified a need to examine these dimensions together and relate them to students' academic performance within the Schools Division of Nueva Vizcaya. Earlier Philippine studies have assessed competencies in K to 12 science teaching and their relationship with learner outcomes (Gamayao & Biñas, 2021; Nbina, 2012; Nipales, 2019), while Padillo et al. (2021) emphasized the relationship between professional development and teacher performance. The present study extends this line of inquiry by modeling direct and indirect pathways among teaching competencies, 21st-century skills, and science achievement.

Accordingly, the study determined the profile of secondary science teachers, assessed their pedagogical, professional, social, and personal competencies, examined their utilization of critical thinking, collaboration, communication, and creativity, described students' academic performance in science, developed a model of the interrelationships among these variables, and proposed an intervention plan for secondary science teachers. The findings were intended to guide school leaders, teachers, curriculum planners, and policy makers in designing targeted professional-development support.

Literature Review

Teaching Competencies in Secondary Science Education

Teaching competence is a multidimensional construct that integrates knowledge, skills, professional dispositions, and the capacity to respond effectively to classroom demands. In science education, competence includes instructional planning, delivery of scientific content, use of appropriate learning resources, assessment, classroom management, and the creation of supportive teacher-student relationships. Philippine studies have similarly emphasized the importance of science teachers' pedagogical and content competence for effective K to 12 implementations (Gamayao & Biñas, 2021; Nipales, 2019).

Pedagogical competence requires teachers to design coherent lessons, use varied strategies, integrate technology, encourage inquiry, and address diverse learner needs. Student-centered teaching and thoughtful technology integration have been identified as important dimensions of contemporary pedagogy (Boholano, 2021; Chen et al., 2022). Professional and social competence complement pedagogy by requiring ethical practice, collaboration, communication, and the development of inclusive classroom relationships (Chubbuck & Zembylas, 2021; Pantic & Florian, 2020).

The dissertation also operationalized personal competence through teachers' Individual Performance Commitment and Review (IPCR) ratings. This reflects the Philippine public-school context in which teacher performance is assessed against professional commitments and expected outputs. Studies cited in the manuscript associate teacher performance with work conditions, professional development, and organizational factors, reinforcing the value of examining competence alongside formal performance indicators (Burgos & Meer, 2021; Padillo et al., 2021).

Twenty-First-Century Skills in Science Teaching

The study focused on the 4Cs: critical thinking, collaboration, communication, and creativity. Critical thinking allows teachers and learners to analyze information, evaluate evidence, formulate questions, and solve problems. Collaboration supports shared knowledge construction and teamwork, while communication enables

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scientific ideas, procedures, and findings to be expressed clearly. Creativity supports the generation, elaboration, and transfer of ideas to new situations. These abilities are consistent with widely recognized frameworks for twenty-first-century learning (Ravitz, 2014; Trilling & Fadel, 2009).

In science classrooms, the 4Cs are not isolated skills. Inquiry-oriented instruction can require students to ask questions, test explanations, work with peers, communicate findings, and generate new solutions. Studies on contemporary science teaching have therefore emphasized the need to integrate these competencies into regular pedagogy rather than treat them as separate enrichment activities (Djudin, 2020; Parker et al., 2022). Sulaiman and Ismail (2020) likewise linked teacher competence with 21st-century skills, supporting the premise that effective pedagogy can provide the conditions through which these skills are enacted.

Creativity and collaboration are particularly relevant to science because scientific work involves the development of ideas, refinement of explanations, and collective problem solving. Creative teaching encourages transfer, elaboration, and flexible thinking (Beghetto & Kaufman, 2014; Cropley, 2016; Runco & Jaeger, 2012), while collaborative learning allows learners to negotiate meaning and jointly develop understanding. These skills also depend on effective communication and classroom relationships, which connect the 4Cs to the broader domains of teaching competence.

Teacher Competence, Professional Development, and Academic Performance

Teacher quality is consistently treated as a key school-based influence on student learning. Studies cited in the dissertation associate teacher competence and professional learning with student achievement, although the strength and form of these relationships vary across contexts (Akiba & Liang, 2021; Nbina, 2012). Competence may influence outcomes directly through instructional quality or indirectly through classroom processes such as engagement, critical thinking, feedback, and the use of effective learning tasks.

Professional development provides a mechanism for strengthening these competencies over time. Effective programs are more likely to influence practice when they focus on subject content and pedagogy, include active learning and collaboration, and provide sustained opportunities for feedback and reflection (Darling-Hammond et al., 2017; El-Deghaidy et al., 2015). The dissertation therefore treated professional development not as a one-time activity but as a response to empirically identified needs in teaching competence and 21st-century skill use.

This orientation is also consistent with evidence that teachers benefit from structured collaboration and reflective professional practice. Teacher performance is strengthened when professional learning is connected to classroom needs and when teachers have opportunities to examine, refine, and share their practice (Padillo et al., 2021; Wilson et al., 2018). The study's proposed intervention plan was consequently designed around workshops, training, coaching, peer feedback, action research, and peer-support communities.

Theoretical and Conceptual Basis of the Study

The dissertation used the Professional Development Theory Cycle (PDTC) as its guiding professional-development perspective. In the manuscript, the PDTC was described through knowledge acquisition, standard requirements, observed models, implementation, effectiveness, and reflection. Together, these components frame professional development as a cycle in which teachers acquire knowledge, align practice with standards, learn from models, implement strategies, evaluate effectiveness, and reflect on outcomes. The framework was used to connect teacher profile, teaching competence, 21st-century skills, professional performance, and the design of a development plan.

The conceptual model further proposed pathways among pedagogical, professional, social, and personal competence; the 4Cs of critical thinking, collaboration, communication, and creativity; and students' academic performance. The model allowed both direct and indirect effects, reflecting the possibility that teaching competence may contribute to achievement through the way teachers use 21st-century skills. This structure was tested through SEM in AMOS rather than assumed from descriptive ratings alone.

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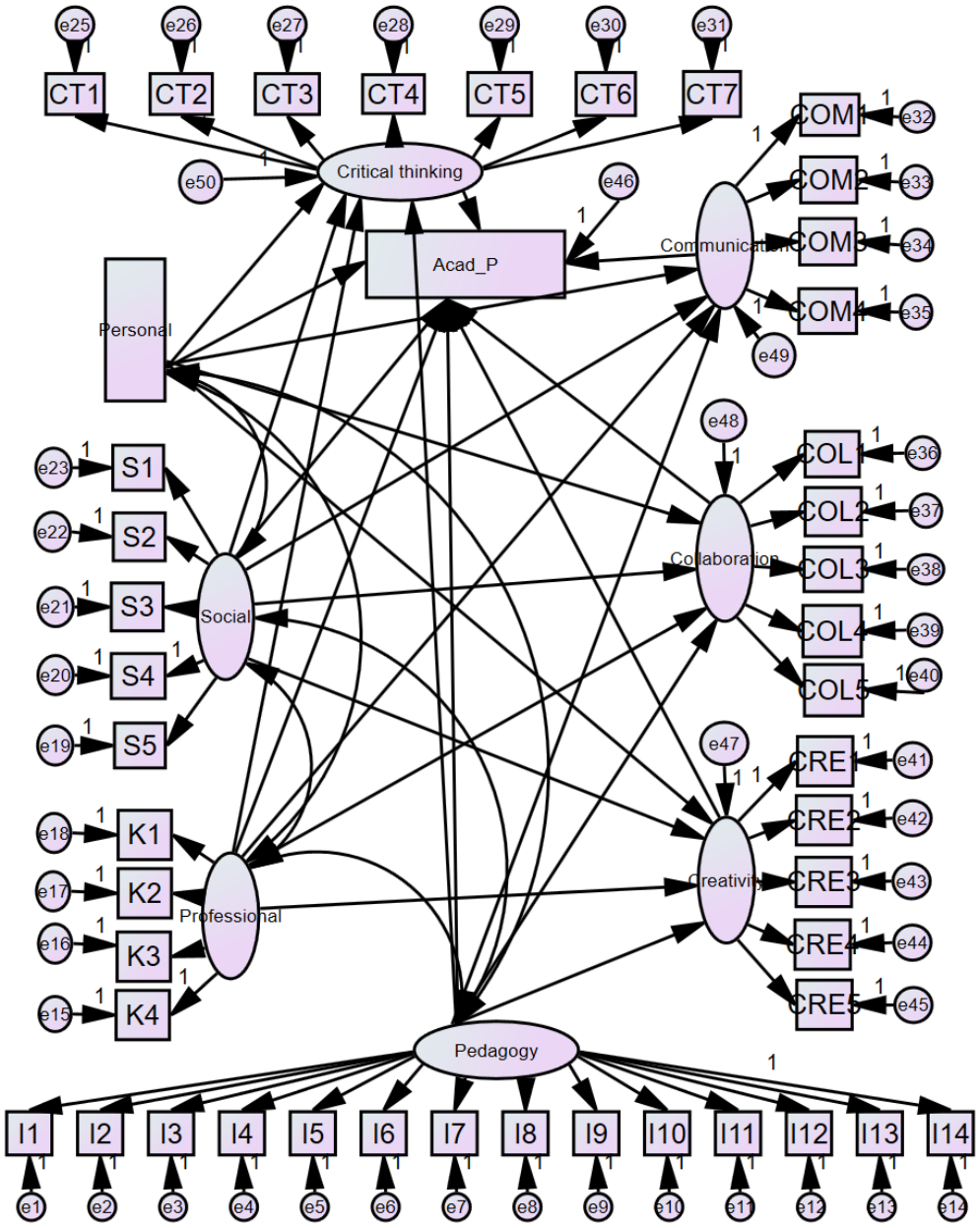
Figure 1. *Hypothesized Model Showing the Matching of Teaching Competencies and 21st-Century Skills to Academic Performance*



METHODS

Research Design

The study used a quantitative descriptive-correlational research design. Descriptive procedures were used to characterize the teachers' profile, teaching competencies, 21st-century skills, and students' academic performance. Correlational analysis was extended through Structural Equation Modeling (SEM) in AMOS to examine the interrelationships among teaching competencies, 21st-century skills, and academic performance and

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to identify paths retained in the final model. The resulting evidence was also used as the basis for an intervention plan for secondary science teachers.

Research Locale

The study was conducted in the Department of Education Schools Division of Nueva Vizcaya, Philippines. The dissertation covered public secondary schools located across 15 municipalities in the province. Schools were categorized by enrollment size consistent with DepEd school-classification guidelines. Integrated schools were excluded because science teachers in those settings could be assigned across both primary and secondary levels.

Participants and Sampling Technique

A multistage sampling procedure was employed. From the reported population of 264 science teachers in the Schools Division of Nueva Vizcaya, 47 secondary science teachers were randomly selected. One teacher-respondent was selected from each small school and two teacher-respondents from each large school. Subsequently, 10 students were systematically selected from each participating teacher's class, producing 470 student respondents. These students provided assessments of their respective teachers' competencies and 21st-century skills.

Research Instrument

The primary instrument was a three-part questionnaire. Part I gathered teacher-profile information, particularly sex, highest educational attainment, and years in the teaching profession. Part II assessed pedagogical, professional, social, and personal competencies, with the competency domains adapted from Padillo et al. (2021). Part III assessed critical thinking, collaboration, communication, and creativity using items adapted from the 21st-century teaching and learning survey of Ravitz (2014). Personal competence was represented by the teachers' IPCR functional-competency rating.

Expert content validation produced a reported validation score of 1.00. Minor revisions were made to clarify selected indicators. Reliability testing yielded an overall Cronbach's alpha of approximately .83, which the dissertation interpreted as demonstrating adequate internal consistency for the instrument.

Data Gathering Procedure

Permission letters were prepared and submitted to the Schools Division Superintendent and to the principals of participating secondary schools. After the instrument had undergone external validation, the questionnaire was administered to the identified respondents. Relevant documents, including academic-performance and teacher-performance records, were also examined as required by the study. The data were checked, organized, and prepared for quantitative analysis.

Data Analysis

Frequency and percentage were used to describe teacher profiles and student academic-performance categories. Means and standard deviations were used to summarize teaching competencies and the extent of utilization of 21st-century skills. Student performance was interpreted using DepEd grading descriptors. SEM in AMOS was used to examine the modeled relationships, with CMIN/DF, CFI, TLI, and RMSEA reported as model-fit indices. Regression weights, estimates, p-values, and modification indices informed the retention or removal of paths. Direct, indirect, and total effects were also summarized for the overall model and for selected teacher-profile groupings.

Ethical Consideration

The researcher sought formal permission from the Schools Division Superintendent and participating school principals before data collection. The student questionnaire explicitly stated that responses would be used solely for the study and would be treated as confidential. These procedures provided the documented safeguards reported in the dissertation for institutional permission and respondent privacy.

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RESULTS AND DISCUSSION

Profile of Secondary Science Teachers and Student Academic Performance

The 47 teacher-respondents were predominantly female (33, 70.21%), while 14 (29.79%) were male. Most held a bachelor's degree (37, 78.72%), and 10 (21.28%) had a master's degree. Thirty-six teachers (76.60%) had 15 years or less of teaching experience, whereas 11 (23.40%) had 16 years or more; the mean teaching experience was 13.04 years. The profile suggests a workforce composed largely of bachelor's degree holders with substantial but generally not long-term teaching experience. The dissertation identified this pattern as relevant to the design of continuing professional-development opportunities.

Table 1. *Profile of the Secondary Science Teacher-Respondents*

Profile Variable	Category	Frequency	Percentage
Sex	Male	14	29.79%
Sex	Female	33	70.21%
Highest educational attainment	Bachelor's	37	78.72%
Highest educational attainment	Master's	10	21.28%
Years in teaching	15 and below	36	76.60%
Years in teaching	16 and above	11	23.40%

Among the 470 students, 32 (6.81%) were Outstanding, 150 (31.91%) were Very Satisfactory, 179 (38.09%) were Satisfactory, and 109 (23.19%) were Fairly Satisfactory; none fell below the minimum passing category. The overall mean science grade was 83.36, interpreted as Satisfactory. Thus, although most learners met or exceeded the satisfactory range, nearly one-fourth remained in the fairly satisfactory category, supporting the dissertation's recommendation for continued instructional improvement and targeted support.

Table 2. *Academic Performance of Students in Science*

Descriptor	Grade Range	Frequency	Percentage
Outstanding	90-100	32	6.81%
Very Satisfactory	85-89	150	31.91%
Satisfactory	80-84	179	38.09%
Fairly Satisfactory	75-79	109	23.19%
Did not meet expectations	Below 75	0	0.00%

Teaching Competencies of Secondary Science Teachers

Students rated their teachers as Highly Proficient in pedagogical competence (M = 3.25, SD = 0.26), professional competence (M = 3.08, SD = 0.23), and social competence (M = 3.17, SD = 0.24). Pedagogically, teachers were strong in lesson preparation, motivation, student participation, feedback, classroom management, and time management, although technology/resource integration (M = 3.11) and the use of varied methods for multiple intelligences (M = 3.18) were comparatively lower. These results are consistent with studies emphasizing that science-teacher competence depends on both strong pedagogy and continuous adaptation to new instructional demands (Boholano, 2021; Gamayao & Biñas, 2021; Nipales, 2019).

Professional competence was also Highly Proficient, but integrating science content with other subjects recorded the lowest mean within the domain (M = 2.97). Social competence was characterized by respect for students' ideas, appropriate communication, demonstrations, learning challenges, and the inclusion of current issues. Personal competence, measured through IPCR, was rated Outstanding for all 47 teachers, with an overall mean of 4.79. The strong IPCR result supports the dissertation's view that the teachers demonstrated high levels of professional responsibility, while the lower individual indicators identify areas where professional development could still be focused (Burgos & Meer, 2021; Padillo et al., 2021).

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Utilization of 21st-Century Skills

All four 21st-century skill domains were rated Highly Proficient: critical thinking (M = 3.18, SD = 0.26), collaboration (M = 3.20, SD = 0.26), communication (M = 3.21), and creativity (M = 3.23, SD = 0.25). Teachers were perceived as using inquiry-oriented questions, respecting different perspectives, structuring collaborative activities, organizing and presenting information clearly, adapting communication to purpose and audience, and elaborating on ideas. These practices align with the 4Cs framework and with studies emphasizing the integration of critical thinking, teamwork, communication, and creativity in contemporary science classrooms (Djudin, 2020; Parker et al., 2022; Trilling & Fadel, 2009).

Creativity obtained the highest overall mean among the 4Cs. The strongest creativity indicator involved elaborating and improving ideas (M = 3.32), while finding sources of information and inspiration when others did not obtain the lowest mean (M = 3.12). The pattern suggests that teachers were more consistently strong in developing and refining ideas than in independently locating novel sources of inspiration. This result is compatible with literature that treats creativity as both idea generation and the capacity to elaborate, transfer, and improve ideas (Beghetto & Kaufman, 2014; Cropley, 2016; Runco & Jaeger, 2012).

Table 3. *Summary of Teaching Competencies and 21st-Century Skills*

Construct	Mean	SD	Interpretation
Pedagogical competence	3.25	0.26	Highly Proficient
Professional competence	3.08	0.23	Highly Proficient
Social competence	3.17	0.24	Highly Proficient
Personal competence (IPCR)	4.79	—	Outstanding
Critical thinking	3.18	0.26	Highly Proficient
Collaboration	3.20	0.26	Highly Proficient
Communication	3.21	—	Highly Proficient
Creativity	3.23	0.25	Highly Proficient

Structural Model of Teaching Competencies, 21st-Century Skills, and Academic Performance

The SEM generated a final model linking teaching competencies, 21st-century skills, and academic performance. The dissertation reported CMIN/DF = 1.616 and RMSEA = .036, both of which meet the fit criteria reproduced in the manuscript. It also reported TLI = .826 and CFI = .84. These latter values are below the .90 acceptable-fit thresholds reproduced in the dissertation itself; therefore, while the thesis characterized the overall model as good to very good, the fit evidence is mixed and should be interpreted with appropriate caution. The numerical values are retained exactly as reported.

In the final effect estimates, pedagogical competence had no direct effect on academic performance but had an indirect positive effect of .41. Critical thinking skills had a direct positive effect of 3.76, and creativity skills had a direct positive effect of 2.54. Professional, social, and personal competence did not show direct effects in the summarized effect table, while collaboration and communication likewise had no direct effect on academic performance. The model therefore suggests that pedagogical competence may contribute to student outcomes through 21st-century skills, especially critical thinking and creativity. This is consistent with the broader proposition that teacher competence is expressed in learner outcomes partly through the quality of classroom processes (Sulaiman & Ismail, 2020; Zohar & Barzilai, 2013).

Table 4. *Direct, Indirect, and Total Effects on Academic Performance*

Variable	Direct Effect	Indirect Effect	Total Effect
Pedagogical competence	—	0.41	0.41
Professional competence	—	—	—
Social competence	—	—	—
Personal competence	—	—	—
Critical thinking skills	3.76	—	3.76
Collaborative skills	—	—	—
Communication skills	—	—	—

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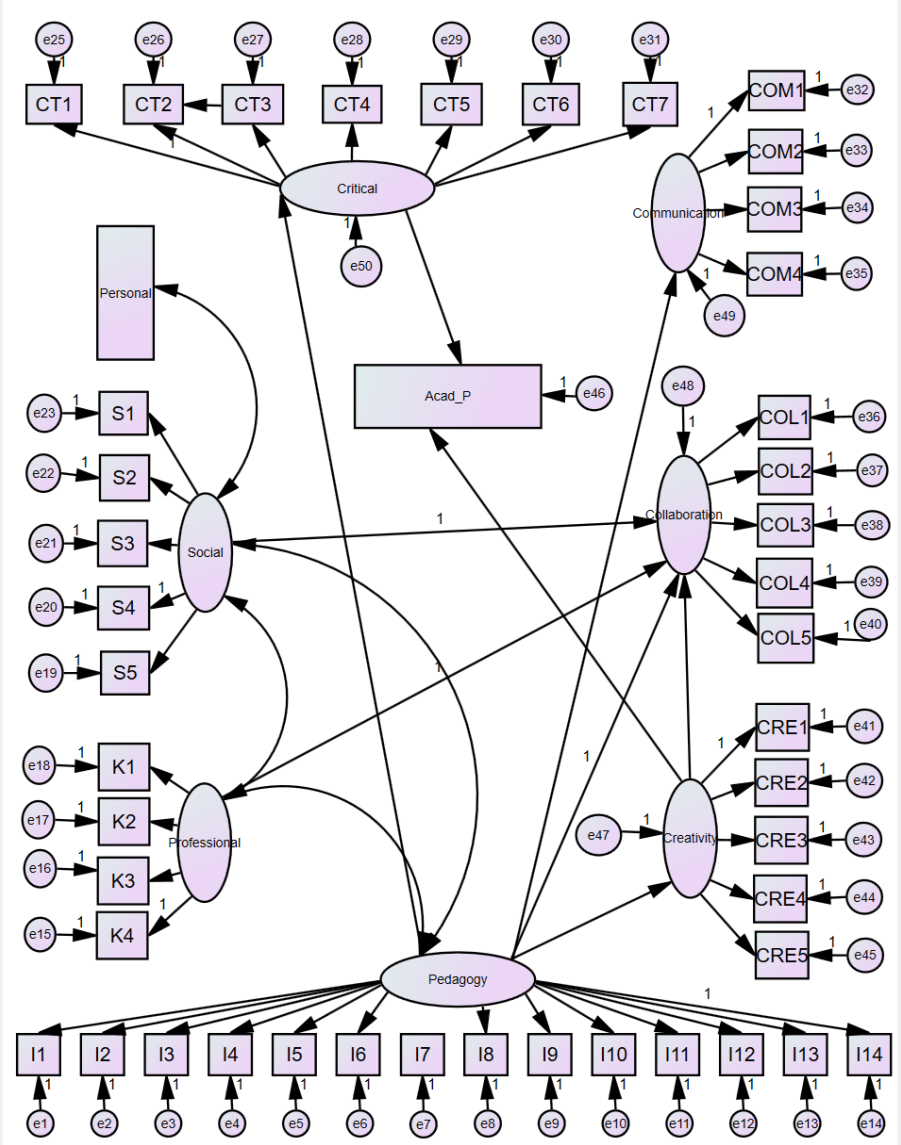
Variable	Direct Effect	Indirect Effect	Total Effect
Creativity skills	2.54	—	2.54

Figure 2. *Accepted Model of the Interrelationship of Teaching Competencies and 21st-Century Skills Associated with Academic Performance*



Profile-Based Differences in Model Effects

The dissertation also compared total effects across selected teacher-profile groupings. Male teachers showed larger modeled effects than female teachers for pedagogical competence (1.59 vs. 0.10), critical thinking (6.45 vs. 1.98), and creativity (3.65 vs. 2.42). Bachelor's degree holders showed larger modeled effects than master's degree holders for pedagogical competence (0.63 vs. 0.51), critical thinking (2.52 vs. 1.83), and creativity (4.44 vs. 2.76). For teaching experience, teachers with more than 16 years showed larger modeled effects for pedagogical competence (1.38 vs. 0.95), critical thinking (4.69 vs. 1.83), and creativity (3.77 vs. 3.57). These values describe the group-specific estimates reported in the thesis; the summarized tables did not provide inferential tests establishing that the between-group differences were statistically significant.

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Table 5. *Selected Total Effects by Teacher Profile Group*

Profile Variable	Group	Pedagogical Competence	Critical Thinking	Creativity
Sex	Male	1.59	6.45	3.65
Sex	Female	0.10	1.98	2.42
Educational attainment	Bachelor's	0.63	2.52	4.44
Educational attainment	Master's	0.51	1.83	2.76
Years in teaching	≤ 15 years	0.95	1.83	3.57
Years in teaching	> 16 years	1.38	4.69	3.77

Taken together, the findings support an intervention approach that does not treat competence and 21st-century skills as separate targets. Strengthening pedagogy can provide the instructional structure within which critical thinking and creativity are practiced, while collaboration and communication support the social processes of science learning. Professional-development activities that combine pedagogical improvement, technology integration, inquiry, communication, collaborative planning, creativity, and reflective practice are therefore consistent with both the descriptive needs and the modeled pathways identified in the study (Darling-Hammond et al., 2017; Wilson et al., 2018).

CONCLUSION

The study established that the secondary science teachers in the Schools Division of Nueva Vizcaya were generally perceived as highly proficient in pedagogical, professional, and social competence and in the four 21st-century skill domains of critical thinking, collaboration, communication, and creativity. Their personal competence, as reflected in IPCR ratings, was outstanding. Students' science achievement was generally satisfactory, with no students falling below the minimum passing category, although a substantial group remained in the fairly satisfactory range.

The final structural model indicated that teaching competencies did not operate as simple direct predictors of academic performance. Instead, pedagogical competence showed an indirect effect, while teachers' critical thinking and creativity showed direct positive effects on student performance. These findings support the view that the contribution of teacher competence to student achievement is partly realized through the quality of twenty-first-century classroom practices. The study therefore contributes a local evidence base for targeted professional development that integrates pedagogy and the 4Cs in secondary science education.

Recommendation

Policy makers and curriculum planners should strengthen professional-development provisions that address pedagogical, professional, social, and personal competence while explicitly integrating critical thinking, collaboration, communication, and creativity into secondary science instruction. Programs should be aligned with identified classroom needs rather than implemented as generic training.

School heads should provide continuing workshops, seminars, mentoring, collaborative planning, and peer-learning opportunities for science teachers. Priority areas identified in the dissertation include technology integration, diverse learning styles, higher-order thinking, interdisciplinary connections, communication, creativity, collaboration, and student-centered strategies. The proposed intervention activity, "Enhancing Teaching Competencies and 21st-Century Skills for Improved Academic Performance in Secondary Science," may be adapted to local school and division needs.

Science teachers should engage in sustained professional learning, use inquiry- and student-centered approaches, strengthen the integration of technology and interdisciplinary content, and deliberately create opportunities for students to analyze evidence, communicate scientific ideas, collaborate in problem solving, and

develop creative solutions. Peer feedback, coaching, action research, and professional support communities may be used to sustain improvement.

Future researchers should test the model with larger samples, other school divisions, other subject areas, and longitudinal designs. Future work should also evaluate the effectiveness of the proposed intervention plan and examine additional factors that may explain academic performance. Where multi-group SEM is used, formal tests of between-group invariance and significance should be reported to support conclusions about differences by sex, educational attainment, and teaching experience.

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