Pedagogical Content Knowledge, Continuing Professional Development and Teachers' Attitude Toward Science: A Structural Equation Model on Science Curriculum Implementation

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Abstract
The study's main objective was to determine the best-fit model for science curriculum implementation of public secondary science teachers in Region XII based on pedagogical content knowledge, continuing professional development, and teachers' attitudes toward science. This study used a stratified sampling technique to choose 400 respondents, a quantitative non-experimental causal research design, and mean, Pearson r, multiple regression, and structural equation model (SEM) as statistical tools. Survey questionnaires were deployed to the respondents using the online Google Form. Results revealed that the level of pedagogical content knowledge was very high, the level of continuing professional development was high, the level of attitude toward science was high, and the level of science curriculum implementation was very high. Moreover, pedagogical content knowledge, continuing professional development, and attitude toward science exhibited a significant relationship with science curriculum implementation. Furthermore, pedagogical content knowledge was the domain that best influences science curriculum implementation. Finally, among the five generated models, Model 5 best-fitted science curriculum implementation with pedagogical content knowledge in terms of subject matter knowledge, instructional objective and context, and knowledge of students' understanding, continuing professional development in terms of updating, reflective, and collaborative activities, and attitude toward science in terms of perceived dependency on context factors, self-efficacy, the difficulty of science teaching, and perceived relevance.
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1. Introduction

Science education will provide learners with the knowledge, skills, and attitude they need to face the challenges outside the classroom and contribute to global prosperity (Organization for Economic Cooperation and Development [OECD], 2020). However, issues in adopting the spiral progression approach in the science curriculum have appeared in various studies among Filipino secondary science teachers. The spiral curriculum necessitated current in-service science teachers trained to specialize in a particular field to teach all science disciplines in a spiral progression approach resulting in teachers' difficulty in teaching science subjects that are not their area of expertise (Bug-os et al., 2021; Malahay, 2021; Walag et al., 2020).

In addition, misalignment in the distribution and arrangement of science contents were discovered (Degorio, 2022), teachers' difficulty in connecting topics from one-grade level to another (Hernandez, 2021), inadequate teaching guides and learning modules in the field, insufficient qualified teachers, scarcity of laboratory equipment and learning resources, inadequate academic conferences and seminar-workshops, and a short time spent on teacher training (Dunton & Co, 2019; Gonzales, 2019; Mangali et al., 2019).

The implemented science curriculum in the Philippines aims to produce scientifically literate individuals and responsible decision-makers who can use scientific knowledge to solve societal problems. However, the dismal performance of the country in international assessments like the PISA and TIMSS revealed that Filipino students need to catch up to the international standards in terms of reading, mathematics, and science (Department of Education, 2019a; OECD, 2019). As a result, the Department of Education (2019b) recognizes the need for a greater emphasis on reviewing and updating the curriculum, upskilling, and reskilling teachers through a transformative professional development program, improving teaching and learning facilities, and mobilizing support and collaboration of all stakeholders.

Curriculum implementation refers to delivering the curriculum blueprint through teachers' instructional practices. In other words, curriculum implementation refers to how a teacher chooses and applies the varied information in a curriculum package (Bediako, 2019). Teachers' instructional practices must align with the intended curriculum to ensure fidelity in implementing the science curriculum. Thus, curriculum implementation needs teachers' preparedness and dedication to accomplish the intended curricular outcomes

(Palestina et al., 2020; Pandey, 2018).

Implementing the curriculum requires an executing agent, which in this case is the teachers. At the classroom level, teachers' pedagogical content knowledge (PCK) accounts for the quality of instruction (Baier et al., 2019; Depaepe et al., 2020; Sorge et al., 2019). Pedagogical content knowledge is indispensable in implementing the science curriculum (Moosa & Shareefa, 2019; Suh & Park, 2017). Similarly, science teachers should be supported by extensive, transformative, and continuing professional development to effectively implement any curriculum reform (Madani & Forawi, 2019; Mamlok-Naaman, 2017; Marshall et al., 2017). Equally important is teachers' attitude toward science, which is a crucial element for the effectiveness of the implementation of science education (McDonald et al., 2019; Thibaut et al., 2018).

Several studies have found that pedagogical content knowledge, continuing professional development, and attitude toward science can significantly influence the implementation of science curricula. For instance, a survey among teachers claimed that teachers equipped with pedagogical content knowledge or an understanding of how they may modify the content, process, product, and learning environment to match students' learning profiles could effectively implement the curriculum (Moosa & Shareefa, 2019). Moreover, PCK is an essential knowledge foundation in a sustained implementation of an argument-based inquiry approach which is critical in achieving scientific literacy among students (Suh & Park, 2017). In this study, two components of PCK, such as teachers' knowledge of students' understanding and knowledge of instructional strategies and representations, were strongly linked to orientations toward teaching science. The synergy of these three components provided a strong foundation for the sustained implementation of an argument-based inquiry approach.

Equally important, curriculum reform and implementation must be backed by extensive and continuing professional development for teachers. Professional development activities will provide teachers with proper professional preparation to implement new curricular materials, guidance, and support while implementing the curriculum, help them become acquainted with recent scientific developments, and keep them updated with innovative curricular materials and teaching strategies (Mamlok-Naaman, 2017). Findings of another study on the implementation of an inquiry-based science curriculum also claimed that teacher participation in a continuous professional development intervention aimed to improve the application of guided inquiry-based instruction in science classrooms, which enhances students' ability to learn science concepts and scientific practices, is an important foundational step to implement the curriculum successfully (Marshall et al., 2017).

Another critical factor that is crucial for curriculum implementation is teachers' attitudes toward the subject matter. Teachers' attitudes toward science and how they teach it are essential in effectively implementing science education. For teachers to effectively prepare students to be future critical players in the STEM workforce, they must ensure that students develop positive attitudes toward science during their school education. The first step to achieving this goal is ensuring that teachers develop positive attitudes toward science and ultimately promote these attitudes to their students (McDonald et al., 2019).

Another study revealed a positive correlation between teachers' attitudes and their teaching practices, specifically in integrating STEM content, problem-centered learning, inquiry-based learning, design-based learning, and cooperative learning (Thibaut et al., 2018). All these studies have pointed out the influence of teachers' pedagogical content knowledge, continuing professional development, and attitude toward science to implement the science curriculum.

The theory of curriculum implementation by Rogan and Grayson (2003) supported this study, highlighting the three interrelated constructs for curriculum implementation, including a profile of implementation, capacity to support innovation, and support from outside agencies. The first construct, the profile of implementation, examines the nature of classroom interaction, the application of practical science work, the integration of science and mathematics in society, and assessment practices.

The second construct, capacity to support innovation, look at the elements that can help or impede the introduction of new ideas and practices in a school, such as physical resources, teacher factors, learner factors, and school ecology and management. The third construct, support from outside agencies, includes the actions taken and help offered by external organizations, including both material and non-material support such as professional development, monitoring, learner support, and physical resources (Rogan & Grayson, 2003).

Moreover, Magnusson et al. (1999) proposed the component model for science supported this study, asserting that pedagogical content knowledge is integral to effective science teaching. They argued that teachers with pedagogical content knowledge could better organize and implement lessons that assist students in acquiring deep and integrated understandings than those with limited and fragmented knowledge. In their proposition, they identified the five components of pedagogical content knowledge for science teaching: orientations toward science teaching, knowledge and beliefs about science curriculum, students' understanding of specific science topics, assessment in science, and instructional strategies for teaching science.

Similarly, the study of Powell and Anderson (2002) on changing teachers' practices in line with curriculum materials and science education reform provided theoretical support for the relationship between continuing professional development and science curriculum implementation. Teachers must undergo a comprehensive and transformative professional development program to improve instruction and implement standards-based science curriculum materials effectively. Through this program, teachers will have a revised conceptual understanding of science content, knowledge of research on how students learn, and pedagogical content knowledge. Thus, when combined with practical, long-term professional development, highly organized standards-based curriculum materials can potentially transform teaching practices, resulting in enhanced student achievement and attitudes toward science.

Furthermore, the theoretical framework proposed by van Aalderen-Smeets et al. (2012), which characterized the constructs of teachers' attitudes toward science and the teaching of science, provided foundational support to this study. In this framework, attitudes are antecedents of behavioral intention, affecting actual behavior, which agrees with Ajzen's (1991) theory of planned behavior. They posited that attitudes toward the behavior, subjective norms, and perceived behavioral control could predict intentions to perform a specific behavior.

As a result, the three dimensions of attitude toward science, namely, cognitive belief, affective states, and perceived control, act as precursors of behavior that ultimately influence the actual behavior. As a whole, this framework proposed that teachers will adapt and enhance their teaching of science topics only if they believe science is relevant and vital, have favorable attitudes toward these subjects, and view themselves to be competent in teaching them without relying on too many context elements (van Aalderen-Smeets et al., 2012).

The hypothesized model of the study is presented in Figure 1, showing the variables that contribute to the science curriculum implementation of secondary science teachers in Region XII. The hypothesized model

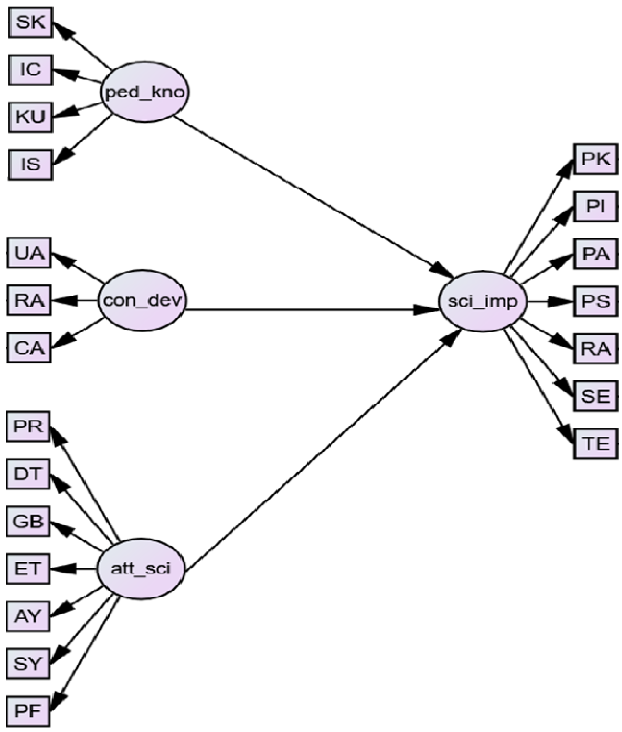

Figure 1: Hypothesized Structural Equation Model of Pedagogical Content Knowledge, Continuing Professional Development, and Teachers' Attitude Toward Science and Science Curriculum Implementation

Legend:
ped_kno - Pedagogical Content Knowledge
SK - Subject Matter Knowledge
IC - Instructional Objective and Context
KU - Knowledge of Students' Understanding
IS - Instructional Representation and Strategies

att_sci - Attitude Toward Science
PR - Perceived Relevance
DT - Difficulty of Science Teaching
GB - Gender-stereotypical Beliefs
ET - Enjoyment
AY - Anxiety
SY - Self-efficacy
PF - Perceived Dependency on Context Factors

con_dev - Continuing Professional Development
UA - Updating Activities
RA - Reflective Activities
CA - Collaborative Activities

sci_imp – Science Curriculum Implementation
PK - Professional Knowledge
PI - Professional Attitude and Interest
PA - Professional Adequacy
PS - Professional Support
RA - Resource Adequacy
SE - School Ethos
TE - Time

comprises two types of latent constructs, namely exogenous and endogenous variables. The exogenous variables of this study are pedagogical content knowledge, continuing professional development, and attitude toward science, whereas the endogenous variable is science curriculum implementation. Each latent construct will be associated with multiple measures or observed variables because the latent variables are not measured directly. Thus, the extent of the regression paths from the latent variables to the observed variables is one of the primary interests of this study.

The first exogenous variable is pedagogical content knowledge adapted from Jang et al. (2009), which has four indicators: *subject matter knowledge, instructional representation and strategies, instructional objective and context*, and *knowledge of students' understanding*. *Subject matter knowledge* refers to how a teacher comprehends a particular subject matter and the concepts inside the discipline. *Instructional representations and strategies* direct how teachers select and use models such as analogies, metaphors, examples, and explanations to make lessons understandable to students. *Instructional objectives and context* refer to teachers' understanding of the goals and processes of education as well as the curriculum's interactive atmosphere, school setting, and instructional values. Finally, *knowledge of students understanding* pertains to teachers' awareness of students' understanding of the lesson, including their prior knowledge, during instruction and knowledge learned at the end of the class.

The second exogenous variable is continuing professional development from the viewpoint of De Vries et al. (2013), which includes three indicators: *updating, reflective,* and *collaborative activities*. *Updating activities* involve participation in courses, workshops, conferences, and training, within or outside the school as well as reading professional literature, new textbooks, and educational websites. *Reflective activities* involve critically examining current knowledge, beliefs, ideas, and actions regarding teaching and learning to improve instructional practices. *Collaborative activities* are about working with colleagues for purposes like discussing classroom challenges, sharing instructional materials, developing educational materials, and team teaching.

The last exogenous variable is the attitude toward science adopted by van Aalderen-Smeets and Walma van der Molen (2013) with the following indicators: *perceived relevance,* the *difficulty of science teaching, gender-stereotypical beliefs, enjoyment, anxiety, self-efficacy,* and *perceived dependency on context factors*. *Perceived relevance* refers to teachers' views of the importance of teaching science. The *difficulty of science teaching* denotes whether teachers view science as complex. *Gender-stereotypical beliefs* pertain to perceptions of gender disparities connected with teaching science and differences between boys and girls concerning science. *Enjoyment* refers to the positive experiences that teachers have regarding teaching science. *Anxiety* refers to the negative experiences of teachers when teaching science. *Self-efficacy* describes teacher's belief in their ability to do a specific task, like teaching science. Finally, *perceived dependency on context factors* pertain to teachers' beliefs and feelings about the influence of external factors on teaching science.

The endogenous variable is science curriculum implementation adapted from Lewthwaite (2001) with indicators: *professional knowledge, professional attitude and interest, professional adequacy, professional support, resource adequacy, school ethos,* and *time. Professional knowledge* refers to teachers' views of their knowledge and understanding of science as part of the curriculum. *Professional attitude and interest* pertain to teachers' perceptions of their attitudes and interest regarding science and the teaching of science. *Professional adequacy* refers to how teachers view their aptitude and competency to teach science. *Professional support* relates to the resources available to teachers in the delivery of science from both inside and outside the school. *Resource adequacy* pertains to the sufficiency of equipment, facilities, and other resources needed to teach science. *School ethos* reflects the beliefs about science as a curricular area and the importance of science as acknowledged by staff, school administration, and the community. Finally, *time* corresponds to the time available to prepare and deliver science as a subject area.

In the context of Philippine science education, while various research exists that delve into the science curriculum, much of these existing studies have been targeted at the issues that Filipino science teachers experienced while delivering the science curriculum (Dunton & Co, 2019; Gonzales, 2019; Mangali et al., 2019). It is imperative to focus on how teachers implement the science curriculum and the factors that may influence the delivery of the curriculum. In addition, the researcher has yet to come across a concrete structural equation model on science curriculum implementation in the local setting considering science teachers' pedagogical content knowledge, continuing professional development, and attitude toward science, thus the study's urgency.

In this connection, the study aims to determine the best-fit model for science curriculum implementation of science teachers in Region XII. Specifically, the study seeks to attain the following objectives: First, to assess science teachers' level of pedagogical content knowledge in terms of subject matter knowledge, instructional representation and strategies, instructional objective and context, and knowledge of students' understanding. Second, to assess science teachers' level of continuing professional development in terms of updating, reflective, and collaborative activities. Third, to determine the level of teachers' attitude toward science in terms of perceived relevance, the difficulty of science teaching, gender-stereotypical beliefs, enjoyment, anxiety, self-efficacy, and perceived dependency on context factors. Fourth, to determine the level of science teachers' science curriculum implementation in terms of professional knowledge, professional attitude and interest, professional adequacy, professional support, resource adequacy, school ethos, and time.

In addition, this study also seeks to determine the significant relationship between pedagogical content knowledge and science curriculum implementation, continuing professional development and science curriculum implementation, and attitude toward science and science curriculum implementation. Furthermore, it aims to determine which exogenous variables best influence science curriculum implementation. Finally, this study seeks to select the model that best fits the science curriculum implementation of science teachers.

The findings of this study will contribute meaningfully to the existing literature under investigation, as well as the relationships of these constructs. In addition, science and technology advancements have undeniably aided economic growth and prosperity. Scientific breakthroughs and technological innovations have helped humanity handle some of the world's most pressing issues, including public health, global climate change, energy development, food security, and economic and social prosperity, to name a few. These are part of sustainable development's social, economic, and environmental dimensions. Thus, it is imperative to ensure the delivery of quality science education to all schools around the world.

Moreover, the dismal performance of Filipino students in international assessments like the PISA and TIMSS has sparked debates on the effectiveness of the delivery of basic education curricula in the country. The result of this study will provide relevant data to support the ongoing efforts of the Department of Education to improve science education in the country. Likewise, this study will be beneficial for reviewing the K to 12 curricula, providing need-based in-service professional development, informing policy and strategic planning, and other academic and administrative support necessary to ensure effective science teaching.

In addition, as central figures in implementing the curriculum, teachers will significantly benefit from this study. Aligning the implemented curriculum to the prescribed standards is crucial for effective and quality science instruction. In the delivery of science education, teachers should be able to facilitate interdisciplinary approaches, contextualized learning, and integrate problem-based and inquiry-based learning. It is also critical that teachers can translate the knowledge to students in an understandable way. Hence, teachers should have adequate pedagogical content knowledge, undergo sustained and transformative professional development, and demonstrate positive attitudes toward the curriculum. This study will provide a venue for teachers to reflect and assess their teaching competence and developmental needs and use this to inform and guide them to enhance teaching quality, which is crucial for students' learning gains.

Furthermore, the study is deemed necessary for the learners. With the aim of science education to develop scientifically literate learners, aligning the implemented curriculum with the intended curriculum is crucial. Suppose fidelity in curriculum implementation is evident in the classrooms. In that case, science education will aim to produce learners who possess scientific knowledge, competencies, skills, and attitudes that they need to confront challenges in real-life situations. Finally, this study will provide critical findings crucial to future researchers investigating curriculum reforms, innovations, and other similar in-depth related studies.

2. Method

This part of the paper presents the description of the research respondent, materials and instrument, and design and procedure.

2.1 Research Respondents

The respondents of this study were high school teachers teaching science subjects in public secondary schools of Region XII, chosen from a total population of 2,497 science teachers for the school year 2021-2022. This study determined a sample size of 400, more than the minimum required by the Raosoft formula, with a 5% margin of error and a 95% confidence level. For structural equation modeling (SEM), a sample size greater than 200 provides sufficient statistical power for data analysis (Kline, 2016; Singh et al., 2016). The number of respondents that comprised the sample was taken from the eight-division offices of Region XII specified as follows: one hundred three (103) from Cotabato, eighty-two (82) from South Cotabato, sixty-seven (67) from Sarangani, sixty-six (66) from Sultan Kudarat, fifty-two (52) from General Santos City, fourteen (14) from Koronadal City, nine (9) from Kidapawan City, and seven (7) from Tacurong City.

The study utilized stratified random sampling in choosing the respondents, where multiple subgroups have shared characteristics (Etikan & Bala, 2017; Sharma, 2017). In this case, the study obtained a representative sample from each of the eight divisions of Region XII to generate the sample size of four hundred science teachers. This sampling process reduced the human bias in selecting the respondents. Thus, this sampling method is preferred because it generates a sample highly representative of the population, allowing for accurate generalizations about the population under study (Sharma, 2017).

The inclusion criteria of this study involved all high school teachers teaching science subjects in public secondary schools of Region XII regardless of their age, gender, and ethnic backgrounds. The researcher believed that they are the population most fit to be the study's respondents because of their field of specialization and experience, which are relevant and appropriate considering the study's objectives.

On the other hand, the study excluded those not teaching science subjects in public secondary schools, teachers teaching in private schools, and all those beyond Region XII. If the respondents feel uncomfortable, they can decline or withdraw participation during the study. If a respondent decides to stop participating in the study for any reason, this will not result in a penalty or a loss of benefits.

The locale of the study was Region XII-SOCCSKSARGEN which covers the southern-central part of Mindanao and encompasses four provinces: Cotabato, Sarangani, South Cotabato, and Sultan Kudarat, as well as four cities, namely General Santos, Koronadal, Tacurong, and Kidapawan City. The town of Koronadal serves as the regional hub. Northern Mindanao bounds the region on the north, the Davao Region on the east, and the Celebes Sea on the southwest.

The entire land area of Region XII is 19 165.87 square kilometers accounting for around 17% of Mindanao's total land area. Cotabato Province is the region's most extensive of the four provinces, with approximately 30.4 percent of the total land area, while Sultan Kudarat is the region's smallest province. General Santos City, on the other hand, has the largest land area of the five cities in the region, while Tacurong City has the smallest.

2.2 Materials and Instrument

This study utilized four adapted-modified questionnaires as research instruments. All the survey questionnaires were modified according to their relevance to the study, underwent validation from a pool of experts, and got an average rating of 4.64 which means very good. Afterward, the questionnaires were pilot-tested using Cronbach's alpha to measure their internal consistency. The survey instrument for pedagogical content knowledge had Cronbach's alpha coefficient of .956, continuing professional development with a coefficient of .974, attitude toward science with a coefficient of .897, and science curriculum implementation with a coefficient of.981, which justified their internal consistency and reliability as survey instruments in the study.

The first instrument measured the pedagogical content knowledge of secondary science teachers in Region XII adapted from the Assessment of Teachers' Pedagogical Content Knowledge (ATPCK) developed by Jang et al. (2009) and modified based on the need of the study. The ATPK instrument is a 28-item inventory divided into four indicators: subject matter knowledge, instructional representation and strategies, instructional objective and context, and knowledge of students' understanding. The second instrument measured the secondary science teachers' continuing professional development, adapted from De Vries et al. (2013) and modified according to the need of the study. The research instrument is a 40-item inventory covering three indicators: updating, reflective, and collaborative activities.

The third instrument measured the science teachers' attitude toward science adapted from the Dimensions of Attitude Toward Science (DAS) instrument developed by van Aalderen-Smeets and Walma van der Molen (2013) and modified according to the need of the study. The research instrument is a 28-item inventory that covered seven indicators: perceived relevance, the difficulty of science teaching, gender-stereotypical beliefs, enjoyment, anxiety, self-efficacy, and perceived dependency on context factors. Each choice will have a numerical value, description, and corresponding interpretation.

The last instrument measured the secondary science teachers' level of science curriculum implementation adapted from the Science Curriculum Implementation Questionnaire (SCIQ) developed by Lewthwaite (2001) and modified according to the need of the study. The research instrument is a 49-item inventory that covers seven indicators: professional knowledge, professional attitude and interest, professional adequacy, professional support, resource adequacy, school ethos, and time.

The study used a scale to measure science teachers' pedagogical content knowledge, continuing professional development, attitude toward science, and science curriculum implementation. A mean of 4.20 to 5.00 has a descriptive level of very high, indicating that science teachers always observed the indicators of pedagogical content knowledge, continuing professional development, attitude toward science, and science curriculum implementation. A mean of 3.40 to 4.19 is high or often observed; 2.60 to 3.39 is moderate or sometimes observed; 1.80 to 2.59 is low or seldom observed; and 1.00 to 1.79 is very low or never observed.

2.3 Design and Procedure

This study utilized a quantitative non-experimental research design through a correlational technique. This type of research design involves measuring the degree of association between or among variables using correlational analysis (Creswell, 2012). In this study, the researcher did not manipulate the variables but only observed them and measured the relationship between the exogenous and endogenous variables. This research design was appropriate because it uses statistical analysis to yield results that describe the relationship between the variables of the study.

The study also employed structural equation modeling (SEM), a multivariate technique to examine structural relationships between measured variables and latent constructs. It involves a combination of confirmatory factor analysis and path analysis. The confirmatory factor analysis measured the associations among latent or unobserved variables, while path analysis measured the causal relationship among variables through a path diagram (Fan et al., 2016). In addition, SEM also involves model conceptualization, parameter identification and estimation, data-model fit assessment, and potential model re-specification (Mueller & Hancock, 2019). The study utilized structural equation modeling to measure the relations among latent or unobserved variables by creating a path diagram and generating the best-fit model for science curriculum implementation. These statistical methods measured pedagogical content knowledge, continuing professional development, attitude toward science, and science curriculum implementation of public secondary science teachers in Region XII.

To determine the best-fit model, all the values of the different indices must fall within the accepted criterion, which is as follows: Chi-Square or Degrees of Freedom (CMIN/DF) is 0 <value< 2, the p-value is > .05, Normed Fit Index (NFI) value is > .95, Tucker-Lewis Index (TLI) value is > .95, Comparative Fit Index (CFI) value is > .95, Goodness of Fit Index (GFI) value is > .95, Root Mean Square of Error Approximation (RMSEA) value is < .05, and P of Close Fit (P-close) value is >.05.

Data collection began with the appropriate research instruments needed for the study. The research instruments were presented to the research adviser for comments and subsequently validated by the panel of experts. The four survey questionnaires were subjected to validation by four member-panel of experts of the Professional Schools of the University of Mindanao and one expert from outside of the University using the validation sheets secured from the University of Mindanao Professional Schools. After obtaining approval and endorsement from all the panel members, the researcher submitted the pertinent documents to the University of Mindanao Ethics Review Committee (UMERC) for ethics review.

After that, with the issuance of a compliance certificate for study ethics protocol review from the University of Mindanao Ethics Review Committee (UMERC), the researcher conducted pilot testing on 30 science teachers. The pilot test received an acceptable value of Cronbach's alpha which ensured the consistency and reliability of the survey instruments. Next, the researcher wrote letters asking permission to conduct the study. The letters, signed by the Research Adviser and Dean of the Professional Schools, were addressed to the Regional Director and Schools Division Superintendents. Due to restrictions brought by the COVID-19 pandemic during the study, the researcher collected data online using Google Forms. The researcher disseminated the online Google Form link to the different division offices and the digital copy of the approved letters and information regarding the study. The researcher also obtained the consent of the respondents.

After completing the survey, all 400 responses were accounted for, collected, collated, and tallied for statistical analysis. The researcher secured the data collected to ensure confidentiality, safeguarded the respondents' identifying information, and saved all information and data on a password-protected computer. Alternatively, if for a good purpose, the information that might identify the respondents, such as their names and other identifying features, will be removed. Ultimately, the researcher deleted the records of responses so there would be no possibility of information reconstruction.

The researcher tabulated the data in an Excel spreadsheet and emailed it to the statistician for statistical analysis using mean, Pearson product-moment correlation, multiple regression, and structural equation modeling. After being subjected to statistical analysis, the statistician forwarded the results to the researcher for interpretation.

The researcher strictly adhered to the ethical standards in the study and received the certification number. The researcher ensured that the respondents' participation was voluntary, kept personal information confidential, obtained an informed consent form, and informed respondents of the risks and benefits associated with the study. In addition, the researcher established proper coordination and communication with the appropriate recruiting parties and acquired permission from the top management before gathering the data. Likewise, the researcher utilized Turnitin software to avoid plagiarism of literature cited in the paper, ensured there was no fabrication and falsification of data, no trace of conflict of interest, no deception or acts of dishonesty, and took proper measures to avoid any technology-related issues. Finally, the researcher whose name appeared in this paper has made a significant contribution to the idea and design, data gathering, data analysis, and interpretation with the support and guidance of the research adviser.

3. Results and Discussion

This section presents a comprehensive description and interpretation of the data on pedagogical content knowledge, continuing professional development, teachers' attitudes toward science, and science curriculum implementation and the implication of the study's findings. The first part presents the level of pedagogical content knowledge, continuing professional development, teachers' attitudes toward science, and science curriculum implementation.

The second part describes the correlation between pedagogical content knowledge, continuing professional development, and teachers' attitude toward science in their science curriculum implementation. The next part displays the variables that best influence science curriculum implementation of science teachers, and the last part shows the structural model that best fits science curriculum implementation.

3.1 Pedagogical Content Knowledge

Presented in Table 1 is the summary of science teachers' level of pedagogical content knowledge, specifically, subject matter knowledge, instructional representation and strategies, instructional objective and context, and knowledge of students' understanding. The overall standard deviation of 0.38 was less than 1.00, which indicated that the respondents' responses were consistent. The respondents' answers recorded an overall mean score of *4.53*, which is *very high*. The result showed that science teachers always manifested pedagogical content knowledge. Taken individually, instructional representation and strategies recorded the highest mean score of *4.56,* which is *very high*. At the same time, subject matter knowledge received the lowest mean score of *4.50* but is still considered *very high*.

Table 1

Level of Pedagogical Content Knowledge of Science Teachers

Indicators	SD	Mean	Descriptive Level
Subject Matter Knowledge	0.42	4.50	Very High
Instructional Representation and Strategies	0.41	4.56	Very High
Instructional Objective and Context	0.42	4.55	Very High
Knowledge of Students' Understanding	0.43	4.53	Very High
Overall	**0.38**	**4.53**	**Very High**

The science teachers' subject matter knowledge, instructional representation and strategies, instructional objective and context, and knowledge of students' understanding resulted in their very high level of pedagogical content knowledge. Science teachers manifested a very high level of pedagogical content knowledge by providing opportunities for students to express their views during class and using multimedia and appropriate examples to explain concepts related to the subject matter. The use of instructional strategies and representations by science teachers, a component of pedagogical content knowledge, is aligned with the view of Suh and Park (2017) that teachers' understanding of instructional strategies and representations, which include analogies, metaphors, examples, and explanations provide a tangible link to their orientations toward teaching science.

Additionally, science teachers displayed a very high level of pedagogical content knowledge by helping their students understand the objectives of the subject and coping with the classroom context appropriately, which supported the idea of Carlson et al. (2019) that the learning context or setting in which a teacher works can have a significant impact on the teaching and learning that occurs. The present study also revealed that teachers consider students' prior knowledge before class and use different approaches to determine whether students understand the discussion. This result supported the findings of Chen et al. (2020), which emphasized that teachers must be aware of the ideas that students bring into the class and address any misconceptions that exist, ultimately helping students reconceptualize their knowledge of a concept more quickly and achieve a greater understanding.

In the same manner, knowing the content they are teaching and selecting the appropriate content for their students contributed to the science teachers' very high level of pedagogical content knowledge. This result reinforced the idea of Lucero et al. (2017) and Mosabala (2018) that pedagogical content knowledge encompasses the facts, concepts, principles, theories, and procedures in a specific discipline from which teachers draw the knowledge they use in classroom instruction and how they transform this knowledge of particular topics into forms that students can easily comprehend. The study's findings agreed with Kulgemeyer and Riese (2018) and Lucenario et al. (2016) that teachers' pedagogical content knowledge accounts for the quality of instruction students get and is an indispensable factor for teachers to be effective in the delivery of instruction.

3.2 Continuing Professional Development
Presented in Table 2 is the summary of science teachers' level of continuing professional development in terms of updating activities, reflective activities, and collaborative activities. The overall standard deviation of 0.51 was less than 1.00, which indicated that the respondents' responses were consistent. The overall mean score was *4.15*, which is *high*, showing that science teachers often manifested most of the items regarding continuing professional development. In particular, updating activities registered the highest mean score of *4.17*, labeled as *high*, followed by collaborative activities with a mean score of *4.14*, labeled as *high*, and lastly, reflective activities with a mean score of *4.13*, labeled as *high*. The results indicated that science teachers often manifest all three indicators.

Table 2
Level of Continuing Professional Development of Science Teachers

Indicators	SD	Mean	Descriptive Level
Updating Activities	0.51	4.17	High
Reflective Activities	0.59	4.13	High
Collaborative Activities	0.58	4.14	High
Overall	**0.51**	**4.15**	**High**

The high level of continuing professional development resulted from science teachers' updating, reflective, and collaborative activities. Specifically, science teachers demonstrated high continuing professional development by participating in schooling and training sessions within the school, professional development activities outside the school, and one-on-one coaching and mentoring in the school. The findings confirmed the earlier study of Borg (2018) and Cirocki and Farrell (2019) that continuing professional development includes participation in courses, workshops, seminars, and formal qualification programs, as well as collaboration between schools and teachers in the form of coaching or mentoring to share their best instructional practices and introduce new teaching practices and effective classroom management techniques.

Moreover, science teachers exhibited their high continuing professional development by sharing their learning experiences with colleagues, discussing teaching problems, and supporting them in their teaching problems. The finding of the study agrees with Zhukova (2018) that mentorship, collegial advice, discussions, and support are essential to improving and maintaining teaching because collaborative work allows teachers to analyze and evaluate their pedagogical ideas and strategies, as well as gain a better understanding of their teaching effectiveness.

Furthermore, science teachers also displayed a high level of continuing professional development by analyzing their class discussions to improve their teaching practice and reflecting on their lessons after the class. This finding agrees with the view of Farrell (2020) that teachers should remember and systematically collect information from their classroom practices and utilize them to make educated decisions to improve their teaching. Likewise, it validated the idea of Aldahmash et al. (2017) that teachers critically examine and analyze their classroom practices to gain helpful information to modify their teaching activities as needed. With this, as asserted by Derakhshan et al. (2020) and Osamwonyi (2016), the educational sector should initiate professional development programs that are practical, relevant, and address the actual needs of teachers in a given classroom setting.

3.3 Attitude Toward Science
Presented in Table 3 is the summary of teachers' level attitudes toward science, measured in terms of perceived relevance, the difficulty of science teaching, gender-stereotypical beliefs, enjoyment, anxiety, self-efficacy, and perceived dependency on context factors. The overall standard deviation of 0.42 was less than 1.00, which indicated that the respondents' responses were consistent. The overall mean score was *3.69*, considered *high*, suggesting that science teachers often manifested most of the items regarding attitude toward science. Notably, perceived relevance received the highest mean score of *4.81*, described as *very high*, indicating that science teachers always manifest this indicator. In contrast, anxiety received the lowest mean score of *2.20*, considered *low*, indicating that science teachers seldom display this indicator.

Table 3
Level of Teachers' Attitude toward Science

Indicators	SD	Mean	Descriptive Level
Perceived Relevance	0.36	4.81	Very High
Difficulty of Science Teaching	0.99	3.50	High
Gender-stereotypical Beliefs	1.10	2.44	Low
Enjoyment	0.49	4.66	Very High
Anxiety	0.94	2.20	Low
Self-efficacy	0.52	4.21	Very High
Perceived Dependency on Context Factors	0.74	4.02	High
Overall	**0.42**	**3.69**	**High**

The high attitude toward science was because science teachers perceived science as relevant, felt a sense of enjoyment when teaching science, and showed very high self-efficacy. The teachers perceived that science education is essential for students' development. This finding is consistent with the report of the OECD (2020) that science education has the potential to support and equip young people with skills, knowledge, and attitudes that will help them overcome many of the challenges that will confront them in the coming years. In this connection, teachers believed that it is vital that inexperienced teachers should receive additional training in science, which supported the findings of Albornoz et al. (2019), who concluded that teachers with little prior experience in teaching science should get support from pedagogical coaches during training sessions to become experts at teaching cognitively demanding tasks.

The result of the present study also reflected teachers' high enjoyment, happiness, and enthusiasm when teaching science. These findings align with Ualesi and Ward (2018), confirming that teachers' joy and passion for teaching science positively influence their attitudes toward teaching science. Similarly, teachers manifested very high self-efficacy, which is evident in their belief that they have enough knowledge of science content to teach well in school, help students make progress when they cannot solve science assignments, and have the ability to deal with students' questions. This finding is in harmony with the critical review of Morris et al. (2017), which revealed that teachers' knowledge, such as content, pedagogical, and technological expertise, and evaluation of this knowledge underpinned their efficacy beliefs. Importantly, teachers' self-efficacy views, as confirmed by Chan and Lay (2021), Emre and Ünsal (2017), and Senler (2016), were found to influence their attitudes toward teaching significantly.

The study also showed that science teachers have a high context dependency, such as the availability of a ready-to-use existing package of materials essential to teaching science. This finding contributed to the literature of Nordlöf et al. (2019) and Ualesi and Ward (2018), who unveiled those teachers expressed positive feelings when there is a provision of resources such as classrooms, textbooks, and learning materials and access to science laboratories with equipment needed to conduct practical experiments.

On the one hand, science teachers reported difficulty in science teaching because they found the topics in science complicated, which pointed to a need for more subject matter knowledge in a specific scientific field. This finding added evidence to the existing literature by Malicoban et al. (2021) and Rebucas and Dizon (2020), who asserted that teachers experienced difficulty teaching outside their area of expertise because they specialized in one field. As a result, De Ramos-Samala (2018) and Nixon et al. (2017) argued that teachers are unlikely to have adequate subject matter knowledge to teach science disciplines that are not their area of expertise. Putting this in the Philippine context, Orbe et al. (2018) claimed that this is challenging for science teachers because of the spiral curriculum, which requires teachers to teach different science disciplines.

On the other hand, science teachers reported a low level of gender-stereotypical beliefs, indicating that regardless of gender, they believed they could do an investigation or technical assignment with students easily and experience enjoyment in teaching science. In addition, science teachers believe that choosing a student for science demonstration, enthusiasm about experimenting and choosing science-related assignments did not differ between male and female students. These results confirmed the earlier findings of E. Santos and R. Santos (2020) and Doornkamp et al. (2022) that students receive equal opportunity and treatment in the classroom, regardless of their gender.

However, despite efforts for gender equity, the gender gap in STEM fields permeates. For instance, the earlier findings of Barth and Masters (2020), Dom and Yi (2018), and Makarova et al. (2019) revealed that female students perceived physics, chemistry, and math classes as a male domain, which may have an impact on both young men and women's aspirations to study in STEM fields at universities. On a positive note, science teachers reported a low level of anxiety, signifying that teachers were less likely to feel nervous and stressed when teaching science. This finding is vital because results from the previous study of Senler (2016) revealed that teachers who are anxious about teaching also lack confidence in their abilities to teach science effectively and pointed out that anxiety may result in a negative attitude toward science education.

3.4 Science Curriculum Implementation

Presented in Table 4 is the summary of the level of teachers' science curriculum implementation, measured in terms of professional knowledge, professional attitude and interest, professional adequacy, professional support, resource adequacy, school ethos, and time. The overall standard deviation of 0.45 was less than 1.00, which indicated that the respondents' responses were consistent. The overall mean score was *4.24*, considered *very high*, suggesting that the science teachers always manifested most of the items regarding science curriculum implementation. When taken individually, professional attitude and interest recorded the highest mean score of *4.64*, which is *very high*. At the same time, resource adequacy received the lowest mean score of *3.82*, which is still considered *high*.

The very high level of science curriculum implementation resulted from science teachers' professional knowledge, professional attitude and interest, professional adequacy, professional support, resource adequacy, school ethos, and time. Teachers' professional attitudes and interests influence science curriculum implementation. They considered science a subject they wanted to teach and expressed positive attitudes towards teaching science and its inclusion in the school curriculum. This result confirmed the previous findings of Caroline (2017) and Thibaut et al. (2018) that teachers' attitude favorably impacts the implementation of instructional practices. Additionally, professional adequacy contributed to science curriculum implementation in which teachers believed they were adequately prepared and competent and manifested a confident and positive self-image in their ability to teach science. This result is similar to the findings of Lindqvist et al. (2017) that feelings of competence, confidence, and preparedness while doing teaching duties are manifestations of one's professional adequacy.

Table 4

Level of Science Curriculum Implementation of Science Teachers

Indicators	SD	Mean	Descriptive Level
Professional Knowledge	0.50	4.29	Very High
Professional Attitude and Interest	0.46	4.64	Very High
Professional Adequacy	0.52	4.41	Very High
Professional Support	0.59	4.25	Very High
Resource Adequacy	0.75	3.82	High
School Ethos	0.62	4.20	Very High
Time	0.63	4.06	High
Overall	**0.45**	**4.24**	**Very High**

In like manner, essential to curriculum implementation is teachers' professional knowledge displayed in their understanding of the scientific knowledge, skills, and attitudes needed in teaching, strategies known to be effective for teaching science, and a clear understanding of the science curriculum. The fact that teachers are responsible for implementing the curriculum in the classroom, this finding supports Alsubaie's (2016) contention that teachers' knowledge, experiences, and competencies are crucial to any curriculum development effort. In this connection, Karakuş (2021) added that for teachers to interpret and implement the curriculum appropriately, educational institutions should allow them to advance their professional knowledge and abilities.

Moreover, professional support as manifested by teachers' ongoing professional or in-service development activities confirmed previous studies by Buttram and Farley-Ripple (2016), Hsu et al. (2020), and Zhang et al. (2017) that such activities offer teachers with academic, technical, emotional, and reflective support. Additionally, this follows previous findings of Syomwene (2018) and Thomas et al. (2019) that support from colleagues helps teachers develop successful teaching strategies, allows sharing ideas, debating current educational concerns, engaging in some informal problem-solving, and addressing work-related issues.

Besides, the respondents expressed that their school's senior management recognized the importance and the position of science as a fundamental subject in the curriculum, which positively influences how they teach science. This result contributed to the previous findings of Furiwai and Singh-Pillay (2020) that teaching and learning culture as a critical aspect of the school's ethos and management significantly impacts the implementation of science education.

While previous research by Fitzgerald et al. (2019), Heba et al. (2017), and Margot and Kettler (2019) revealed that the most significant teachers experience in the delivery of science curriculum is insufficient time, especially in the context of inquiry-based instruction, the respondents of this study expressed that they have enough time allocated to teach the requirements of the science curriculum. This inconsistency must be explored in future research, considering the instruction context may differ. Regarding resource adequacy, which reported a high mean yet comparatively lower than other science curriculum implementation indicators, the respondents conveyed that they have ready access to science materials and resources.

This experience may not be accurate for other science teachers, as evident in previous studies by Boakye and Ampiah (2017), Yeboah et al. (2019), and Zengele and Alemayehu (2016) that many developing countries have no access to all science resources that teachers need in teaching science. This is consistent with the earlier findings of Hadji Abas and Marasigan (2020), Orbe et al. (2018), and Sadera et al. (2020) that in the Philippines, lack of laboratory room, insufficient laboratory facilities, malfunctioning laboratory equipment, and inadequate learning materials are all typical problems which resulted to students missing out on actual science experiments.

3.5 Significance of the Relationship between Pedagogical Content Knowledge and Science Curriculum Implementation of Science Teachers

Presented in Table 5.1 are the results of the test of the relationship between pedagogical content knowledge and science curriculum implementation of science teachers. The overall correlation coefficient of .683 with a p-value less than the 0.05 level of significance implied the rejection of the null hypothesis. It means a significant relationship exists between pedagogical content knowledge and the science curriculum implementation of science teachers. Specifically, the correlation of the indicators of pedagogical content knowledge to science curriculum implementation resulted in a significant relationship, with subject matter knowledge having a correlation coefficient of .625, instructional representation and strategies with .569, instructional objective and context with .649, and knowledge of students' understanding with .622.

Table 5.1

Significance of the Relationship between Pedagogical Content Knowledge and Science Curriculum Implementation of Science Teachers

Pedagogical Content Knowledge	**Science Curriculum Implementation**							
	Professional Knowledge	Professional Attitude and Interest	Professional Adequacy	Professional Support	Resource Adequacy	School Ethos	Time	**Overall**
Subject Matter Knowledge	.640**	.573**	.651**	.502**	.306**	.403**	.428**	**.625****
	.000	.000	.000	.000	.000	.000	.000	**.000**
Instructional Representation and Strategies	.535**	.590**	.551**	.447**	.275**	.415**	.377**	**.569****
	.000	.000	.000	.000	.000	.000	.000	**.000**
Instructional Objective and Context	.616**	.625**	.629**	.521**	.321**	.476**	.439**	**.649****
	.000	.000	.000	.000	.000	.000	.000	**.000**
Knowledge of Students' Understanding	.570**	.576**	.584**	.498**	.320**	.466**	.446**	**.622****
	.000	.000	.000	.000	.000	.000	.000	**.000**
Overall	**.654****	**.654****	**.669****	**.545****	**.339****	**.488****	**.468****	**.683****
	.000	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**	**.000**

Likewise, the correlation of the indicators of science curriculum implementation with pedagogical content knowledge yielded a significant relationship, with professional knowledge having a correlation coefficient of .654, professional attitude and interest with .654, professional adequacy with .669, professional support with .545, resource adequacy with .339, school ethos with .488, and time with .468.

The study revealed a significant relationship between teachers' pedagogical content knowledge and science curriculum implementation which is consistent with the previous finding of Moosa and Shareefa (2019) that implementing the curriculum requires teachers to have pedagogical content knowledge such as awareness of how they may modify the learning content, teaching methods, and learning environment to match students' learning backgrounds. In a similar case, the result of the current study supplemented Suh and Park's (2017) findings that a solid foundation for the sustained implementation of the curriculum is teachers' knowledge of students' understanding as well as their knowledge of instructional strategies and representations. This idea signifies that teachers' knowledge, skills, and competencies as curriculum implementers are integral to curriculum implementation. With this, teachers should receive relevant professional development programs to prepare them for implementing the intended curriculum.

3.6 Significance of the Relationship between Continuing Professional Development and Science Curriculum Implementation of Science Teachers

Presented in Table 5.2 are the results of the test of the relationship between continuing professional development and science curriculum implementation of science teachers. The overall correlation coefficient of .646 with a p-value lower than the 0.05 level of significance implied the rejection of the null hypothesis. This finding suggests a significant relationship between continuing professional development and science curriculum implementation by science teachers. Taken individually, the correlation of the indicators of continuing professional development with science curriculum implementation showed a significant relationship at 0.05 level of significance, with updating activities having a correlation coefficient of .609, reflective activities with a correlation coefficient of .590, and collaborative activities with a correlation coefficient of .579.

Table 5.2

Significance of the Relationship between Continuing Professional Development and Science Curriculum Implementation of Science Teachers

Continuing Professional Development	**Science Curriculum Implementation**							
	Professional Knowledge	Professional Attitude and Interest	Professional Adequacy	Professional Support	Resource Adequacy	School Ethos	Time	**Overall**
Updating Activities	.563** .000	.428** .000	.549** .000	.528** .000	.391** .000	.421** .000	.454** .000	**.609**** **.000**
Reflective Activities	.493** .000	.367** .000	.467** .000	.510** .000	.433** .000	.418** .000	.491** .000	**.590**** **.000**
Collaborative Activities	.482** .000	.335** .000	.456** .000	.527** .000	.437** .000	.431** .000	.445** .000	**.579**** **.000**
Overall	**.557**** **.000**	**.409**** **.000**	**.533**** **.000**	**.569**** **.000**	**.460**** **.000**	**.462**** **.000**	**.506**** **.000**	**.646**** **.000**

Similarly, the correlation of the indicators of science curriculum implementation with continuing professional development showed a significant relationship, with professional knowledge having a correlation coefficient of .557, professional attitude and interest at .409, professional adequacy at .533, professional support at .569, resource adequacy at .460, school ethos at .462, and time at .506.

The findings indicated a significant relationship between continuing professional development and science curriculum implementation, which is congruent with the conclusions of Madani and Forawi (2019), Mamlok-Naaman, (2017), and Marshall et al. (2017) that teachers supported by transformative continuing professional development activities could effectively implement the curriculum. These will equip teachers with the knowledge and skills needed to implement the curriculum and update them with new scientific breakthroughs, curriculum materials, and teaching techniques.

Likewise, the findings of the present study are in agreement with Marshall et al. (2017) findings that a crucial first step in successfully putting an inquiry-based science curriculum into practice is teachers' participation in a continuous professional development intervention aimed at improving guided inquiry-based instruction in science classrooms, which enhances students' capacity to learn science concepts and scientific practices, and Madani and Forawi's (2019) findings that administrators should encourage teachers' involvement in professional development activities to implement the science curriculum successfully. Additionally, administrators must be sensible about teachers' challenges while implementing innovative approaches and offer professional development support to help them overcome these barriers.

3.7 Significance of the Relationship between Teachers' Attitude Toward Science and Science Curriculum Implementation

Presented in Table 5.3 is the significance of the relationship between science teachers' attitudes toward science and science curriculum implementation. The result indicated a significant relationship between attitude toward science and science curriculum implementation, with an overall correlation coefficient of .292 and a p-value lower than the 0.05 level of significance, suggesting the rejection of the null hypothesis. The result implied a significant relationship exists between teachers' attitudes toward science and science curriculum implementation.

On the one hand, the correlation of the indicators of attitude toward science with science curriculum implementation resulted in a significant relationship, with perceived relevance at a correlation coefficient of .340, enjoyment with a correlation coefficient of .493, self-efficacy with a correlation coefficient of .674, and perceived dependency on context factors with a correlation coefficient of .193. On the other hand, the following indicators of attitude toward science are insignificant: the difficulty of science teaching with a correlation coefficient of -.005, gender-stereotypical beliefs with a correlation coefficient of .040, and anxiety with a correlation coefficient of -.042.

In the same manner, the correlation of the indicators of science curriculum implementation with attitude toward science resulted in a significant relationship significant at 0.05 level of significance, with professional knowledge having a correlation coefficient of .246, professional attitude and interest at .139, professional adequacy at .249, professional support at .266, resource adequacy at .246, school ethos at .191, and time at .227.

It can be revealed in the table that there is a significant relationship between attitude toward science and science curriculum implementation, with an overall correlation coefficient of .292 and a p-value of .000. The results are in harmony with the previous findings of McDonald et al. (2019) that the attitudes and approaches of the teachers influence the successful implementation of science education. Teachers' favorable attitudes toward science can help students develop positive attitudes toward science throughout their education and prepare them to be future leaders in the STEM profession. The current study also supported the view of Thibaut et al. (2018) that teachers' positive attitudes have a beneficial influence on the delivery of instruction and teaching practices, specifically, the incorporation of STEM material, problem-centered learning, inquiry-based learning, and cooperative learning.

Table 5.3
Significance of the Relationship between Teachers' Attitude toward Science and Science Curriculum Implementation of Science Teachers

Teachers' Attitude toward Science	Science Curriculum Implementation							
	Professional Knowledge	Professional Attitude and Interest	Professional Adequacy	Professional Support	Resource Adequacy	School Ethos	Time	**Overall**
Perceived Relevance	.327** .000	.502** .000	.345** .000	.266** .000	.105* .036	.264** .000	155** 002	**.340**** **.000**
Difficulty of Science Teaching	-.040 .419	-.044 .384	-.012 .813	.041 .418	.056 .264	-.021 .670	-.034 493	**-.005** **.923**
Gender-Stereotypical Beliefs	-.015 .772	-.168** .001	.000 .997	.084 .095	.153** .002	-.050 .314	122* 014	**.040** **.423**
Enjoyment	.497** .000	.619** .000	.560** .000	.377** .000	.156** .002	.365** .000	258** 000	**.493**** **.000**
Anxiety	-.085 .088	-.251** .000	-.153** .002	.002 .961	.111* .026	-.003 .958	033 507	**-.042** **.405**
Self-efficacy	.714** .000	.516** .000	.721** .000	.507** .000	.343** .000	.468** .000	484** 000	**.674**** **.000**
Perceived Dependency on Context Factors	.171** .001	.161** .001	.150** .003	.137** .006	.136** .006	.164** .001	136** 006	**.193**** **.000**
Overall	**.246**** **.000**	**.139**** **.005**	**.249**** **.000**	**.266**** **.000**	**.246**** **.000**	**.191**** **.000**	**.227**** **.000**	**.292**** **.000**

3.8 Significance of the Influence of Pedagogical Content Knowledge, Continuing Professional Development and Teachers' Attitude Toward Science on the Science Curriculum Implementation

Presented in Table 6 are the results of the linear regression analysis, which aimed to show the significance of the influence of pedagogical content knowledge, continuing professional development, and attitude toward science on the science curriculum implementation. The results showed that the exogenous variables significantly influenced science curriculum implementation, as indicated by the F-value of 153.296 and a corresponding p-value of .000 which implied the rejection of the null hypothesis.

The analysis generated an R^2 of .537, meaning 53.7% of the variance of science curriculum implementation resulted from the predictor variables, pedagogical content knowledge, continuing professional development, and attitude toward science. In comparison, other factors not covered in the study account for 46.3% of the variation. When examined further, the analysis showed that the standard coefficient of pedagogical content knowledge has the highest βeta coefficient of .454. This result indicated that pedagogical content knowledge has the most significant influence on science curriculum implementation compared to continuing professional development with a βeta of .331 and attitude toward science with a βeta of .045.

Table 6

Significance of the Influence of Pedagogical Content Knowledge, Continuing Professional Development and Teachers' Attitude toward Science on the Science Curriculum Implementation

		Science Curriculum Implementation			
Exogenous Variables		*B*	β	*t*	*Sig.*
Constant		.424		2.058	.040
Pedagogical Content Knowledge		.536	.454	10.043	.000
Continuing Professional Development		.290	.331	6.975	.000
Teachers' Attitude toward Science		.049	.045	1.218	.224
R	.733				
R^2	.537				
ΔR	.534				
F	153.296				
ρ	.000				

The results of the present study strengthened the previous research findings of Lucenario et al. (2016), Moosa and Shareefa (2019), and Suh and Park (2017), which claimed that teachers' pedagogical content knowledge is requisite for a successful curriculum implementation manifested in the teachers' instructional practices. Additionally, the results affirmed the views of Kulgemeyer and Riese (2018) that teachers' mastery of the pedagogical content significantly impacts the quality of instructional practices and learning that students experience in the classroom. Thus, pedagogical content knowledge in the lens of Gess-Newsome et al. (2017) underpinned teachers' understanding of how to effectively teach a given curricular content to students of various abilities and interests in specific ways that will result in improved student understanding.

In the same way, the findings showed that continuing professional development significantly influences science curriculum implementation, which supplemented the existing literature of Marshall et al. (2017) that teachers' involvement in a continuous professional development intervention is a pivotal step in implementing the science curriculum. The findings also affirmed Azevedo and Duarte's (2018) argument that providing quality in-service scientific lectures to teachers is critical to keep their skills, knowledge, and teaching practices current. The finding also supported Farrell's (2018) viewpoint that reflective activities help teachers improve their understanding of their instructional practices, become more proactive and confident when delivering lessons, and guide effective lesson planning and curriculum decision-making.

3.9 Summary of Goodness of Fit Measures of the Five Generated Models

Presented in Table 7 is the summary of the goodness of fit measures of the five generated models. Among the five generated models, model five passed the criteria for assessing the best-fit model with a p-value of 0.062, CMIN/DF value of 1.873, RMSEA value of 0.047, TLI value of .974, NFI value of .964, CFI value of .983, and GFI value of .957. Hence, model five is the best-fit model that explains the science curriculum implementation. Conversely, models one, two, three, and four fell short of the required measure for the GFI, CFI, NFI, and TLI while exceeding the standard necessary for CMIN/DF and RMSEA. In this case, models one, two, three, and four did not qualify as best-fit models.

Table 7

Summary of Goodness of Fit Measures of the Five Generated Models

Model	P-value (>0.05)	CMIN / DF (0<value <2)	GFI (>0.95)	CFI (>0.95)	NFI (>0.95)	TLI (>0.95)	RMSEA (<0.05)	P-close (>0.05)
1	.000	9.454	.682	.716	.694	.680	.146	.000
2	.000	8.277	.701	.758	.735	.724	.135	.000
3	.000	7.254	.701	.791	.767	.763	.125	.000
4	.000	6.758	.719	.809	.784	.782	.120	.000
5	.062	1.873	.957	.983	.964	.974	.047	.661

Legend: CMIN/DF - *Chi Square/Degrees of Freedom* NFI - *Normed Fit Index*
GFI - Goodness *of Fit Index* TLI - *Tucker-Lewis Index*
RMSEA - *Root Mean Square of Error Approximation* CFI - Comparative *Fit Index*

Presented in Figure 2 is the Best Fit Model 5, showing the direct causal relationship of the latent exogenous variables, which include pedagogical content knowledge, continuing professional development, and attitude toward science towards the latent endogenous variable, which is science curriculum implementation. The figure displays the hypothesized model that satisfied the best-fit model criteria. Among the three exogenous variables, only pedagogical content knowledge directly correlates with science curriculum implementation. Moreover, pedagogical content knowledge, including subject matter knowledge, instructional objective and context, and knowledge of students' understanding, exhibits a direct relationship with science curriculum implementation.

Specifically, the science curriculum implementation of teachers is directly affected by professional knowledge, professional adequacy, professional support, resource adequacy, school ethos, and time. These results supported the existing literature by Suh and Park (2017) that teachers' knowledge of students' understanding is an essential knowledge foundation for sustained implementation of instructional practices. In addition, the result of the study confirmed the previous findings of Lucero et al. (2017) and Mosabala (2018), which asserted that teachers with a high degree of knowledge in the subject matter experienced less trouble creating real-world connections and integrating a broader range of knowledge, and transforming this knowledge of specific topics into forms that students can easily comprehend.

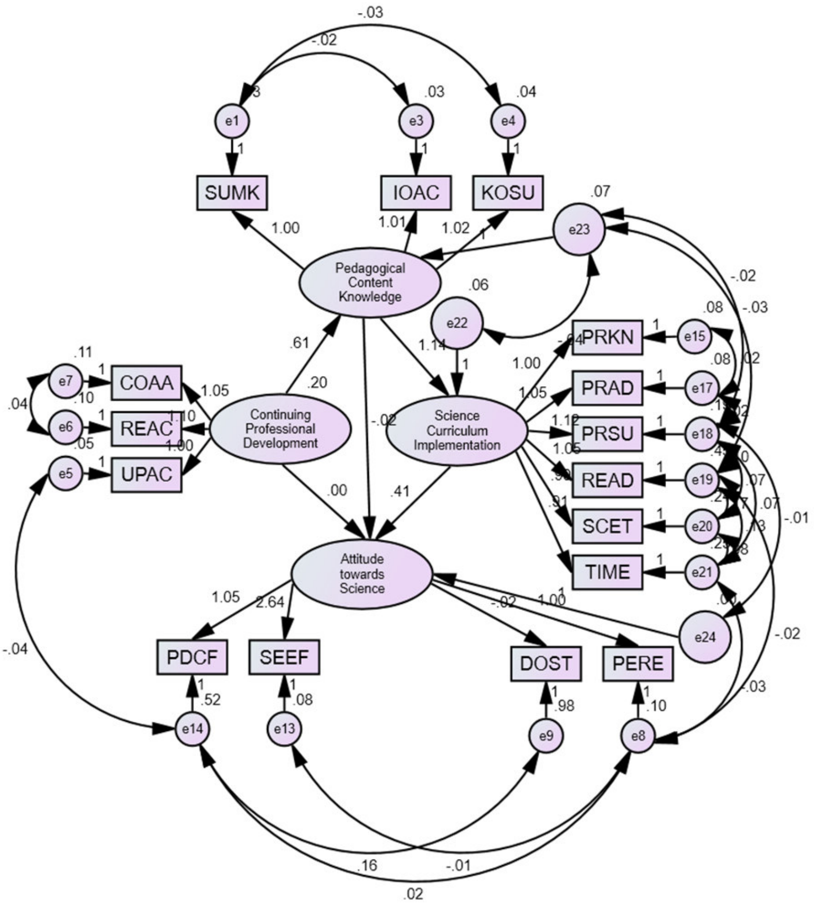

Figure 2. Best Fit Model 5 in Standardized Solution

Legend:

SUMK-subject matter knowledge

IRAS-instructional representation and strategies

IOAC-instructional objective and context

KOSU-knowledge of students' understanding

UPAC-updating activities

REAC-reflective activities

COAA-collaborative activities

PERE-perceived relevance

DOST-difficulty of science teaching

GESB-gender stereotypical beliefs

ENJO-enjoyment

ANXI-anxiety

SEEF-self-efficacy

PDCF-perceived dependency on context factors

PRKN-professional knowledge

PAAI-professional attitude and interest

PRAD-professional adequacy

PRSU-professional support

READ-resource adequacy

SCET-school ethos

3.10 Direct and Indirect Effects of the Independent Variables on Science Curriculum Implementation of Best Fit Model

Presented in Table 8 is the direct relationship between pedagogical content knowledge and science curriculum implementation. The best-fit model showed that three indicators were involved, namely subject matter knowledge, instructional objective and context, and knowledge of students' understanding. Continuing professional development indirectly affects science curriculum implementation. In contrast, attitude toward science does not directly or indirectly affect science curriculum implementation.

Table 8

Direct and Indirect Effects of the Independent Variables on Science Curriculum Implementation of Best Fit Model 5

Variables	Direct Effect	Indirect Effect	Total Effect
Pedagogical Content Knowledge	1.137	-	1.137
Continuing Professional Development	-	.691	.691
Attitude toward Science	-	-	-

The findings supported the component model by Magnusson et al. (1999), which asserted that pedagogical content knowledge is essential to successful science instruction. They argued that teachers with pedagogical content knowledge are better equipped to plan and implement lessons that help students develop comprehensive understandings than those with limited and fragmented knowledge. This theory served as a basis for understanding the relationship between pedagogical content knowledge and science curriculum implementation.

3.11 Estimates of Variable Regression Weights in Generated Best Fit Model

Presented in Table 9 are the regression weights exhibited by the influence between latent variables measured. Among the paths shown in the model, the paths between pedagogical content knowledge and science curriculum implementation generated a p-value of less than 0.01. This finding indicated that pedagogical content knowledge significantly explained the science curriculum implementation of teachers.

Table 9

Estimates of Variable Regression Weights in Generated Best Fit Model 5

			Estimate	S.E.	Beta	C.R.	P-value
Pedagogical_Content_Knowledge	<---	Continuing_Professional_Development	.607	.042	.716	14.528	***
Science_Curriculum_Implementation	<---	Pedagogical_Content_Knowledge	1.137	.075	1.056	15.163	***
Attitude_towards_Science	<---	Science_Curriculum_Implementation	.410	.072	1.031	5.687	***
Attitude_towards_Science	<---	Continuing_Professional_Development	.003	.029	.009	.110	.912
Attitude_towards_Science	<---	Pedagogical_Content_Knowledge	-.019	.044	-.045	-.437	.662
SUMK	<---	Pedagogical_Content_Knowledge	1.000		.908		
IOAC	<---	Pedagogical_Content_Knowledge	1.007	.051	.912	19.700	***
KOSU	<---	Pedagogical_Content_Knowledge	1.023	.057	.896	17.846	***
UPAC	<---	Continuing_Professional_Development	1.000		.887		
REAC	<---	Continuing_Professional_Development	1.105	.058	.838	19.109	***
COAA	<---	Continuing_Professional_Development	1.045	.058	.811	18.171	***
PERE	<---	Attitude_towards_Science	1.000		.454		
DOST	<---	Attitude_towards_Science	-.020	.319	-.003	-.063	.950
SEEF	<---	Attitude_towards_Science	2.642	.307	.837	8.615	***
PDCF	<---	Attitude_towards_Science	1.047	.251	.231	4.170	***
PRKN	<---	Science_Curriculum_Implementation	1.000		.828		
PRAD	<---	Science_Curriculum_Implementation	1.053	.046	.834	22.917	***
PRSU	<---	Science_Curriculum_Implementation	1.123	.083	.781	13.509	***
READ	<---	Science_Curriculum_Implementation	1.054	.112	.579	9.382	***
SCET	<---	Science_Curriculum_Implementation	.904	.072	.601	12.538	***
TIME	<---	Science_Curriculum_Implementation	.913	.074	.598	12.414	***

Legend:

SUMK-subject matter knowledge
IRAS-instructional representation and strategies
IOAC-instructional objective and context
KOSU-knowledge of students' understanding
UPAC-updating activities
REAC-reflective activities
COAA-collaborative activities
PERE-perceived relevance
DOST-difficulty of science teaching
GESB-gender stereotypical beliefs
ENJO-enjoyment
ANXI-anxiety
SEEF-self-efficacy
PDCF-perceived dependency on context factors
PRKN-professional knowledge
PAAI-professional attitude and interest
PRAD-professional adequacy
PRSU-professional support
READ-resource adequacy
SCET-school ethics

4. Conclusion and Recommendation

Considering the analyses and findings, this part of the paper presents the following conclusions and recommendations. As perceived by the public secondary science teachers in Region XII, the level of pedagogical content knowledge was very high, with its indicators of subject matter knowledge, instructional representation and strategies, instructional objective and context, and knowledge of students' understanding having very high ratings. With this, the researcher recommends that science teachers may strengthen their subject matter knowledge, particularly knowing how theories or principles of science developed, knowing the whole structure and direction of science, and knowing the answers to questions that students ask about science so that they can effectively teach science in a way that the students can easily understand.

In addition, science teachers may demonstrate an understanding of the instructional objective and context of science education, specifically, be able to cope with the classroom context appropriately, prepare additional teaching materials to teach science, and actively demonstrate the value of teaching science. Likewise, teachers must know students' understanding, including being aware of students' learning difficulties before the science class, giving assignments that facilitate students' knowledge, and ensuring that the assessment methods evaluate science understanding.

Results also indicated that the level of continuing professional development registered a high rating with its indicators, namely updating activities, reflective activities, and collaborative activities having a high rating. As a result, the researcher recommends that science teachers continuously engage in professional updating activities such as reading professional journals and scientific literature, studying discipline-based books and teaching materials, reading about training opportunities in teacher training institutes, and participating in conferences sponsored by professional associations. Similarly, teachers may undertake reflective activities such as seeking feedback from students about the lesson's delivery, visiting colleagues' classes to learn from them, and asking colleagues to attend classroom instruction and get feedback. As a supplementary, it is also important to collaborate with colleagues to write new curriculum materials, construct digital teaching materials, and use colleagues' teaching materials that are applicable in teaching the science content.

Additionally, the attitude toward science was rated high, and its indicators, namely perceived relevance, enjoyment, and self-efficacy, obtained very high ratings. While the difficulty of science teaching and perceived dependency on context factors registered high responses, gender-stereotypical beliefs and anxiety gained low ratings. In answer to the problem of teaching science, the education sector's top management may need to address the mismatch of teacher education preparation to what is happening in the classrooms where teachers are required to teach science disciplines outside their expertise.

Further, the result revealed that the level of science curriculum implementation obtained a very high rating, including its indicators, professional knowledge, professional attitude and interest, professional adequacy, professional support, and school ethos. Similarly, resource adequacy and time recorded high responses. Notably, the school administrators may monitor and evaluate if the science curriculum is implemented by science teachers as intended by the curriculum developers using validated monitoring and evaluation tools anchored on the K to 12 science curriculum standards.

Furthermore, the correlation analysis showed that the three exogenous variables, pedagogical content knowledge, continuing professional development, and attitude toward science, significantly related to science curriculum implementation among public secondary science teachers in Region XII. Among the three exogenous variables, pedagogical content knowledge best influences science curriculum implementation. The study's findings align with the framework by Magnusson et al. (1999), which outlined the components of pedagogical content knowledge required for science instruction. Teachers with pedagogical content expertise can effectively implement the science curriculum and support the development of scientific knowledge and skills among a diverse group of students. Thus, training and upskilling may target improving teachers' pedagogical content knowledge and addressing their pedagogical and content needs to ensure fidelity in implementing the science curriculum.

Notably, among the five generated models, Model 5 best fits the science curriculum implementation of teachers because it successfully passed all the criteria of a best-fit model. In this case, curriculum programs and efforts may focus on teachers' pedagogical content knowledge, specifically, subject matter knowledge, knowledge of students' understanding, and instructional object and context. The Department of Education may conduct subject-specific enrichment programs to capacitate teachers with inadequate knowledge, particularly on science topics outside their expertise.

Likewise, the Department of Education may invest more time and resources to provide teachers with transformative in-service professional development programs and activities that will result in lasting and positive change in the delivery of science education. Similarly, teachers may engage in collaborative activities such as mentoring and team teaching to learn innovative practices from colleagues and reflective activities through seeking feedback from students and colleagues to assess if students achieved the intended outcomes, if not, improve the delivery of the lesson.

The education sector may also consider looking into teachers' attitudes towards science, primarily self-efficacy, perceived relevance, perceived dependency on context factors, and difficulty of science teaching. The top management may consider providing need-based in-service professional development programs to address the teachers' content and pedagogical needs. Also, with the teachers' dependency on context factors such as the availability of science resources to teach science, the provision of and access to adequate science resources and laboratory facilities and equipment is a pressing concern of the Department of Education.
Finally, future research may delve into other factors not covered in this study that may influence science curriculum implementation.

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