

Development and Validation of a STEM-Based Education with PCK Training Manual for Biology Teachers

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ABSTRACT

The study aimed to develop and validate a professional training manual integrating Pedagogical Content Knowledge (PCK) and Science, Technology, Engineering, and Mathematics (STEM) education teaching approach (PCK+STEM) to enhance the instructional competence of public school Biology teachers in Iligan City. Guided by the ADDIE model—Analyze, Design, Develop, Implement, and Evaluate. The study employed a mixed-method research design, integrating both quantitative and qualitative approaches to systematically develop and comprehensively evaluate the training manual. The manual was conceptualized based on the identified needs of Biology educators and encompasses the topics of 1st quarter of Grade 9 Science following the essential domains of PCK and seven (7) stages of STEM Education by Sutaphan & Yuenyong, (2019). The validation process involved six PhD experts specializing in STEM and PCK education who evaluated the manual's content, structure, and instructional coherence. Quantitative data were collected using a validated instrument across the domains of Analyze, Design, and Development, while qualitative feedback was gathered from open-ended expert comments to improve clarity, relevance, and usability. The evaluation results revealed that the training design manual achieved overall “Excellent” quality, with a grand mean of 3.53. These findings indicate that the training manual meets expert expectations in terms of pedagogical soundness, content validity, and practical applicability for teacher training. Moreover, the training manual serves as a validated resource for professional development programs in promoting Biology teachers' integrated understanding of disciplinary knowledge, pedagogy, and STEM-based instruction. It is recommended to implement and assess the manual's effectiveness in actual teacher training and classroom settings, focusing on its impact on teachers' PCK enhancement and students' engagement and achievement in Biology.

Keywords: ADDIE Model, Pedagogical Content Knowledge, STEM Education, Training Manual

INTRODUCTION

The rapid transformation in science and technology calls for teachers to possess not only content expertise but also pedagogical flexibility to adapt instructional practices to the demands of STEM education. Public school Biology teachers frequently encounter difficulties in integrating STEM-based pedagogies due to limited pedagogical content knowledge (PCK), as many teachers lack the necessary pedagogical depth to connect content with inquiry-based and interdisciplinary STEM approaches, as emphasized by Margot and Kettler, (2019) and reinforced by Garcia's, (2023) findings in Philippine Biology classrooms. Recognizing this, the study aimed to develop a STEM- PCK training manual that supports Biology teachers in enhancing their teaching competencies. The manual was structured based on the ADDIE model—Analyze, Design, Develop, Implement, and Evaluate—to ensure a systematic and research-based development process. The initiative aligns with the Department of Education's advocacy to promote inquiry-based and integrative STEM instruction across secondary education.

Likewise, as emphasize in EDCOM II, (2023) in order for DepEd to address issues hindering teachers from delivering quality instruction prior to the full implementation of the revised curriculum. These include teacher training and the development and distribution of learning resources. DepEd should also formulate a contingency plan to ensure that teachers and learners will have adequate learning resources by the upcoming school year.

Likewise, it is also highlighted in PISA, OECD, (2015) that teacher training and ensuring that teachers have access to teaching resources is also of critical importance in improving the quality of -learning.

Meanwhile, training manuals are equally essential for teachers because they provide structured guidance that supports consistent, effective, and high-quality instructional practices. Just as employees rely on manuals to master tasks, teachers benefit from well-designed manuals that outline pedagogical strategies, classroom procedures, assessment guidelines, and best practices aligned with curriculum standards. These resources enhance teachers' confidence, improve instructional coherence, and support professional growth by offering clear, step-by-step directions and evidence-based approaches. According to Darling-Hammond et al. (2017), well-developed professional learning resources—including manuals and structured guides—help teachers deepen their knowledge, strengthen teaching practices, and improve student learning outcomes.

Besides, STEM education frameworks across the globe advocate for inquiry, design thinking, and interdisciplinary integration to produce scientifically literate learners. Likewise, Sutaphan and Yuenyong, (2019), proposed a STEM education model that uses real-life situations to engage learners in engineering-based problem solving. Their approach emphasizes contextualization, creativity, and collaboration—core competencies aligned with 21st-century learning skills. This model has influenced many Southeast Asian educators seeking systematic and authentic STEM implementation. However, the successful integration of STEM frameworks such as that of Sutaphan and Yuenyong, (2019), depends largely on teachers' instructional readiness. Teachers often report difficulties in selecting appropriate activities, designing assessments, and applying PCK in STEM contexts (Park & Oliver, 2008). Thus, providing a comprehensive training manual can support teachers in standardizing their practices and applying the STEM-PCK model more effectively. Such a manual acts as both a reference and a guide to ensure coherence, quality, and fidelity in STEM instruction.

Moreover, Pedagogical Content Knowledge (PCK) emphasizes the blending of content mastery and pedagogical techniques to facilitate meaningful learning (Kind, 2009). In STEM contexts, teachers must design lessons that integrate scientific inquiry, technological tools, and engineering perspectives (Sutaphan & Yuenyong, 2019). The ADDIE model has been widely used for instructional material development, ensuring structured design and iterative improvement (Molenda, 2003). Locally and internationally, studies reveal the gap in teachers' competencies in integrating STEM principles effectively into classroom practice (Bybee, 2013; Bautista & Tan, 2018). These gaps underscore the necessity of developing validated training manuals tailored to teachers' contexts. Although various training programs and workshops exist for STEM education, there remains a notable lack of systematic and well-structured training manuals that integrate the ADDIE instructional design model, STEM pedagogical frameworks, and Pedagogical Content Knowledge (PCK) principles within a single resource. Existing STEM training materials often focus on isolated strategies or content-specific demonstrations, resulting in fragmented support for teachers (Bybee, 2013). Many teachers still struggle to translate STEM theory into coherent classroom practice because available guides do not provide step-by-step, research-based instructional frameworks (English, 2016).

Furthermore, several studies emphasize that teachers require sustained guidance and structured instructional resources, yet many existing training manuals lack clear instructional flow, contextual authenticity, and interdisciplinary integration (Honey et al., 2014). Even when STEM resources exist, they often fail to align with empirically developed models such as the STEM education framework proposed by Sutaphan & Yuenyong (2019), which highlights real-world problem solving and engineering design processes. Another major gap concerns validation and quality assurance. Research shows that many teacher manuals and modules in STEM education are seldom subjected to rigorous expert evaluation, making it difficult to determine their effectiveness, content accuracy, and pedagogical soundness (Lou et al., 2011). Without structured evaluation, instructional materials may lack alignment with PCK constructs, resulting in inconsistencies in how teachers interpret and implement STEM lessons (Park & Oliver, 2008). Therefore, the present study addresses this gap by designing a training manual based on the ADDIE model while incorporating the STEM-PCK approaches recommended by Sutaphan and Yuenyong. The manual is further subjected to expert evaluation to ensure its content quality, structural organization, instructional coherence, and practical applicability for classroom teaching.

Research Objectives

This study aimed to develop and validate a STEM-PCK training manual for public school Biology teachers.

Specifically, it sought to:

1. Describe the process of developing the manual based on the ADDIE model;
2. Determine the experts' evaluation of the manual in terms of content, structure, and instructional coherence

THEORETICAL FRAMEWORK

This study is anchored on Shulman's (1986) theory of Pedagogical Content Knowledge, which emphasizes the teacher's ability to integrate subject matter expertise with effective instructional strategies. Complementing this, Sutaphan & Yuenyong's, (2019) STEM Education Framework serves as the pedagogical basis for integrating scientific inquiry with real-world applications. The ADDIE instructional design model guided the development of the training manual, ensuring a systematic approach from analysis to evaluation. Conceptually, the study posits that a well-designed STEM-PCK training manual can enhance teachers' competencies, improve classroom implementation of STEM, and foster learner-centered teaching practices.

Significance of the Study

The study is significant for several educational stakeholders. For teachers, it serves as a resource to strengthen their pedagogical understanding of STEM integration. For administrators and curriculum planners, it provides a framework for designing professional development programs grounded in research-based models. For future researchers, it contributes to the growing literature on teacher education and PCK-STEM frameworks, especially in the Philippine context.

Scope and Delimitation

The study focused on the development and validation phases of the training manual using the ADDIE model. Respondents included public school Biology teachers in Iligan City. Validation was limited to six PhD experts specializing in PCK and STEM education. Implementation and long-term impact of the manual were not covered, as the research was confined to the development and validation stages.

METHODOLOGY

Research Design

The study employed a descriptive research design with qualitative support. The quantitative component generated measurable indicators of effectiveness—such as mean scores, standard deviations, and descriptive ratings—which provided an objective basis for determining the manual's overall quality. Meanwhile, the qualitative component captured evaluators' comments, reflections, and contextual observations, offering deeper insight into areas of strength and aspects requiring improvement. The integration of these two forms of data strengthened the credibility and validity of the findings through data triangulation, thereby enhancing the depth and richness of interpretation. This methodological approach aligns with the recommendations of Creswell and Plano Clark (2018) and Johnson et al., (2007), who emphasize that mixed-method designs provide a more comprehensive understanding of complex educational phenomena.

Research Subjects

The respondents of the study consisted of fifteen (15) public school Biology teachers from Iligan City who participated in the training needs analysis to determine their challenges, gaps, and areas for improvement in STEM-PCK integration. The development process followed three completed stages of the ADDIE model: Analyze, Design, and Develop. During the analysis phase, the specific instructional needs and integration gaps of the teachers were systematically identified. In the design phase, learning objectives, content outlines, and instructional activities were crafted to align with STEM pedagogy and PCK principles. The development phase resulted in the creation of a prototype training manual, which was subjected to expert validation to ensure accuracy and coherence.

For implementation, three (3) Biology teachers were involved in the pilot testing of the manual to assess its

usability and applicability in classroom-related training contexts. Moreover, of the 34 teachers who initially expressed their interest, only thirteen (13) ultimately participated in the implementation training due to various constraints. Additionally, six (6) experts evaluated the manual in terms of relevance, clarity, structure, and instructional coherence. Ethical considerations were strictly observed throughout the study, ensuring voluntary participation, informed consent, and the confidentiality of all respondents' information.

Data Gathering Procedure

Data were collected through a systematic and structured process that involved both surveys and interviews. The surveys helped identify teachers' challenges, existing resource gaps, and specific training needs related to STEM education and PCK integration. Complementing this, the interviews generated deeper, qualitative insights into teachers' classroom experiences, instructional difficulties, and perceptions of STEM-PCK pedagogy. Following data collection, a pilot implementation of the Teacher Training Manual was conducted to test its clarity, usability, and relevance in actual instructional settings. Feedback from the pilot phase, along with evaluation results, informed further revisions and refinement of the manual. Altogether, the data gathered served as a comprehensive foundation for developing, validating, and improving the Teacher Training Manual.

RESULTS AND DISCUSSION

Process in Making a Training Manual

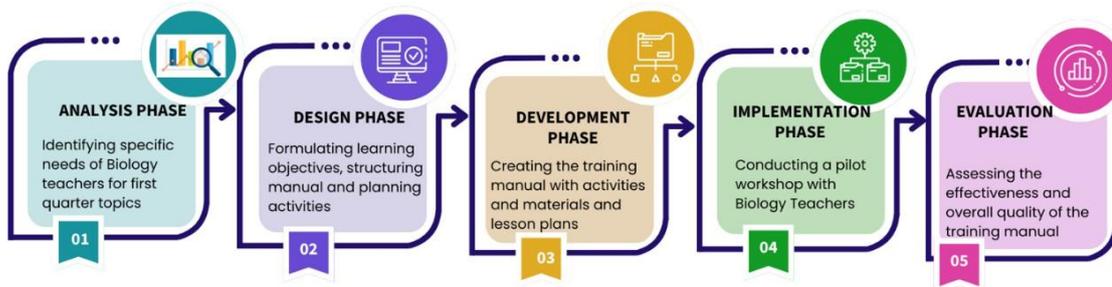


Figure 1. Process in Making a Training Manual using ADDIE Model

During the preliminary assessment phase, input for developing the Training Design Manual will be gathered by asking targeted questions to gain insights into the specific training needs related to STEM education. The training will include workshops, hands-on activities, collaborative projects, and lectures aimed at improving teachers' PCK in STEM. This information served as the primary reference for designing the manual, ensuring it addressed the gaps identified in classroom interactions. Following this, the Training Design Manual underwent validation by a panel of experts, who evaluated its content, style, and the appropriateness of the training approach to ensure its quality and relevance. Then, their feedback will be analyzed thematically with their suggestions and recommendations to be incorporated to refine and enhance the design, which will be finalized for implementation.

The development of the Teacher Training Manual in Biology for first-quarter topics— organ systems, genetics, biodiversity, and ecosystems—was guided by the ADDIE Model of instructional design, which includes five key phases: Analysis, Design, Development, Implementation, and Evaluation. This systematic model provided a structured framework to ensure that the manual was research-based, learner-centered, and aligned with curriculum standards. Each phase played a critical role in producing a validated and effective professional development material for Biology educators.

Analysis Phase

The first phase, Analysis, focused on identifying the specific needs of Biology teachers in teaching first-quarter topics. Fifteen (15) science teachers participated in surveys, interviews, and informal discussions to identify their challenges, current instructional practices, and professional development needs. The analysis revealed that while teachers were knowledgeable in content, many experienced difficulties in integrating STEM education principles and Pedagogical Content

Knowledge (PCK) into classroom instruction. Moreover, gaps were identified in available instructional

resources that support inquiry-based and contextualized learning in topics such as organ systems, genetics, biodiversity, and ecosystems. The results of this phase served as the foundation for developing a training manual that responds directly to these instructional needs while aligning with the Department of Education’s K to 12 Science Curriculum standards.

Design Phase

In the Design phase, the framework and structure of the teacher training manual were systematically organized. Specific learning objectives were formulated based on the competencies outlined in the K to 12 curriculum and the PCK-STEM framework developed by Sutaphan & Yuenyong, (2019). Each training module was designed to promote teacher growth in both content mastery and instructional practice. The design also outlined instructional strategies, learning activities, assessment tools, and teaching scripts that would guide participants in facilitating student-centered learning. The topics were sequenced logically—from understanding basic biological concepts to exploring real-life applications—to ensure that learning is cumulative and meaningful. Visual organizers, concept maps, and interactive exercises were planned to foster higher-order thinking, creativity, and collaboration among teachers.

Development Phase

The Development phase involved the actual creation of the training manual based on the design blueprint. Each manual was developed using clear and teacher-friendly language and integrated Sutaphan and Yuenyong’s 7-Stage STEM Education Teaching Approach, (2019), which includes stages such as (1) *Identification of social issues*, (2) *Identification of potential solution*, (3) *Need for knowledge*, (4) *Decision-making*, (5) *Development of prototype or product*, (6) *Test and evaluate the Solution*, and (7) *Socialization and completion decision stage*.

The manual featured practical activities, reflection prompts, and sample lesson plans that illustrate the integration of STEM and PCK in teaching Biology. Special emphasis was given to developing engaging materials for complex topics like non-Mendelian genetics and ecosystem processes, which often pose challenges to learners. To ensure quality and accuracy, the manual underwent content and design validation by science educators, subject specialists, and curriculum experts. The validators assessed the manual’s clarity, relevance, content accuracy, and pedagogical suitability. The feedback obtained was carefully analyzed and incorporated into the revised version of the manual.

Implementation Phase

The Implementation phase served as the pilot testing of the training manual. A trial implementation was conducted with three (3) selected public school Biology teachers who served as the target users. During the implementation, teachers were oriented on how to use the manual effectively, including its learning flow, suggested time allocation, and facilitation methods. The sessions provided opportunities for participants to perform sample teaching demonstrations, and engage in reflective discussions about their instructional practices.

In the full implementation of the training program, thirteen (13) teachers participated and were involved in the delivery, practice, and application of the training activities. Through observation and feedback collection, the researcher was able to gather data on the manual’s usability, practicality, and efficiency in promoting PCK and STEM integration. The teachers’ active participation and insights offered valuable information for further refining the manual.

Table 1. Sample Teacher Responses During Pilot Implementation of the PCK + STEM Training Manual

Questions	Teacher 1 (T1)	Teacher 2 (T2)	Teacher 3 (T3)
1. How clear are the instructions and procedures in the manual for the 1st quarter Biology topics?	Mostly clear. Activities were easy to follow, but the rubric for the group projects needed more explanation.	Very clear. Step-by-step guides for STEM inquiry activities helped me plan lessons efficiently.	Somewhat clear. I struggled with the sequencing of PCK prompts in the “Human Body Systems” lesson.

2. How effective are the STEM-integrated activities in connecting Biology content to real-life situations?	Very effective. Students will enjoy designing models/prototypes and seeing practical applications.	Effective. The outputs are challenging yet it will make concepts more tangible.	Moderately effective. Some students needed extra guidance for the classification activity.
3. How well does the manual support teachers in applying Pedagogical Content Knowledge (PCK)?	Helpful. The PCK prompts guided me in anticipating misconceptions.	Very helpful. It gave strategies for explaining difficult concepts like organ system functions.	Helpful, but I needed more examples on integrating PCK with hands-on STEM activities.
4. Are the suggested materials and resources for activities feasible in your classroom?	Mostly feasible. Some materials for model-building were hard to find locally.	Feasible. Most resources are low-cost and easy to prepare.	Partially feasible. Limited lab equipment made certain experiments challenging.
5. What challenges did you encounter while using the manual?	Time management during hands-on STEM activities was difficult.	Some students might struggle in doing prototypes, STEM problem-solving tasks initially.	Understanding and applying PCK prompts simultaneously with STEM tasks was challenging.
6. What improvements can be made to enhance the manual for teaching 1st quarter Biology topics?	Include more sample worksheets and student guides for STEM activities.	Add QR links to demonstration videos for hands-on experiments.	Simplify PCK prompts and provide suggested discussion questions for each topic.

The results demonstrated that the manual was highly acceptable in terms of clarity, organization, content relevance, and instructional effectiveness. Furthermore, teachers reported enhanced understanding of STEM integration and improved pedagogical strategies after engaging with the manual. The findings from this phase provided strong evidence that the developed training manual is a valid and effective tool for professional development in Biology education. Overall, the ADDIE model provided a systematic and research-based framework that guided the entire development process of the Biology Teacher Training Manual. Through careful analysis, thoughtful design, rigorous development, practical implementation, and comprehensive evaluation, the manual emerged as a validated and pedagogically sound resource aimed at empowering teachers to deliver meaningful and integrated Biology instruction in the 21st-century classroom.

Evaluation Phase

The final phase, Evaluation, involved assessing the effectiveness and overall quality of the teacher training manual. This included both formative evaluation, conducted during the development and pilot stages, and summative evaluation, carried out after implementation. Formative evaluation focused on continuous improvement through feedback from validators and pilot participants. Meanwhile, summative evaluation measured the manual’s content validity, functionality, and impact on teacher performance and confidence in delivering Biology lessons. Evaluation instruments such as Likert-scale questionnaires, reflective journals, and open-ended feedback forms were utilized to gather comprehensive data. The results demonstrated that the manual was highly acceptable in terms of clarity, organization, content relevance, and instructional effectiveness. Furthermore, teachers reported enhanced understanding of STEM integration and improved pedagogical strategies after engaging with the manual. The findings from this phase provided strong evidence that the developed training manual is a valid and effective tool for professional development in Biology education.

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Evaluation of Training Manual

The developed PCK+STEM training manual was subjected to a thorough validation process conducted by six experts in teaching pedagogy adapted from the study of Kurt, (2017). Based on their feedback, the researcher carefully revised and refined both the training design and evaluation instruments to enhance clarity, reliability, and alignment with the training objectives. The succeeding tables present the consolidated validation results of the training design as assessed by the panel of experts.

Table 2. Evaluation of Analyze Phase

Analyze Phase			
Criteria	Mean	SD	Description
Training aligns with educational needs	3.70	0.45	Excellent
Describes both the current state and desired state of performance or skills using cases or situation to be addressed	3.55	0.50	Excellent
Determines if training is the most effective way to close a given performance gap	3.60	0.48	Excellent
Analyze learners’ characteristics and needs based on the context and developmental level of the students	3.45	0.46	Very Good
Grand Mean	3.58	0.47	Excellent

The Analyze Phase of the training manual provides a systematic examination of the learning needs, performance gaps, and the contextual characteristics of the learners. The overall Grand Mean of 3.58 (SD = 0.47) indicates that the Analyze Phase was evaluated as Excellent, suggesting that the foundational processes involved in identifying and defining the training problem were conducted effectively and aligned with established standards in instructional design. Meanwhile, in the first criterion, “Training aligns with educational needs” (M = 3.70, SD= 0.45), obtained an Excellent rating. This highlights that the training manual successfully identifies and connects instructional goals with actual educational requirements. According to Brown and Green, (2020), alignment between training content and organizational or learner needs is essential to ensure relevance, learner engagement, and improved performance outcomes. The second criterion, “Describes both the current state and desired state of performance or skills using cases or situations” (M = 3.55, SD = 0.50), also received an Excellent rating. This suggests that the manual effectively differentiates what learners can currently do from what they are expected to achieve. Identifying this performance gap is considered the foundation of needs analysis because it determines whether training is truly necessary (Smith & Ragan, 2019). When well-defined, the performance gap guides the design of instruction toward solving an existing problem rather than providing generic content.

Then, the third criterion, “Determines if training is the most effective way to close a performance gap” (M = 3.60, SD = 0.48), demonstrates another area of excellence. Not all performance challenges require training; some may be caused by environmental, motivational, or organizational factors. As Morrison et al., (2019) emphasize, a well-conducted analysis must first diagnose the root cause before recommending training as a solution. The high rating implies that the manual appropriately distinguishes between problems that require instructional intervention and those that do not. The fourth criterion, “Analyzes learners’ characteristics and needs based on context and developmental level” (M = 3.45, SD = 0.46), received a Very Good rating. This indicates strong, though slightly less consistent, attention to understanding learner profiles, readiness, motivation, and background knowledge. Considering learner characteristics is vital because it ensures that content, strategies, and activities are aligned with developmental appropriateness and contextual realities (Reigeluth & Carr-Chellman, 2020). A more detailed and nuanced learner analysis may further elevate this part of the phase in future revisions.

Overall, the ratings reflect that the analyze phase provides a solid and research-based foundation for the training manual. It demonstrates strong alignment with core instructional design principles, especially regarding needs assessment, learner analysis, and justification of training as a solution. Strengthening the depth of learner profiling could further improve this phase, but the results collectively show that the manual is well-positioned to support an effective and context- responsive training program.

Table 3. Evaluation of Design Phase

Design Phase			
Criteria	Mean	SD	Description
Offers a clear, concise, detailed, and accurate description of the training	3.55	0.50	Excellent
Organization of content is in logical order	3.50	0.49	Excellent
Learning objectives are SMART	3.40	0.47	Excellent
Performs Task Analysis to make the activity clear	3.30	0.48	Very Good
Freedom to choose instructional strategy and mode of delivery	3.60	0.51	Excellent
Grand Mean	3.47	0.50	Excellent

The Design Phase of the training manual focuses on translating the identified needs into a structured instructional plan that clearly outlines what learners must achieve and how instruction will be delivered. The findings show a Grand Mean of 3.47 (SD = 0.50), interpreted as Excellent, indicating that the design components of the training manual demonstrate strong alignment with principles of instructional design and pedagogical effectiveness.

The first criterion, “Offers a clear, concise, detailed, and accurate description of the training” (M= 3.55, SD = 0.50), is rated Excellent. This suggests that the manual provides a well-defined overview of the training program that supports smooth implementation. Clear descriptions are a cornerstone of effective instructional design, as they ensure that trainers, administrators, and learners share a common understanding of the training’s purpose, scope, and expectations (Gagné, et al., 2019). A well-articulated training description also enhances transparency and facilitates alignment between instructional plans and learning outcomes.

The second criterion, “Organization of content is in logical order” (M = 3.50, SD = 0.49), also received an Excellent rating. This implies that the training content follows a coherent sequence that supports cumulative learning. Logical flow is crucial because learners build new knowledge more effectively when instructional material is presented in a structured and progressively scaffolded manner (Clark & Mayer, 2016). The strong rating indicates that the manual successfully arranges content in a way that enhances comprehension, reduces cognitive load, and supports meaningful learning experiences. The third criterion, “Learning objectives are SMART” (M = 3.40, SD = 0.47), likewise rated Excellent, reflects the clarity and measurability of the training outcomes. SMART objectives—specific, measurable, achievable, relevant, and time-bound—serve as guideposts for designing activities, assessments, and instructional strategies (Mager, 2018). This rating indicates that the manual effectively incorporates precise and performance-based learning objectives that direct both teaching and learning processes.

Furthermore, the fourth criterion, “Performs Task Analysis to make the activity clear” (M = 3.30, SD = 0.48), is rated Very Good, indicating that while task analysis is present, it can still be strengthened. Task analysis is essential in breaking down complex skills into manageable components, enabling the designer to align instructional strategies with specific learner needs (Dick et al., 2015). A slightly lower rating suggests potential areas for refinement, such as providing more detailed procedural steps or deeper analysis of prerequisite skills to enhance clarity and learner readiness.

The fifth criterion, “Freedom to choose instructional strategy and mode of delivery” (M = 3.60, SD = 0.51), achieved the highest mean among the indicators, earning an Excellent rating. This demonstrates that the training manual effectively incorporates flexible approaches to teaching and learning. Flexibility is increasingly recognized as a key characteristic of modern instructional design, allowing trainers to adapt methods to diverse learner profiles, technological tools, and contextual constraints (Branch & Kopcha, 2014). The high score indicates that the manual empowers trainers to apply varied pedagogical strategies and delivery formats—traditional, online, blended, collaborative, or experiential—enhancing learner engagement and accessibility.

Overall, the results of the Design Phase confirm that the training manual exemplifies strong instructional design quality. The high ratings across criteria indicate careful planning, clear articulation of objectives, coherent sequencing of content, and appropriate flexibility in instructional strategy. These attributes align with contemporary instructional design models emphasizing learner-centered, systematic, and adaptable approaches to training. Further enhancement of the task analysis component could elevate the Design Phase

even more, but the overall evaluation affirms a robust and well-structured design foundation for the training program.

Table 4. Evaluation of Development Phase

Development Phase			
Criteria	Mean	SD	Description
C.1 Develop a strategic plan to solve a problem	3.60	0.47	Excellent
C.2 The training schedule is reasonable given the learning objectives, instructional strategies, and time and budget constraints	3.50	0.50	Excellent
C.3 Training was modified to accommodate the unique contexts of the students	3.45	0.48	Very Good
C.4 Training incorporates essential values of the chosen students and teachers	3.60	0.50	Excellent
Grand Mean	3.54	0.49	Excellent

The Development Phase of the training manual focuses on the creation, refinement, and adaptation of instructional materials and strategies necessary to implement the planned training successfully. The overall findings show a Grand Mean of 3.54 (SD = 0.49), interpreted as Excellent, indicating that the training manual demonstrates strong quality and sound adherence to principles of instructional development. This phase reflects the transition from theoretical planning to the production of practical, usable, and context-responsive learning materials.

The first criterion, “Develop a strategic plan to solve a problem” (M = 3.60, SD = 0.47), received an Excellent rating, highlighting the well-developed problem-solving orientation of the training manual. Strategic planning is a central aspect of development because it aligns instructional resources, teaching methods, and learner activities with the core problem identified in the Analyze phase (Morrison et al., 2019). The high score suggests that the manual integrates systematic and evidence-based strategies to address performance gaps, ensuring that the solutions provided are clear, actionable, and pedagogically grounded.

Next, the second criterion, “The training schedule is reasonable given the learning objectives, instructional strategies, and time and budget constraints” (M = 3.50, SD = 0.50), also earned an Excellent rating. This indicates that the training manual successfully balances instructional rigor with logistical considerations. Effective training development requires realistic scheduling that considers the readiness of learners, pacing of activities, resource availability, and institutional limitations (Clark & Mayer, 2016). The strong rating reflects that the planned schedule is achievable and appropriately aligned with the instructional goals, avoiding cognitive overload and maximizing learner engagement.

Also, the third criterion, “Training was modified to accommodate the unique contexts of the students” (M = 3.45, SD = 0.48), was rated Very Good. This suggests that contextualization efforts—such as adapting content based on students’ background, learning styles, classroom settings, and cultural considerations—are evident but could be further enhanced. Contextual adaptation is vital because learners benefit more when instruction resonates with their lived experiences, needs, and socio-cultural realities (Reigeluth & Carr-Chellman, 2020). A slightly lower score indicates that while the manual incorporates contextual modifications, deeper personalization or additional differentiated learning materials may strengthen its adaptability.

Then, the fourth criterion, “Training incorporates essential values of the chosen students and teachers” (M = 3.60, SD = 0.50), achieved another Excellent rating. This reflects the manual’s alignment with value-oriented education, which emphasizes respect, collaboration, responsibility, and other core values inherent to learners and educators. Integrating values into instructional materials supports holistic learning and contributes to a positive learning culture (Gagné et al., 2019). The high rating suggests that the manual effectively embeds these values into training activities, content, and evaluative processes.

Overall, the results of the Development Phase indicate that the training manual successfully transforms instructional plans into well-designed, contextually grounded, and value-oriented learning experiences. The

strong ratings across the criteria align with the expectations of instructional development models, which emphasize strategic planning, resource alignment, contextualization, and learner-centered material creation. While there is room for enhancement in tailoring the training more deeply to individual learner contexts, the overall results confirm that the Development Phase is executed at an excellent level of quality.

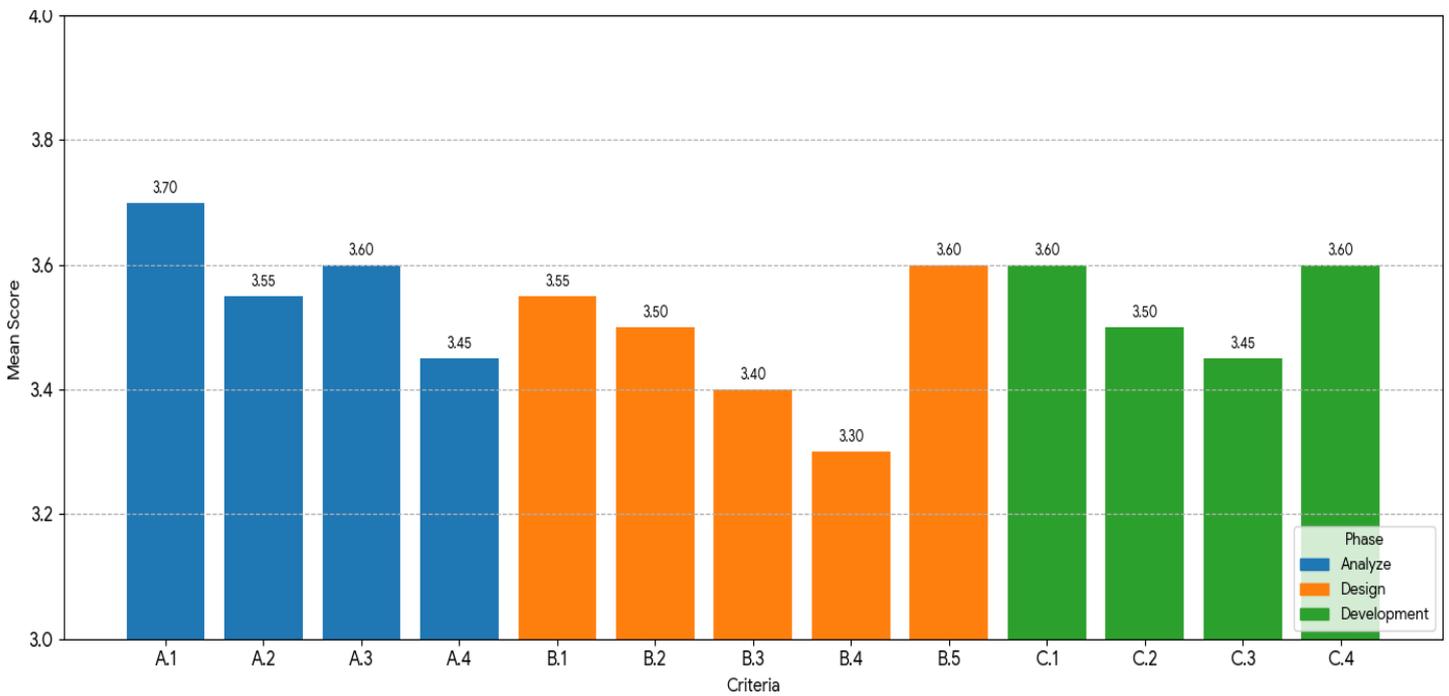


Figure 1. Summary of all the Ratings

Based on the results presented in Figure 1, the training manual demonstrates strong performance across the key phases of the instructional design process—Analyze, Design, and Development. In the Analyze Phase, indicator A1, which measures the alignment of the training with educational needs, received a high mean rating of 3.70, categorized as Excellent. This finding suggests that the training manual effectively reflects a clear understanding of learners’ current performance levels, learning gaps, and contextual needs. Such alignment is essential because accurate needs assessment is consistently identified as the cornerstone of effective instructional design, ensuring that training interventions address real performance gaps rather than perceived ones (Branch, 2009; Brown & Green, 2020). A rating at this level implies that the manual successfully integrates data-driven analysis—an essential first step in establishing relevance and instructional purpose.

In the Design Phase, indicator B1 received a mean score of 3.55, also in the Excellent range. This aspect evaluates the presence of a well-constructed strategic plan within the manual, including logical sequencing of content, clear learning objectives, and appropriate instructional strategies. High performance in this area suggests that the manual’s structure adheres to design principles that promote coherence, learner engagement, and alignment between objectives and learning tasks. This is consistent with the literature, which emphasizes that effective instructional design requires purposeful planning that links analysis findings to pedagogically sound instructional methods (Gagné et al., 2005; Dick et al., 2015). The strong score reflects that the manual demonstrates careful consideration of instructional flow and learner experience, hallmarks of high-quality training design. Moreover, for the Development Phase, which assesses the creation of a strategic plan to address the identified training problem, received a mean rating of 3.60, again within the Excellent category. This indicates that the training materials produced are clear, functional, and aligned with the earlier phases. In instructional design scholarship, the Development phase is where theoretical plans become tangible materials, and consistency across phases is considered essential for instructional integrity (Morrison et al., 2019). A high rating in this dimension suggests that the training manual effectively translates its analyzed needs and design specifications into well-developed tools and resources that support the intended learning outcomes.

In summary, the ratings from the analyze, design and development phase indicate that the training manual is not only well-aligned with learner needs but also effectively designed and carefully developed. The consistency of Excellent scores across these indicators demonstrates that the manual embodies established principles of high-quality instructional design, and aligns well with best practices described in research and professional literature.

Table 5. Comments and Suggestions of the Evaluators

Criteria	Qualitative Questions for Experts	Expert Comments	Suggestions for Improvement
Content Accuracy and Relevance	How accurate and relevant are the concepts presented in the manual to the K–12 Science Curriculum?	“The content is aligned with the learning competencies in Grade 9 Biology. Each topic is scientifically sound and consistent with current curriculum standards.”	Ensure that terminologies and examples reflect the latest DepEd updates and contextual examples in the Philippine setting.
Organization and Structure	Is the content logically sequenced and easy to follow for teachers during training?	“Manual is well-organized; topics flow from basic to complex. The transitions between topics are clear.”	Include a table of contents with page references for easy navigation during the workshop.
Instructional Design	Are the learning activities and strategies appropriate for developing teachers’ PCK and STEM integration skills?	“The activities are interactive and encourage application of STEM approaches. The inclusion of teacher-student scripts is commendable.”	Add more real-world problem-solving examples for the Genetics and Ecosystem modules.
Clarity of Instructions	Are the instructions for facilitators and participants clear and understandable?	“Instructions are clear and easy to follow. The manual provides sufficient guidance for independent facilitation.”	Simplify some instructions for group activities to avoid confusion among new teachers.
Design and Layout	Is the visual presentation (fonts, figures, colors, layout) appealing and professional?	“The layout is visually pleasing and professionally formatted. The diagrams and illustrations enhance understanding.”	Use uniform color schemes for all module headers and ensure all diagrams are high-resolution.
Applicability and Usability	How applicable is the manual for classroom use and teacher training workshops?	“The manual is practical and can be easily adapted for both pre-service and in-service teacher trainings.”	Include a sample implementation plan or timeline for school-based use.
Innovation and Integration	How effectively does the manual integrate STEM and PCK frameworks in the training modules?	“Integration of STEM-PCK is evident throughout. The use of Yuenyong’s model is innovative and suitable for Biology instruction.”	Provide short theoretical overviews before each activity for deeper conceptual linkage.
Overall Quality and Impact	What is your overall impression of the manual as a teacher training tool?	“The manual is well-developed, content-valid, and addresses the instructional needs of Biology teachers. It promotes 21st-century learning skills.”	Consider including a digital version or e-module format for online implementation.

Based on the qualitative comments and overall ratings, the training manual demonstrates excellent quality, relevance, and applicability as a teacher training tool integrating Pedagogical Content Knowledge (PCK) and STEM education principles. Most criteria—such as *content accuracy*, *clarity of instructions*, *design and layout*, *applicability*, and *overall quality*—received an “Excellent” rating, indicating that experts found the manual highly aligned with educational standards and effective for teacher professional development. The qualitative analysis of expert validators’ feedback provided valuable insights into the strengths and areas for improvement of the developed *Teacher Training Manual in Biology* focusing on the 1st Quarter topics: organ systems, genetics, biodiversity, and ecosystems.

The experts’ comments were analyzed thematically based on the ADDIE model evaluation framework and established instructional material standards. Their qualitative responses were classified under several criteria, namely: content accuracy, organization, instructional design, clarity, layout, applicability, integration, and overall impact.

Content Accuracy and Relevance

Experts affirmed that the content of the manual was scientifically accurate and aligned with the K–12 Science Curriculum, specifically the learning competencies of Grade 9 Biology. They recognized that the inclusion of contextualized examples and localized phenomena made the material relevant to Filipino learners. According to Brown and Green (2016), the content validity of instructional materials depends on their alignment with curriculum outcomes and current scientific knowledge. The experts also emphasized the importance of maintaining curriculum congruence and regularly updating terminologies to ensure relevance to national standards. This finding supports the assertion of Branch, (2009) that the Analysis phase of ADDIE ensures the accuracy of instructional goals through alignment with learner needs and curriculum requirements.

Organization and Structure

The manual was praised for its logical sequencing of topics and coherent flow of activities, progressing from foundational concepts to application-based tasks. The use of module-based organization allowed for ease of navigation and continuity between lessons. Experts noted that this structure reflects the systematic design principle emphasized in Dick et al., (2015), where instruction must be organized to facilitate cumulative learning. Additionally, they recommended including a more detailed table of contents to further improve accessibility for users. This supports the idea that clear structure enhances instructional efficiency and user satisfaction (Molenda, 2015).

Instructional Design

Feedback from validators highlighted the manual’s effective incorporation of learner-centered and inquiry-based strategies, aligned with the Pedagogical Content Knowledge (PCK) and STEM integration frameworks. The training activities encouraged teachers to engage in reflective thinking and experiential learning. The use of Sutaphan & Yuenyong’s (2019), 7-Stage STEM Education framework was commended for promoting authentic, interdisciplinary learning experiences among teachers. As emphasized STEM education should encourage scientific inquiry and contextual problem-solving to strengthen teachers’ PCK. Experts suggested, however, that additional real-world examples be integrated into topics like Genetics and Ecosystems to enhance the contextual connection of concepts.

Clarity of Instructions

The validators agreed that the instructions were clear, concise, and easy to follow, particularly for teachers using the manual independently. The use of teacher and student scripts was identified as a strength because it guided classroom facilitation effectively. Clear instructional language, according to Morrison et al., (2019), enhances user comprehension and ensures fidelity in implementation. However, experts suggested simplifying some multi-step activities to avoid confusion among teachers unfamiliar with inquiry-based approaches.

Design and Layout

The visual presentation of the manual was described as “professional, appealing, and well-organized.” The consistent formatting, use of diagrams, and well-labeled figures contributed to ease of reading and visual engagement. Reigeluth (2012) highlights that visual organization and instructional aesthetics contribute significantly to learner motivation and cognitive processing. Experts recommended ensuring uniform color schemes across all modules and using high-resolution visuals for better print quality. This aligns with Smaldino et al., (2015), who emphasized that effective visual design improves readability and knowledge retention.

Applicability and Usability

Experts noted that the manual is practical and adaptable for use in both pre-service and in-service teacher training programs. Its structured format supports guided facilitation while remaining flexible enough for classroom adaptation. This reflects the principle of usability testing in instructional design, where materials must be functional and adaptable in real teaching contexts (Clark & Mayer, 2016). The experts’ recommendation to include a sample implementation plan or schedule aligns with the Implementation phase of ADDIE, which focuses on ensuring ease of adoption in authentic learning environments.

Innovation and Integration

The manual's integration of STEM and PCK frameworks was regarded as one of its strongest features. Experts highlighted how each module effectively connects scientific content with pedagogical strategies and 21st-century learning principles. As noted by Shulman (1987), PCK represents the intersection between content knowledge and pedagogy, enabling teachers to translate disciplinary understanding into effective instruction. The inclusion of Yuenyong's STEM model further strengthens interdisciplinary learning by linking scientific inquiry with technological and engineering design processes. Experts suggested adding brief theoretical overviews before each activity to deepen teachers' conceptual grounding.

Overall Quality and Impact

In general, the experts rated the manual as "Very Satisfactory" to "Excellent" across all evaluation dimensions. They agreed that it is a valid, research-based, and pedagogically sound material for Biology teachers' professional development. According to Gagné et al., (2005), instructional products that undergo systematic validation and iterative refinement tend to demonstrate higher instructional effectiveness and learner satisfaction. The experts also recommended developing a digital version of the manual to increase accessibility and sustainability, aligning with the growing need for flexible and technology-supported teacher training resources.

This means that the qualitative feedback from expert validators indicates that the Teacher Training Manual in Biology is a comprehensive, well-designed, and pedagogically aligned material. Its strong integration of STEM education principles and PCK, combined with a clear structure and engaging design, makes it a valuable tool for enhancing teacher competence and instructional quality. Minor revisions were suggested to further improve its accessibility, contextualization, and visual presentation. Mainly, the overall positive evaluation validates the manual as an effective output of the developmental research process using the ADDIE model. Based on the experts' qualitative responses, the training manual was rated between "Very Satisfactory" and "Excellent" across all evaluation criteria. The comments emphasized the manual's alignment with curriculum standards, clarity of instructional flow, and strong integration of STEM-PCK frameworks.

Minor revisions were suggested to enhance the manual's visual design, activity clarity, and inclusion of localized examples. Overall, the experts affirmed that the manual is a valid, relevant, and pedagogically effective material for professional development in Biology teaching.

CONCLUSION

The study successfully developed and validated a STEM-PCK training manual for public school Biology teachers using the ADDIE model. The manual attained excellent ratings from expert validators, confirming its effectiveness and quality. It addressed the identified gap in teachers' limited familiarity with STEM-based pedagogies. The conclusion underscores the importance of structured instructional design in developing professional learning resources for educators. It is recommended that the manual be pilot-tested in classroom settings and integrated into teacher training programs to assess its impact on teaching practices and student outcomes. Future research may extend the study to other disciplines and include the implementation and evaluation phases of the ADDIE model.

Moreover, the organization, instructional design, and innovation were rated as "Very Good," suggesting that while the materials are strong, there remains room for minor improvements such as enhancing sequencing features (e.g., table of contents), adding real-world problem-solving tasks, and expanding theoretical linkages. These refinements would further support teacher understanding and application of STEM-PCK integration. The Excellent overall interpretation indicates that the manual meets the expectations of quality instructional materials for teacher training, reflecting valid content alignment with the K-12 Science Curriculum. Experts affirmed that the manual is scientifically accurate, contextually relevant to the Philippine setting, and effectively promotes 21st-century learning competencies such as collaboration, critical thinking, and innovation.

The strong expert ratings align with studies emphasizing that teacher professional development materials must be accurate, organized, and pedagogically sound to promote deeper understanding and effective classroom practice. According to Shulman (1986), Pedagogical Content Knowledge (PCK) bridges content and pedagogy, helping teachers transform subject matter into forms comprehensible to students. The manual's use

of teacher-student scripts and STEM-based activities demonstrates such transformation, supporting meaningful science instruction. Furthermore, the integration of STEM and PCK aligns with Sutaphan & Yuenyong's (2019) framework, which emphasizes inquiry, contextualization, and problem-solving to connect science concepts with real-life applications. Experts' suggestions to include more real-world problems and theoretical overviews reflect this same framework—highlighting the importance of conceptual depth and authentic learning contexts. The manual's clarity and usability correspond with findings by Darling-Hammond et al. (2017), who note that effective training materials should provide clear guidance, coherence, and opportunities for active learning. The manual's clear instructions and structured modules enable both independent facilitation and collaborative learning among teachers.

After the incorporation of the panel's feedback, the training design evolved into a more coherent, comprehensive, and outcome-driven professional development tool. The researcher integrated revisions to improve the logical sequencing of activities, making the transition between phases smoother and more meaningful. The training content was refined to emphasize the practical application of Pedagogical Content Knowledge (PCK) through real-world STEM activities that encourage inquiry, collaboration, and problem-solving—core tenets of STEM education. The assessment framework was also strengthened by adding rubrics and reflection prompts that align with the desired learning outcomes, thus promoting a cycle of continuous feedback and improvement among participants.

Mainly, this study contributes to the growing body of research on STEM-integrated professional development by providing a validated, context-specific training manual tailored to public school Biology teachers in the Philippines. The manual serves as a practical and replicable model for teacher training institutions, school administrators, and curriculum developers seeking to enhance instructional quality through STEM-PCK integration. By supporting teachers' pedagogical competence and confidence, the manual has the potential to improve classroom instruction, learner engagement, and ultimately student learning outcomes in science education. Moreover, for future research directions should focus on piloting the manual in actual classroom and training settings to examine its impact on teachers' instructional practices, pedagogical beliefs, and students' learning outcomes. Subsequent studies may also extend the implementation and evaluation phases of the ADDIE model to assess long-term effectiveness and sustainability. Additionally, the framework and training design may be adapted and validated across other science disciplines or subject areas to broaden its applicability. Comparative studies examining STEM-PCK training across different educational contexts may further strengthen the evidence base for integrated professional development models.

RECOMMENDATIONS:

1. Curriculum Alignment – Within one academic year, align the training manual with the K to 12 curriculum and MELCs through systematic review to enhance the integration of STEM and pedagogical content knowledge (PCK) in classroom instruction.
2. Implementation and Utilization – By the next INSET cycle, implement the training manual in selected schools or divisions as part of teacher professional development through LAC sessions and blended learning modalities.
3. Enhancement and Sustainability – Establish a regular monitoring and evaluation process with annual content revisions to ensure the continued relevance and effectiveness of the training manual.
4. Future Research and Collaboration – Within two years, collaborate with educational experts to conduct validation and localization studies aimed at expanding the manual's application across diverse educational contexts.

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