

Pedagogical Content Knowledge and Teaching Practice: A Socio-Behavioral Examination of Teacher Development in Science and Mathematics

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ABSTRACT

The deteriorating quality of basic education in the Philippines, particularly in Science and Mathematics, has drawn the attention of both national and local government agencies. In response, Bukidnon State University, in partnership with the Department of Education, Division of Malaybalay, Bukidnon, implemented the extension project Pedagogical Content Knowledge in Action – a continuing professional development program for Science and Mathematics teachers in basic education. This study evaluated the impacts of the PCK extension project. The study employed an evaluation research methodology, guided by the input-process-output-outcomes-impact framework. Data were collected through in-depth interviews with training participants and the reports generated by the extension project. Findings revealed that the project was successfully implemented by the partner institutions. The training yielded several outcomes, including the adoption of active learning strategies, enhanced teacher confidence and professional growth, development of contextualized instructional materials, improved student engagement and learning outcomes, and the integration of formative assessment and responsive teaching. Overall, the project generated positive impacts on participants, students, and the broader community. These impacts included shifts in teaching paradigms, gains in student engagement and performance, professional leadership development, and the formation of collaborative communities. The PCK training model positively influenced instructional practices, improved student outcomes, and fostered professional growth, demonstrating its effectiveness as a strategic solution for enhancing the quality of Science and Mathematics education. The extension project may be replicated in other districts of the Department of Education to further extend its benefits.

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INTRODUCTION

Quality education is a foundation for lifelong learning and the groundwork for higher learning. A strong foundation for basic skills such as reading, writing, science, and math helps learners succeed in the future. Studies show that foundational literacy and numeracy acquired early are strong predictors of educational attainment and labor market outcomes later in life. Recognizing the importance of quality primary education, Sustainable Development Goal 4 ensures inclusive and equitable quality education and promotes lifelong learning opportunities. One of the targets in 2030 is to ensure that all youth and a substantial proportion of adults, both men and women, achieve literacy and numeracy. As of 2024, it was reported that many countries face challenges such as inadequate education infrastructure, teacher shortages, and insufficient teacher training. According to Antoninis et al. (2023), approximately 44 million primary and secondary school teachers are still needed to meet

universal education targets by 2030, especially in sub-Saharan Africa and South Asia. Teachers' conditions and training emerged as crucial challenges to reach quality pedagogy (Zickafoose et al., 2024). Specifically, many teachers are not trained according to minimum standards in their country (United Nations, 2024). Darling-Hammond et al. (2020) further emphasize that teacher preparation quality significantly affects student achievement and long-term learning outcomes, hence, investing in teacher education a vital component of any educational reform.

In a developing country like the Philippines, where scarce resources are allocated for education, education is still in crisis, with a foundational deficit in literacy and numeracy. The quality of foundational learning among Filipino students has been a persistent concern in education. Igarashi and Suryadarma (2023) found that many Filipino students in Grades 4 to 10 have

not mastered foundational math skills expected by Grade 3, with performance in math declining from 2003 to 2019. Despite increased enrollment, many students fail to master basic skills taught in early grades. The supplemented data from World Bank survey results, Programme for International Student Assessment (PISA), the Southeast Asia Primary Learning Metrics (SEA-PLM), and the Philippine Institute for Development Studies (PIDS) revealed the poor performance of the Philippine learners, particularly in Science and Math education. Hence, curriculum reforms are welcomed in producing lesson exemplars that allow teachers flexibility in pedagogy and ensure quality lessons with emphasis on training for developing learning materials (Second Congressional Commission of Education [EDCOM 2], 2025).

Pedagogy plays an important role in the delivery of quality education. Literature reveals challenges in science education concerning scientific literacy, teacher competence, and instructional approaches. Disconnect between teaching competencies and student achievement in primary science education, indicate that even high self-assessed professionalism and instructional skills among teachers do not necessarily translate to improved student performance (Canuto et al., 2024). Similarly, Ashari et al. (2023) found that students generally perform poorly in scientific literacy domains such as explaining phenomena, interpreting evidence, and evaluating scientific information, with overall competency categorized as low. These findings highlight a recurring problem: despite teachers' perceived competence, student outcomes in science remain suboptimal. Meanwhile, Newman (2023) and Daniel (2013) advocate for continually evolving teacher education programs to include subject-specific pedagogical content knowledge (PCK) and active research engagement to ensure effective science teaching. This need is echoed by Lee et al. (2019), who emphasize the importance of integrating engineering design and Technological Pedagogical Engineering Knowledge (TPAEK) in STEM education.

In Asia, Singapore's Math and Science education is considered best. Singapore invests in engaging, meaningful, authentic problem-based learning. Educators used pedagogical

practices and their models were adapted in western countries (Rose, 2025). There is now a great emphasis in training teachers in pedagogy. Pedagogical training created positive attitude to educators in implementing competency-based curriculum (Habiyaemye et al., 2023). Hence, in transforming learning in science education, educators' changes in pedagogies and content contribute to increased emotional awareness and growing preparedness for classroom implementation (Lai, & Wang, 2025).

Additional literature reinforces the critical impact of teacher competency on student achievement. Sudargini and Purwanto (2020) explored the effect of teachers' pedagogical competencies on student learning outcomes, revealing that teacher competency – particularly in curriculum and learning management – positively influences students' academic success. However, self-development as a component of teacher competency showed a negative correlation, while ethical conduct and professional morality influenced students' analytical thinking and problem-solving abilities. Hakim (2015) similarly confirmed the significant contribution of pedagogical, personal, experiential, and social competence on students' learning performance, affirming that well-rounded teacher abilities enhance the quality of learning. Rahmatullah (2016) emphasized the importance of learning effectiveness and teacher performance, concluding that improved teacher competency directly supports higher instructional quality. Wahyuddin (2017) added that headmaster leadership and teacher competence strongly influence student achievement in school, indicating that leadership and instructional capability must work in tandem for academic success. On a broader scale, Zickafoose et al. (2024) highlighted teacher education and training as core challenges in achieving inclusive and quality education, noting that teacher preparation and continuous professional development remain pivotal barriers to educational equity, especially in low-resource regions.

Highlighting the challenges in the pedagogy of science and mathematics education, Bukidnon State University (BukSU), a public Higher Education Institution in the

Philippines and the Department of Education (DepEd) – Malaybalay City Division entered into a Memorandum of Agreement through an extension project for the capability development of the science and math teachers in basic education for PCK trainings. The training aimed to enhance the teachers’ competencies in lesson preparation, delivery, and instructional materials development. The project provided seminar workshops for elementary and secondary in-service teachers to effectively deliver science and mathematics lessons to their students. The project was conducted in two (2) phases: Phase 1: a series of trainings and workshops on lesson planning, lesson delivery demonstrations, and development of Instructional Materials; Phase 2: school-based enhancement training on PCK retooling in Science and Mathematics. The project was implemented in 2018-2021 with the DepEd – Malaybalay City Division as a partner.

In areas of education in the Philippines, there is a lack of localized PCK impact evaluation, hence this study is conceptualized. The researchers aimed to look at the outcomes and impact of the PCK training project provided by BukSU to the DepEd Science and Math faculty.

Research Objectives

The study aimed to determine the impacts attributed to a state university’s extension project “Pedagogical Content Knowledge in Action.” Specifically, this study addressed the following objectives:

1. Describe the implementation of the pedagogical content knowledge training conducted for the Science and Math Public School Teachers.
2. Determine the training outcomes for the science and math teachers and students.
3. Explore the impacts attributed to the pedagogical content knowledge training.

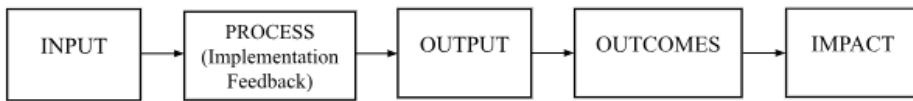
Framework of the Study

The researchers used the theory of change introduced by Weiss (1995) as anchorage. The theory-based evaluation emphasizes the importance of the underlying assumptions linking programs, activities, and projects to

outcomes. The theory of change fits to improve the design, implementation, and evaluation of social programs like extension programs introduced by state universities and colleges in the communities for societal changes. In further studies, Connell and Kubisch (1998) refined the theory of change to a more comprehensive community initiative. The application of the theory extends to education, health, and community services. From thereon, the theory has been pivotal in conducting project impact evaluation. The theory of change outlines the causal pathways connecting activities to outcomes and impacts, explicitly discussing assumptions and factors influencing the pathways (Vogel, 2012). Vogel emphasized a participatory approach to the theory of change involving multiple stakeholders in assessing intended outcomes.

The study’s framework is an Input-Process-Output-Outcome-Impact model. This framework illustrates how the theory of change connects the activities conducted to the output and outcomes of a community project.

The input considered in this evaluation of extension project were the documents, such as the approved project proposal, annual, and terminal reports. To better understand the experiences of the participants and the institutions, another input considered was the in-depth interviews from the training participants, focusing on the output and outcomes, which will supplement the data. The training proposal of the College of Education of BukSU used the Shulman’s PCK Theory. Shulman (1986), highlights that effective teaching requires integration of the content, pedagogy, learners and the educational context or learning environment. The concept is centered on holistic development of student emphasizing the strategies in teaching considering the subject matter and the context of learners. Scholars found interest in PCK and became a subject to more research. Newsome and Carlson (2013), summarizes PCK to encompass the knowledge, rationale, planning, and teaching strategies to teach effectively a topic to a specific group of learners aiming to improve learning outcomes.

Figure 1*Input-Process-Output-Outcome-Impact Conceptual Framework of the Study*

The process defines how the PCK was acquired by the basic elementary school teacher-beneficiaries. The feedback from the participants of the training helped in the assessment of the training's output. The sources of information were the extension annual reports and the participants' feedback.

The assessment of the outputs was based on the delivery of the project objectives and the activities conducted in implementing the project. This also includes the number of training sessions conducted, the participants, and the output generated from the training, including the IMs developed.

The project's outcomes were the short-term, intermediate-term, and long-term outcomes of the training for public school teachers. Outcomes also included the competencies acquired and improved by the public-school teachers in the three domains: knowledge, attitude, and skills, particularly focusing on teaching and delivery, and Instructional Materials development.

After five years from the project closure, the impacts can be seen through direct and indirect changes in the lives of the teachers, the students and the organization. Depending on the magnitude of change on the intervention or the PCK training in teaching and learning science and math, these impacts may be felt at the personal, professional, and community levels.

METHODS

This study used an evaluation research methodology, specifically the impact evaluation method. The researchers systematically assessed the outputs, outcomes, and impacts of the project using available quantitative and qualitative data. They collected data from annual project reports, approved proposals, and other related

documents, and they supplemented this with interviews of training participants regarding their experiences during the project implementation and the outcomes of the training.

Research Participants

The researchers selected public school teachers who taught Mathematics and Science and who had participated in the PCK training conducted by faculty from the Master of Education Program of BukSU. They purposely selected these participants based on their attendance in the PCK training, regardless of their age, gender, length of service, or rank. The researchers excluded teachers who had not completed the training. From the list of participants provided by the extension project implementers, the researchers approached the identified teachers in the identified national high school. After which, to complete the participants of the paper, those pre-identified participants referred the researchers to other training participants.

Research Tool

The researchers used a validated interview guide as the primary research instrument. Academic and industry experts validated the instrument in terms of content and language. An academic expert reviewed the English content and language, while a senior DepEd faculty member evaluated the appropriateness of the content for the participants. The researchers conducted the interviews either face-to-face or online, whichever was convenient and preferred by the participants.

Before conducting the interviews, the researchers secured formal permission from the university and the Research Ethics Committee clearance. After approval, the participants were informed, and consent was sought from

each before the formal data gathering. There were 14 participants: 7 Science teachers and 7 Mathematics teachers. To document the interviews, the proceedings were audio-recorded, transcribed them verbatim, and translated into English if the participants responded in the vernacular language. The researchers treated all collected data as confidential in accordance with the Data Privacy Law.

The researchers used thematic analysis for the qualitative data. From the transcribed and translated interviews, the researchers organized the data into frames. The researchers manually coded the responses of the participants, grouped the codes to come up with themes. The themes were reviewed, analyzed, and discussed. The researchers used member checking to validate the codes and themes.

Ethical Statement

The researchers followed the university's ethics protocol and submitted the study for full review and clearance. After obtaining ethical clearance, they contacted the participants with the assistance of the extension project implementors. The implementors provided the list of participants and their contact details, and the researchers reached out via email or phone. Only those who gave consent participated in the study.

The participants included basic education teachers from the DepEd – Malaybalay City Division who taught Mathematics and Science. Although the participants did not belong to a vulnerable group, the researchers asked them to indicate their length of employment as part of the consent process. The researchers provided each participant with an informed consent form and the interview guide before the interview. The consent form included information on the study's title, objectives, potential risks and benefits, estimated duration, voluntary nature of participation, compensation (if any), confidentiality, and researcher contact details. The researchers conducted a short orientation before each interview to clarify the study's purpose and process. There were no physical risks involved in participating in this study.

However, since the training project concluded in 2021, the researchers anticipated challenges in locating participants. They mitigated this risk by collaborating with the project leader and faculty extensionists. They also accounted for geographical distance by offering online or phone interviews, minimizing cost and time burdens.

Another concern was participants' recall accuracy, given the time elapsed and pandemic-related educational disruptions. To address this, the researchers increased the number of interviewees and maximized each interview session, which lasted 30 to 60 minutes. Participants could withdraw at any point without consequences, and the researchers offered debriefing sessions for those who experienced discomfort or inconvenience during the interview.

To maintain confidentiality, the researchers assigned codes to all participants and ensured the data was used solely for this study. They stored the data on a password-protected computer accessible only to the two researchers. After publication, they transferred the files to a secure Google Drive folder. Once the study's results were fully disseminated and utilized by stakeholders, the researchers will delete the data from both the computer and the drive.

The researchers did not participate in the implementation of the extension project and were not part of the BukSU Master of Education faculty. Therefore, no conflict of interest existed. The study represented a collaborative effort between BukSU and San Isidro College.

The findings of this study aimed to benefit both public and private basic education schools in the country. These results may serve as a basis for launching new extension projects or enhancing existing initiatives focused on developing PCK among educators.

RESULTS

Profile of the Participants

Fourteen Science and Math basic education

teachers participated in the interview for the impact study of the extension project conducted by the College of Education of BukSU on PCK training. Table 1 presents the profile of the participants.

Table 1
Profile of the Participants

Teacher	Age	Sex	Length of Service	No. PCK Training Attended
Teacher 1	29	Female	7	1
Teacher 2	27	Female	6	1
Teacher 3	38	Female	11	1
Teacher 4	30	Male	7	1
Teacher 5	40	Male	14	1
Teacher 6	27	Male	3	1
Teacher 7	27	Male	6	1
Teacher 8	41	Female	17	1
Teacher 9	59	Female	33	1
Teacher 10	56	Female	12	1
Teacher 11	31	Female	7	1
Teacher 12	38	Female	11	1
Teacher 13	57	Female	30	1
Teacher 14	52	Female	28	1

In terms of teaching experience, 36% of the participants have experienced teaching Math or Science in 6-10 years and the same percentage for those who were connected with the DepEd as teachers for 10-20 years, while 21% have more than 20 years of experience. Notably, all the participants expressed that they only received one PCK training provided by BukSU. All the participants were classroom teachers whose ages varied from 27 to 59.

PCK Training Implementation

Based on their experiences, the participants expressed a successful project implementation. The training design, the extension proposal, and the Memorandum of Agreement of BukSU and DepEd – Malaybalay City Division as input of the assessment provided baseline data to investigate the outcomes of the PCK training. Table 2 shows the themes and descriptions of the participants during the PCK

training. The themes describe the participants' overall experiences on how the training project and the engagement of the participants in the training.

Experiences of Time and Intensity

The program took the shape of a three-day all-inclusive (7- 8 hours/day) intensive seminar carried out during the semestral holiday periods and the weekend to maximize the availability of teachers. Daily monitoring of attendance and certification maintained high levels of participation, and trainers provided a large repertoire of materials to support capacity building--printed curricula, exemplar lesson plans, and computer programs (GeoGebra, Bagatrix). The participants of the training were selected based on their field of specialization.

"I was chosen by our division to be a participant of the PCK training organized by Bukidnon State University and facilitated by their brilliant Math professors and science Professors." - Teacher 5

Not only did the official selection process confirm the professional status of the participants, but it also increased their commitment and responsibility. The quality of the facilitators was also significant. A participant shared:

"The training was organized by experienced Instructors/Professors and subject matter expert in Bukidnon State University." - Teacher 1

In combination, these physical (manuals) and interactive (software) resources established a strong ecology of provision that, in addition to building up theoretical PCK models, allowed teachers to quickly modify and maintain new techniques within their heterogeneous school environments. A math teacher stated:

"We were given software that is useful to our teaching, such as BAGATRIX and GEOGEBRA." - Teacher 5

Additional experience was shared by a science teacher:

"Yes, the resources were generally adequate. We received manuals, sample lesson plans, assessment rubrics, and links to online resources. Also, we had

access to Smart board, internet connection, and most of the materials were up-to-date and aligned with the current K-12 curriculum, which was very helpful.”
- Teacher 1

This observation demonstrates that the trainers were highly qualified and well-informed about their respective subjects. Combined, the above aspects made an effective learning environment characterized by credibility, respect among peers, and a climate that favors wholehearted acceptance of innovative teaching techniques.

Table 2
Implementation of PCK Training for Science and Mathematics Teachers: Themes and Descriptions

Themes	Descriptions
Experiences of Time and Intensity	<ul style="list-style-type: none"> Conducted of 24-hour intensive training with daily performance and attendance monitoring. Provision of training materials both in prints and electronic copies. High level of participants’ engagement.
Navigating Learning Approaches	<ul style="list-style-type: none"> Rigorous training balanced with differentiated instructional methods. Addressed misconception of k-12 education.
Embodied Modes of Delivery	<ul style="list-style-type: none"> Used of face-to-face instruction and online sessions.
Moments of Engagement and Collaboration	<ul style="list-style-type: none"> Engagement of micro teaching classes, peer feedbacking, shared lesson planning, role playing in lesson demonstration.
Perceived Value and Accountability	<ul style="list-style-type: none"> Use of assignments for training completion Developed and defended lesson plans Developed instructional materials

Navigating Learning Approaches

PCK training Content and Curriculum Design was created not only to help teachers first conceptualize what they will be working on, but also to make connections between theory and practice right at the very beginning, so

that teachers could visually realize the specific strategy and apply it as soon as possible.

“The teachers and participants performed immediately, followed by a presentation right away.” - Teacher 13

Participants explained that it involved an output-based sequence whereby, in their words, they showed a video sample first, then afterwards, before being asked to do the task, therefore building theoretical discussion on finite examples preceding an independent task. Another math teacher stated that:

“Output-based: they showed a video sample first before we were asked to do the task.” - Teacher 12

Embodied Modes of Delivery

The advantages of the blended training format and schedule underline this theme, which refers to the flexibility and accountability strengthened by the blended nature of the training, where one of them quoted:

“For the online session, I recall “Sir A” sent it to us before releasing our certificates once we completed our output.” - Teacher 12

The participants recalled that the trainings were delivered in face-to-face modality before COVID-19 pandemic movement restrictions was implemented but shifted to on-line modality during its last years of project implementation. The subject matter experts used different online platforms such as google meet or zoom to effectively deliver the designed modules. The learning materials were also given to the participants through emails and other modalities. The participants complied with the assigned tasks and performance outputs before the completion of the training and certificates were given.

“The PCK training was organized to take place every weekend, with each week focusing on different topics presented by various speakers. Sessions were conducted online through platforms such as Google Meet and Zoom.” - Teacher 6

Moments of Engagement and Collaboration

The strategy that was used in the PCK training developed a very participatory learning environment in which teaching as a participant changes the teachers to be active co-producers of pedagogical knowledge. First, the pressure of imminent action, the forcing to act, at once, to prescribe, to act, and to perform. A math teacher highlighted:

"It was interactive: we were asked to go up, present immediately, perform, and they actively solicited our ideas, we were Grade 8 students." - Teacher 11

It ensured that each participant could go through the whole teaching cycle, exemplified by the facilitator, doing it with their hands, and receiving feedback from their peers. Second, dynamic group modalities were interspersed during every session. A science teacher openly shared:

"Instructional strategies were delivered through dynamic formats including group work, peer feedback, and demo teaching, fostering deeper engagement and reflection." - Teacher 3

It was consistent with the values of social constructivism, which holds that learning is mediated by cooperation and discussion. Lastly, there is the lectureship versus the practical skill-focused learning. A science teacher positively noted:

"Rather than relying solely on lectures, the training focused on developing practical skills through hands-on workshops and collaborative projects. Participants practiced techniques through micro-teaching, provided feedback to peers, worked together to create action plans, and developed resources tailored to their community's needs." - Teacher 1

It replicated the experiential learning cycle (Kolb, 1984) and tutored the ability of teachers to translate PCK tactics into their classrooms. Overall, these interactive practices went further in crystallizing conceptual knowledge, besides creating a reflective community of practice, which was ready to engage in long-term pedagogical enhancement.

Perceived Value and Accountability

The element of the PCK training proved to be a significant policy to guarantee accountability and practical learning. It was ensured that the tracking of participation was thorough and pervasive, which is verified by the participants, a math teacher who claimed:

"There was an attendance sheet – no one could escape since everyone had to perform." - Teacher 14

Assignment to attend and be actively involved in every session was a clear expectation. It merged with this output-based system of certification. A participant noted that:

"Attendance was monitored in every session to ensure accountability and engagement. One of the main outputs of the training was the development of lesson plans and instructional materials, allowing teachers to demonstrate their understanding and readiness to implement the strategies discussed." - Teacher 2

This ruling ensured that attendance was accompanied by tracking of tasks, and this ensured a performance-driven culture. A science teacher added:

"As an output of the training, we developed a contextualized instructional material in Mathematics that integrated Pedagogical Content Knowledge (PCK) strategies. Additionally, we produced an action research proposal, which was later refined and published." - Teacher 4

Moreover, the program produced both scholarly and practical outputs that extended beyond the workshop sessions. These documents served as evidence of skills mastery and facilitated the continuation of professional exploration and school improvement initiatives. Overall, the training was implemented in accordance with the design outlined in the approved extension project proposal. To provide a summary of the training's overall conduct, Table 3 presents stakeholders' satisfaction ratings for the 66 participants, measured on a 4-point Likert scale. The survey was conducted to evaluate the overall implementation, highlight areas of success, and identify areas requiring improvement.

Table 3
Summary of the Training-Participants Satisfaction Survey

Area	Mean Score	Qualitative Description
Participation of Stakeholders	3.75	Very High
Timeliness of Delivery of Service	3.74	Very High
Accuracy of Service or Problem Solved	3.65	Very High
Relevance to Situation/Community Need	3.76	Very High
Opportunity to Apply/Use Product or Technology	3.76	Very High
Overall Satisfaction	3.70	Very High

Table 3 presents a very high satisfaction in the conduct of training during the face-to-face training-workshop sessions. The themes generated in Table 2 support the result of the satisfaction survey, which was conducted in 2018-2019.

The participants expressed their personal and professional experiences as an outcome of the training. These experiences were analyzed and presented into themes and descriptions presented in Table 3. The narratives of the participants were also presented to support the themes generated.

PCK Training Outcomes for Teachers and Students

Professionally, the training yielded positive outcomes for the participants. The themes: adoption of active learning strategies, enhanced teacher confidence and professional growth, development and utilization of contextualized instructional materials, improvement in student engagement and learning outcomes, and integration of formative assessment and responsive teaching came out as a result of the applications of the PCK training to the actual teaching and learning process, especially in the delivery of instruction in Science and Math basic education. Furthermore, the students demonstrated improvement in subject knowledge, engagement, and learning outcomes.

Table 4
Outcomes of PCK Training for Science and Math Teachers and Their Students: Themes and Descriptions

Themes	Descriptions
Adoption of Active Learning Strategies	Teachers implement “think-pair-share,” virtual manipulatives, and collaborative group exercises to simplify complex topics and foster deeper conceptual understanding.
Enhanced Teacher Confidence and Professional Growth	Participants report increased self-efficacy in delivering challenging Math and Science content, strengthened by resourcefulness and openness to pedagogical innovation.
Development and Utilization of Contextualized Instructional Materials	Educators produce tailored lesson plans, manipulatives, and teaching videos that reflect local classroom realities and support student-centered learning.
Improvement in Student Engagement and Learning Outcomes	Students demonstrate heightened participation, motivation, and assessment performance – evidence of effective PCK-informed instructional approaches.
Integration of Formative Assessment and Responsive Teaching	Teachers incorporate diagnostic checks (exit slips, rubrics) to identify learning gaps in real time and adapt instruction to meet diverse learner needs.

Adoption of Active Learning Strategies

The sheer extent of reorientation of the teacher as an instructor is expressed by the desire to be the facilitator, as learner-centered, and to enhance their abilities, as formulated with the remark:

“We act as facilitators; the focus is learner-centered and their skills get a real boost.” - Teacher 12

These statements express the conscious shift towards learners’ autonomy and independence. This statement was also supported by other teacher participants emphasizing the immediate shift in teaching approaches from lecture as content deliverer to facilitator of learning. Some of the innovation applied by the teachers as an outcome PCK training include incorporation of structured

peer-interaction processes, such as think-pair-share and the use of virtual manipulatives which allowed educators to render abstract mathematical concepts concrete, collaborative tasks, reducing cognitive demand and the possibility of co-constructing knowledge.

"I routinely employ 'think-pair-share' techniques to foster deeper conceptual understanding and utilize virtual manipulatives to make complex topics more accessible and engaging." - Teacher 1

For others, incorporating visual aids and everyday applications in an everyday manner further ensured the anchoring of instructions in real life, thereby providing students with the capacity to balance between formal theory and informal solving of problems.

"One of the new techniques I now use regularly is incorporating real-life applications and visual aids to help students better grasp abstract concepts." - Teacher 6

These are experiential learning in accordance with the Kolb (1984) experiential learning cycle (concrete experience, reflective observation, abstract conceptualization and active experimentation) and with social-constructivism (an emphasis on scaffolded interaction) as proposed by Vygotsky (1978), with the overall result being increased conceptual understanding, improved critical thinking skills, and increased ownership of the education process by the learner. The adoption of the active learning strategies created a learner-centered teaching environment.

Enhanced Teacher Confidence and Professional Growth

Participants also consistently stated that the courses in PCK had produced meaningful increases in their professional growth and self-efficacy as instructors. The workshop helped to create a sense of mastery.

"We learned things we could apply." - Teacher 12
"As a result, I feel more confident in delivering clear and meaningful instruction." - Teacher 7

This expertise was in turn carried into

a sense of greater confidence.

"The training also boosted my confidence in teaching Math... I feel more prepared and equipped with practical tools that I can use in my daily teaching." - Teacher 2

These thoughts correspond to the social-cognitive framework, developed by Bandura (1997), in which mastery experiences are considered the major determinant of self-efficacy beliefs. Designing the sessions in a way that gave the significant emphasis on the real PCK tasks, which appeared in the form of co-building a lesson plan up to micro-teaching lessons, the participants were able to learn not only new methods of teaching and pedagogy but also to reaffirm their confidence in the ability to use those new practices in their classrooms. In turn, such an increase in self-confidence should promote long-term professional development. Teachers will be far more willing to explore new ways of teaching, engage in reflective practice, and become leaders in their schools.

Development and Utilization of Contextualized Instructional Materials

The participants emphasized that the PCK training prompted the development of very contextual instructional artifacts specific to their classroom needs. The tools were modified to relate directly to the purposes of the lesson.

"Rubrics should specify your topic, this is exactly where you'd place 'evolution.'" - Teacher 11

The prospect of a ranking-related certificate became a strong incentive to produce more, indicating the motivational value of tangible credentials to ensure long-term material development. Indeed, multimedia translation of the principles of the PCK can be directly evidenced by the fact that, as output, teachers were coming up with context-sensitive lesson plans, teaching materials, and even a piece of instructional video showing better methods.

"As outputs, teachers developed context-sensitive lesson plans, instructional materials, and even teaching videos that showcased improved strategies." - Teacher 3

Lastly, the point that the participants did not receive generic templates but co-created tailor-made materials in the form of manipulatives, guided worksheets, and multimedia modules that incorporated PCK ideas into their local curricula also reflects this theme.

"We developed a contextualized instructional material in Mathematics that integrated PCK strategies." - Teacher 4

Combining all these findings will indicate the healthy cycle of design, production, and reflective refinement in which teachers applied incentives and collaborative support to effectively realize the PCK concepts into ready-to-use and teaching classroom materials.

Improvement in Student Engagement and Learning Outcomes

The subjects continued to mention that the transition to student-centered practices significantly increased engagement and learning achievement. Indicating the way active learner-based environments promotes participation.

"They were engaged because it was student-centered." - Teacher 11

"They become more participative." - Teacher 10

These statements mean that classroom interactivity increases when students see ownership of their work. A participant provided additional evidence of such a tendency.

"Students are more attentive, participative, and motivated during lessons. Many of them have shared that they enjoy the activities more and find the lessons easier to follow." - Teacher 2

These testimonials are consistent with constructivist and self-determination theories, in which autonomy support and collaboration positively affect intrinsic motivation, processing, and eventual academic performance. By focusing on the active participation and the reality context of the learners, the teachers could not only make the classroom a much better place. However, they were also able to improve the conceptual

learning capabilities of students and long-term interest in learning.

Integration of Formative Assessment and Responsive Teaching

The participants claimed that the formative assessment focus on the training had essentially added to their ability to diagnose and react to the student learning requirements. The performance tasks are a part of the learning activities and assessment data points.

"The concern is also output-based, outcomes-based." - Teacher 9

"Most importantly, I can now tailor instruction in real time, thanks to formative assessment techniques introduced during the training." - Teacher 1

Reading of their outputs and evaluation of their communication require some time, and educators get accurate information about both the personal and group misunderstandings. In addition, the participants said that they learned to use rubrics better when dealing with performance-related assessment, seeing that the evaluation criteria closely matched the learning objectives and gave clear feedback.

"I also learned how to use rubrics more effectively for performance-based assessments." - Teacher 1

These practices constitute a responsive-teaching paradigm: constant cycles of data-driven assessments are used to determine specific interventions, sinking roots in more thorough learning and reducing chronic misunderstandings.

"Teachers also became more adept at identifying learning gaps and applying differentiated instruction, aided by new assessment tools introduced during the training." - Teacher 3

Part of these criticisms' points to an apparent over-reliance on generic approaches at the expense of identifying conceptual gaps in learners. Consequently, the PCK training supplied teachers with specific formative assessment instruments, including exit tickets, concept checks, and diagnostic quizzes, that,

according to participants, helped them detect learning gaps in real-time and implement differentiated instructions. Teachers integrated these assessment cycles into their daily efforts. They, therefore, went beyond a one-size-fits-all plan and created differentiated courses of action that suit a variety of student profiles and strengthen both the acquisition of information and comprehension of concepts.

Impacts Attributed to PCK Training for Science and Math Teachers

Participant-reported outcomes of PCK training are reduced to four major themes in Table 5. Based on the qualitative analysis of teacher experiences, these themes reveal (1) transformational change in both teaching identity and self-efficacy, (2) student engagement and performance gains, (3) professional leadership and professional growth, and (4) collaborative community formation. Collectively, they are used to explain how context-specific PCK interventions can transform the individual's pedagogical beliefs, generate measurable increases in pupil performance, new leadership roles, and an enduring community of practice.

Transformational Shift in Teaching Identity and Self-Efficacy

The theme summarizes how the PCK training was presented as a radical shift in understanding the role of teachers as either carriers of knowledge or the creators of the learner experience, in which the involvement of the learners is the most significant element, regardless of the method of intervention.

"No matter how good your strategy is, it depends entirely on the student's interest." - Teacher 11

These words are indications that practical training, which can be applied, helped develop confidence and an eagerness to experiment. This change was long-term.

"In the long term, the PCK training has fundamentally shifted my approach to teaching. I now see myself not just as a content deliverer, but as a facilitator of learning." - Teacher 1

Table 5

Impacts Attributed to PCK Training: Themes and Descriptions

Themes	Descriptions
Transformational Shift in Teaching Identity and Self-Efficacy	Participants described a constructivist shift from traditional lectures to a facilitator-of-learning approach, which boosted their self-efficacy, creativity, and empowerment, and helped them regularly simplify complex Math and Science concepts in innovative ways.
Student Engagement and Performance Gains	Educators noted clear improvements in student participation, motivation, and assessment scores, demonstrating the effectiveness of active learning and PCK-informed methods applied consistently over the years through innovations learned from the PCK training and the outputs developed.
Professional Leadership and Growth	Teachers advanced into leadership roles, as mentors, curriculum designers, content validators, and unit developers, strengthening school improvement and peer training, and achieving career growth even during the pandemic.
Collaborative Community Formation	The training fostered a strong professional learning community where teachers systematically shared and benchmarked materials, co-designed lessons, and reflected together. Public sharing of modules became a platform for peer review and a living record of pedagogic innovation, supporting collective intellect and continuous instructional improvement.

These statements, in combination, describe a shift in the constructive-facilitative type of pedagogy, a type under which teacher expertise is not utilized in lecturing, but in supporting inquiry, responsiveness to students, and maintenance of innovation during their delivery practice. Participants' common report was that the PCK training had an energizing effect on self-efficacy and creative pedagogical practices.

"There is something you developed, something you've really grown through." - Teacher 12

This statement stressed how the

practical development of lesson materials was an experience of mastery that builds confidence.

"I feel significantly more competent and confident in my ability to teach complex math concepts." - Teacher 1

This response highlights the effect of training on teachers' beliefs concerning their capabilities as teachers. Another participant observed, indicating the direct results of strategies and resources applied in a practical sense of preparedness.

"The training also boosted my confidence in teaching Math... I feel more prepared and equipped with practical tools that I can use in my daily teaching." - Teacher 2

These results correspond to the social-cognitive model of Bandura (1997), in which mastery experiences serve as the most powerful factor that drives self-efficacy, and they also demonstrate that the provision of specific (based on PCK) tools can not only help an educator to gain confidence but also stimulate creativity in the planning and implementation of lessons.

Student Engagement and Performance Gains

According to the participants, the PCK training elicited the ripple effect, where students got more engaged and inquisitive and had measurable academic progress. This increased participation was in the form of prolonged results.

"The ripple effect extended to students, with improved engagement, better academic performance, and more curiosity-driven learning." - Teacher 3

This is an indication of how motivational changes at an early stage can determine their career orientation and academic excellence. Further, the participants reported on the ability of students to perform well in high-stakes situations, indicating the development of confidence and advanced inquiry skills in the PCK-informed, active-learning environment.

"They excel in national research; they're amazingly

fast." - Teacher 14

Perhaps most notably, the widespread misconception of mathematics as inherently daunting was effectively challenged.

"The mindset of students that mathematics is a difficult subject was erased. They now love Mathematics." - Teacher 5

It means a different shift in the attitude of feeling that educational psychology has associated with greater tenacity and more profound comprehension. Taken together, this set of consequences shows that student-oriented PCK practices enhance short-term engagement and performance and bring about sustained changes in learner identity, self-efficacy, and aspiration.

Professional Leadership and Growth

The participants commented that the PCK training served as a catapult to meaningful professional growth and leadership at their schools and the wider professional community. The fact that one teacher received formal acknowledgment of their contributions marked how PCK-driven products turned into avenues of career difference.

"Authorship (promoted); we've already received recognitions like ICON Classroom Outstanding." - Teacher 12

It is an indication of the development of critical revision and domain knowledge. Others wrote about expanded scholarly functions.

"I have taken new role in our school because after the training I became Grade 7 Mathematics teacher leader. I became also a validator in video lesson and script in RBI." - Teacher 5

Most importantly, the training resulted in new appointments to leadership positions, reflecting both vertical mobility and horizontal recognition of leadership within the institution. This leadership development was further reinforced through peer mentorship.

"I've been asked to mentor junior teachers in

integrating new ICT teaching strategies and contribute to our school's math curriculum improvement plan."
- Teacher 1

Collaborative Community Formation

The training formed a long-term professional learning community where the teachers supported one another all the time outside the workshop. Educators incorporated collaborative reflection in daily practice by designing forums where peer exchange would occur.

"If there's time for benchmarking, we can share, many are doing so; we displayed ours in the library." - Teacher 13

This training gained momentum following the sessions, leading to continuous mutual learning structures. Further, the teachers converted personal products into departmental resources, thus sharing expertise in the department.

"Collaboration among teachers flourished post-training, with greater sharing of resources, co-planning lessons, and peer mentoring through Learning Action Cells (LACs)." - Teacher 3

Participants observed that the PCK training became a form of concrete spirit of collegiality of resource-sharing, which can be aptly captured in the crisp commandment. Educators started sharing lesson examples, manipulatives, and assessments openly.

"Collaboration among teachers flourished post-training, with greater sharing of resources, co-planning lessons, and peer mentoring through Learning Action Cells." - Teacher 3

Teacher collaboration had blossomed after training, as more resources were shared, as more co-planning of lessons occurred, and as more peer mentoring through Learning Action Cells was a possibility, showing that systematic cross-reflection and mentoring had become a part of school life. Additionally, the participants indicated that in the past, they had the booklets in their cabinets, which were the stepping stones about SIM and possession of a certificate about

ranking, acted as a major force in encouraging the group to develop more material.

"We still have the booklets in our cabinets; they served as stepping stones for the SIM, and having a certificate tied to ranking really motivated us to produce more."
- Teacher 13

In combination, these reflections demonstrate that the PCK initiative not only furnished individual teachers with fresh approaches but also cultivated a community of professional workers in instruction, characterized by shared responsibility, mutual support, and constant peer-to-peer learning, that has been shown in the literature to be a fundamental factor in driving sustained instructional improvement. The PCK training generated multiple positive outcomes to students and faculty yielding from personal, professional, and community level growth.

DISCUSSION

The change theory of Weiss served as the theoretical anchor in evaluating the impacts of the PCK training implementation. It proved useful in analyzing BukSU's extension project – from the assessment of inputs and outputs to outcomes and impacts. The PCK training yielded positive results for the partner institution (DepEd – Malaybalay City Division), the students, and the community of Malaybalay. The inputs for the analysis included the approved project proposal and its implementation. Through interviews and satisfaction surveys conducted with the participants, the training was found to have resulted in a high level of satisfaction. Moreover, despite the COVID-19 pandemic disrupting face-to-face training, online platforms such as Zoom, Google Meet, and social media served as alternative venues for meetings and discussions, allowing the project to be completed. The faculty facilitators were subject-matter experts from BukSU whose extensive experience in teaching science and mathematics education enabled them to effectively master and apply the PCK framework.

The Math and Science PCK training design was anchored on Shulman's (1986)

foundational concept of Pedagogical Content Knowledge (PCK), integrating inquiry-based modules and experiential learning activities such as micro-teaching, peer feedback, role-playing, and collaborative lesson planning. These components reinforced the connection between theory and practice, enabling participants to produce tangible instructional outputs such as contextualized lesson plans and video exemplars. The design reflects best practices identified by König et al. (2017), who emphasized the importance of well-structured learning opportunities in teacher preparation to foster the acquisition of pedagogical knowledge. The outputs of the training, particularly the collaboratively developed lesson plans and instructional materials, left a lasting impact on the participants.

This training delivery model, comprising a series of intensive three-day seminars conducted during semestral breaks and weekends, supplemented with online sessions, provided flexibility to accommodate teachers' schedules without disrupting their classroom duties. The incorporation of active learning strategies such as think-pair-share, real-life problem-solving tasks, and the use of virtual manipulatives, aligned with the learning theories of Kolb (1984) and Vygotsky (1978), made the sessions more engaging and effective in enhancing learning outcomes and pedagogical practice. The institutionalization of the program involved the use of printed manuals, exemplar lesson plans, online applications (e.g., GeoGebra and Bagatrix), and smart technologies to reinforce instructional transfer and classroom integration. Moreover, the provision of learning modules offered participants clear direction and motivation to carry out their tasks and apply their newly acquired knowledge and skills in their respective classrooms.

One of the most significant impacts of the training was the reported increase in teachers' self-efficacy and pedagogical innovation. Teachers described heightened confidence in delivering complex Mathematics and Science concepts, along with a greater willingness to experiment with new instructional approaches. These outcomes align with Bandura's (1997) theory that mastery experiences play a central role in developing self-efficacy. Similarly, Jacob

et al. (2020) found that strong pedagogical content knowledge (PCK) supports informed instructional decision-making, particularly when teachers are empowered through hands-on training and collaborative lesson design.

Similarly, the Science and Mathematics teachers developed differentiated instructional materials contextualized to their classroom settings, including multimedia resources, manipulatives, and customized lesson plans. These findings are consistent with Iserbyt et al. (2017), who demonstrated that professional development programs emphasizing specialized content knowledge and its practical application can significantly enhance both enacted PCK and student performance.

Evidence from this study also shows that students responded positively to PCK-informed teaching practices. They demonstrated higher levels of engagement, improved assessment performance, and more positive attitudes toward traditionally difficult subjects such as Mathematics. These ripple effects echo Gess-Newsome et al.'s (2019) findings, which confirm that gains in teacher professional knowledge are strongly correlated with improved student learning outcomes.

The integration of real-time formative assessment tools, such as rubrics, exit slips, and concept checks, enabled teachers to identify learning gaps and implement differentiated instruction more effectively. Fernandez (2014) emphasized that responsive teaching and formative assessment are essential components of any robust PCK model. These practices support data-driven teaching that adjusts to learner needs, thus enhancing instructional equity and effectiveness.

Beyond classroom-level effects, the PCK training facilitated a paradigm shift in teacher identity. Educators transitioned from being content transmitters to becoming facilitators of learning. They assumed leadership roles in mentoring peers, validating instructional materials, participating in curriculum reviews, and conducting internal training in provincial and regional levels. These developments are in line with König et al. (2017), who asserted that

structured learning opportunities cultivate not only pedagogical knowledge but also leadership and innovation in teaching.

Sustainability and scalability were also notable outcomes of the training. The creation of modular, pandemic-resilient materials ensured that teachers could continue using and refining what they learned, even during disruptions like COVID-19. Participants emphasized the importance of continued support through coaching and refresher workshops. Peer-led structures such as Learning Action Cells (LACs) emerged as vital platforms for collaborative lesson planning, reflective discussion, and the institutionalization of best practices—similar to what Smit et al. (2017) described as a durable shift in professional attitudes fostered by short but intensive PCK interventions.

One of the most important suggestions that could be given in order to maintain the project is the institutionalization of continuous support, followed by well-organized follow-up in the form of regularly planned coaching sessions, refresher workshops, as well as peer-mentoring cycles, along with digital platforms and tools. Integrating such mechanisms within the professional-development structure will not only support and derive the initial PCK benefits but also allow the scaling and data-driven adjustment of the choice of teaching approaches so that educators stay capable of responding to the changes in the curricular requirements and technological progress.

Ultimately, this study affirms the findings of Jacob et al. (2020) and Fernandez (2014), who argue that systemic instructional improvement is achievable through targeted professional development grounded in PCK. By empowering educators with theory-informed, practice-oriented tools, the PCK training program catalyzed individual, institutional, and systemic change in instructional culture across the participating schools. It stands as a promising and scalable model for transforming Science and Math instruction in low-resource educational settings.

To summarize the findings of this paper, there is a seen change in the teaching

strategy and instructional delivery of the teacher-participants of the PCK training conducted by BukSU. The changes positively affected the of the Math and Science educators and learners in the DepEd – Malaybalay City Division. After 5 years of training implementation, students showed interest in math and science programs in tertiary education. Thus, Weiss' Theory of Change is proven as an effective framework in the impact analysis.

CONCLUSION

The findings of this impact evaluation reveal that the PCK training initiative by BukSU had profound and sustained effects on the quality of Science and Mathematics education in the Malaybalay City Division. The training's well-structured curriculum, dynamic delivery formats, and hands-on approach created an effective professional development model that promoted active learning, differentiated instruction, and community collaboration. Teachers gained greater confidence and mastery in subject-specific pedagogy, developed contextualized instructional materials, and integrated responsive teaching strategies. These outcomes, in turn, contributed to measurable gains in student engagement, motivation, and academic performance. The formation of collaborative professional communities and the assumption of leadership roles among participants further extended the training's influence, establishing it as a sustainable model for capacity-building in resource-constrained educational contexts. Therefore, the PCK training project proved effective in positively impacting the learners, teachers, and the wider community in the teaching of Science and Mathematics.

RECOMMENDATION

It is recommended that the DepEd – Malaybalay City Division replicate and institutionalize the PCK training model across other schools to maximize its positive impact on Science and Mathematics education. Bukidnon State University, in collaboration with DepEd, may sustain the initiative by integrating it into continuing professional development programs

and adapting its framework for other subject areas. Future implementations should establish a systematic monitoring and evaluation mechanism to track long-term teacher and learner outcomes, while also strengthening partnerships among schools, communities, and higher education institutions to ensure continuous capacity-building and shared professional growth.

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