

Validation of Acquisition-Capacitation-Optimization (ACO) professional development framework for Out-of-Field Science teachers

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ABSTRACT

A professional development framework is fundamentally indispensable in the context of science education, where out-of-field teaching is prevalent. With OOF teachers filling in the gaps to deliver content in the actual classroom, a structured professional development program can systematically address science content gaps, pedagogical challenges, and affective barriers. The practice of out-of-field science teaching has institutional implications not only for teacher identity and instructional quality but also for student learning outcomes and achievement. Within the Philippine education system, quality education is at the core principle of the K to 12 Basic Education program (RA 10533), and the Philippine Professional Standards for Teachers (DO 42, s. 2017) recognizes the importance of continuing professional development of teachers and the role of teacher quality towards learner achievement. This legal framework and professional guideline explicitly articulate a high standard for teacher quality and student literacy; however, the persistence of OOF science teaching proved otherwise and substantiated institutional and policy constraints. A professional development framework becomes necessary to reconcile the ideal standard with the current status quo in the educational landscape. This study aimed to develop, implement, and evaluate a professional development framework for out-of-field science teachers using the ADDIE model for the key processes. A Developmental Research Design was utilized in this study with the four different phases (Analysis, Design and Development, Implementation, and Evaluation). The study was carried out with the help of OOF science teachers and their students. The study developed the Acquisition-Capacitation-Optimization (ACO) Professional Development Framework, which promoted OOF science teachers' competence and students' performance. Thus, it is recommended that the ACO Framework be implemented with larger cohorts, expanded on a broader scale to cover wider topics in science and other domains, and further examined through cross-cultural validation.

Keywords: Professional development, professional development framework, Science education, Out-of-field Science teaching, Out-of-field teachers.

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INTRODUCTION

A well-crafted professional development framework for out-of-field (OOF, for brevity) science teachers is crucial to promote equitable and quality science education. Teaching science out of field is prevalent in many schools worldwide (Campbell et al., 2023). Globally, OOF science teaching is considered a recurring problem (Luft et al., 2020). This perennial problem of OOF teaching has never been properly addressed for several myriad reasons. (Hobbs, 2014). Teacher shortages (Kenny & Hobbs, Researching with In-service Teachers Teaching "out of field", 2015) and inadequate teacher staffing that simply fill gaps in subjects where no qualified teachers are available (Aburto et al., 2024) were among the reasons for OOF teaching. In the US, the number of OOF science teachers was low due to strict certification requirements, but the lack of subject-matter knowledge remained a problem (Morris, 2022). On the other hand, in Germany, continuous professional development programs were offered through various qualification programs and training courses to OOF teachers (Schueler et al., 2015). It is important for OOF teachers to have professional learning opportunities to support their teaching (Hobbs & Porsch, 2021).

Professional development programs can help out-of-field teaching by enhancing teacher knowledge and skills. It provides opportunities to acquire specific professional skills and to renew basic knowledge in a given field (Ceren, 2019). Professional teacher development is grounded in the belief that the primary reason for learner success is the effectiveness of educators (Fahimeh, et al., 2024). As such, the quality of learners is built upon the foundations of quality education. Quality education is a fundamental human right (UNESCO, 2023), and all children across the world must have access to it. Achieving quality education has been one of the Sustainable Development Goals (SDGs) of the United Nations' 2030 Agenda. The SDG 4 specifically provides to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (Incheon Declaration and SDG 4, 2016, p. 29). Increasing the number of qualified teachers has been one of the targets (4c) and indicators (37) of SDG 4. Hence, achieving quality education means having quality teachers in the classroom to provide inclusive and equitable instruction.

In the Philippine context, the K to 12 Basic Education program (R.A. 10533) specifically provided for inclusive and quality science education. The addition of two years of senior high school was an important curriculum reform in the country, in line with its vision to make Filipino learners globally competitive and equipped with 21st-century skills (Salvan & Hambre, 2020). Alongside this vision, the NEDA Ambisyon Natin 2040 sets aspirations for Filipinos who are well educated, smart, and innovative, and who will continuously improve the quality of their lives. Towards achieving this end of a Matatag, Maginhawa, at Panatag na buhay, Filipino students must acquire foundational literacies and develop competencies through the formal education system in the classroom. The Philippine educational system, with its curriculum reform and the adoption of the Philippine Professional Standards for Teachers (D.O. 42 s. 2017) has specifically laid down the guidelines and requirements for teacher quality. The Department of Education (DepEd, for brevity) recognizes the importance of enhancing teacher quality towards learners' achievement.

However, OOF science teaching posed an undeniable challenge inside the classroom (Talili, et al., 2021) where teachers teach subjects where they have an inadequate background or no formal training of the content and no certification (Hobbs & Porsch, 2021). OOF teaching is widely happening in the Philippines, both in public and private secondary schools (Torcino & Villocino, 2023). The recent report of the Second Congressional Commission on Education (EDCOM II) found that about 62% of teachers teaching in high schools taught subjects which were not their college major or field of specialization. It is important to look

into this practice of out-field teaching because in the aforementioned global and local efforts of providing quality education, the teacher quality is of paramount importance. Qualified teachers must meet these expectations and should have the academic qualifications in content knowledge and pedagogy (Francisco, 2020; Gaganao & Odon, 2024).

Several studies about OOF teaching were conducted in the Philippines. Several studies looked into the lived experiences of out-of-field teachers (Bugwak, 2020; Arendain & Limpot, 2022; Torcino & Villocino, 2023; Abrantes et al., 2024), their academic qualifications (Tenorio, 2022) and performance (Talili et al., 2021), their self-efficacy and motivations (Castro et al., 2023). The common findings in these studies were mainly on OOF teachers' challenges both in academic content and pedagogical competence. Out-of-field teachers need technical assistance and additional training to improve their pedagogical techniques and assessment methods (Castro et al., 2023). In general, out-of-field teachers need support from administrators, ongoing professional development programs, and active involvement in professional learning opportunities (Talili et al., 2021), such as workshops, seminars, and training sessions, or to enroll in and study skill-related programs to enhance their capabilities.

An important finding by Tenorio (2022) in his study of out-of-field public secondary teachers was that some schools lack a framework for capacity-building mechanisms to support the desired changes in the out-of-field teachers' practice and that the institution fails to acknowledge the unique needs of OOF teachers. Considering these challenges, they must be provided with professional development opportunities (Abrantes & Bargamento, 2024), and this should be implemented for all OOF science teachers. A professional development program that is responsive to their needs is of paramount importance, particularly an instructional support system for out-of-field science teaching practice. Addressing the challenges associated with OOF science teaching is a pressing concern with implications for instructional quality and educational equity in the current educational landscape.

If support mechanisms are not effectively targeted and provided, there would be greater risks and a negative impact on teacher quality in the delivery of science instruction. On the other hand, a well-crafted, structured professional development framework can provide a targeted response to the challenges faced by OOF teachers.

Professional development that equipped OOF teachers with both content knowledge and pedagogy to support complex student learning processes and learners' achievement (Hammond et al., 2017) was of paramount importance. There were various professional development initiatives in the Philippine context to address out-of-field science teaching. The Cross-specialization training of science teachers on their non-major science subject (NCR_RM_s2018_145; DM1195 09-14-18; RM No. 110, s. 2018), which started as a national training initiative that was cascaded to the different regional offices and division levels across the country. These cross-specialization training sessions aimed to enhance the knowledge and skills of OOF teachers and science teachers in their non-major specialization by providing content and pedagogy training across the four science domains: Earth science, Biology, Chemistry, and Physics.

Also, there were Mentoring Program Initiatives (Tenorio et al., 2022; Barrios, 2024) in which mentors were experienced in-field teachers who provided guidance to OOF teachers, particularly in subject-matter expertise, and helped structure and organize classroom activities and instructional strategies. This intervention had enhanced instructional strategies and the OOF teachers' self-efficacy and confidence. Moreover, the Collaborative Learning Action Cell (Sumbilla et al., 2022; Javines, 2024) was modeled after DepEd's Learning Action Cell (LAC), in which a learning facilitator took charge of planning and implementing the targeted intervention program. The CLAC intervention for out-of-field science teachers,

which followed the LAC framework, had positively impacted OOF teachers' self-efficacy after exposure to the program.

Several initiatives were undertaken to address OOF teaching in the Philippines. However, as previously noted by Tenorio et al. (2022), out-of-field teachers have unique needs, and the professional development programs designed for them must be responsive to both their personal and professional needs to enhance their efficacy and instructional capacities. This study aimed to develop, implement, and evaluate a professional development framework for out-of-field science teachers. It is essential that the professional development framework deliberately and carefully organizes OOF teachers' learning progress into a series of intentional and connected stages. This ensures a properly sequenced support that starts with building the foundational science content knowledge, progresses to developing pedagogical skills and effective teaching strategies, and involves a continuous refinement of instruction. The implementation of this structured PD framework for out-of-field science teachers is expected to yield positive outcomes, including improved content knowledge, enhanced pedagogical skills, and increased instructional confidence, enabling them to deliver more accurate, engaging, and inquiry-oriented science instruction.

Thus, the present study developed a concrete, context-specific framework for upskilling and improving the competence of out-of-field science teachers. The professional development framework, designed, implemented, and evaluated, was responsive to the OOF teachers' needs in teaching science, particularly in content knowledge, pedagogical skills, and technology integration. A tangible, realistic support system for out-of-field science teachers was achieved, bridging the gap between teacher qualifications and the content knowledge requirements.

Statement of the problem

The objectives of this study include the exploration of the implementation process of the Revised School-Based Management (SBM) Framework through the identification of its best practices, challenges, and lessons learned by the school leaders. Particularly, this study seeks to uncover further understanding of how the school leaders implement the SBM framework, overcome SBM-related implementation challenges, and support school governance and improvement. Through the findings of the study, recommendations are made to improve the capacity of the school leaders, school governance, and the process of SBM implementation itself.

1. Investigate how school leaders implement the Revised School-Based Management (SBM) Framework in their respective institutions.
2. Identify the best practices in the implementation of the Revised SBM Framework practiced by school leaders.
3. Uncover the challenges faced by school leaders in the implementation of the Revised SBM Framework.
4. Determine the lessons learned by school leaders concerning the implementation of the SBM framework.
5. Analyze the impact of the SBM framework implementation on the school governance, leadership, stakeholders, and resources.
6. Formulate recommendations that may improve the leadership, governance, and the process of SBM implementation.

METHODOLOGY

This study employed the Developmental Research Design of Richey and Klein (2005), which is widely recognized as one of the fundamental methods used in developing instructional materials (Ibrahim, 2016). As a pragmatic type of research, developmental research design involves the process of designing, developing, and evaluating instructional programs grounded in data systematically derived from actual practice. Of the two types identified by Richey and Klein (2005), this study specifically utilized Type 2, which involves constructing and validating models and processes, and which is composed of three phases: model development, model use, and model validation. This study focused on the design, implementation, and evaluation of a professional development framework for out-of-field (OOF) science teachers, drawing on both quantitative and qualitative data. According to Ibrahim (2016), developmental research proceeds through four stages, beginning with analysis, in this case an analysis of OOF teachers' challenges and needs, followed by a design and development phase in which a context-specific and needs-responsive professional development framework was crafted and subsequently implemented among OOF science teachers, and culminating in the evaluation of the program's value and effectiveness. During the implementation phase, a program timeline was established and a corresponding training program matrix was followed. The trainer was selected on the basis of his qualifications as a content expert in the field, and the training participants were selected based on their profiles. The professional development program was conducted in person through one-on-one mentoring and microlearning sessions. In the evaluation phase, the value and effectiveness of the professional development framework were assessed in terms of the out-of-field teachers' attributes, their individual narratives of their experience during the program, and their students' learning outcomes as measured through a pretest and posttest. The pretest and posttest items used to evaluate students' learning outcomes were adopted from the Department of Education's Science 10 Learner's Material. To ensure the rigor and credibility of the evaluation, both quantitative and qualitative data were systematically analyzed using appropriate statistical and thematic procedures, and the results were used to determine the program's effectiveness in addressing the needs of out-of-field teachers as well as to identify areas for improvement and refinement of the professional development framework.

This study was conducted in the Lapu-Lapu City school division in Cebu Province. Lapu-Lapu City has eighteen (18) public secondary schools, including night high schools, spread across the ten (10) districts of the division, along with fifteen (15) private secondary schools, both sectarian and non-sectarian. The Division of Cebu Province, in comparison, has two hundred (200) secondary schools distributed across fifty-four (54) districts. The secondary schools included in the study were identified as having OOF teachers teaching science, based on the current school year 2025-2026 allocation of teachers' teaching loads. Three (3) big schools, in terms of student population, and one smaller school from the Lapu-Lapu City Division were included, together with two (2) big schools from the Division of Cebu Province. Specifically, the study was conducted in four (4) high schools within the Lapu-Lapu City division, corresponding to districts 1, 5, 8, and 10, and in two (2) high schools from the southern districts of the Cebu Province Division. These particular schools were purposefully selected because they have large student populations within their respective divisions and a high likelihood of out-of-field teaching in science. Out-of-field teacher-participants came from these four (4) schools in the Lapu-Lapu City Division and two (2) schools in the Cebu Province Division, and all of them took part in the model development phase, particularly during the research analysis stage. Two of these OOF teachers, from two schools within the Lapu-Lapu City Division, went on to participate in the

implementation of the professional development program, and their corresponding students were evaluated for the outcomes of the program. The teacher-participants and their students were drawn from the schools identified earlier on the basis of student population and the prevalence of out-of-field science teaching.

The respondents of the study consisted of thirty (30) OOF teachers whose attributes and experiences were examined and evaluated to determine their needs in relation to teaching science out of their field. Of these, eight (8) were male and twenty-two (22) were female, with the majority aged twenty-six (26) to thirty (30) years old. In terms of educational background, twenty-three (23) of the thirty (30) teachers, or 77%, held a Bachelor of Secondary Education (BSED) degree; three (3), or 10%, held a Diploma in Preschool Education (DPE); and four (4), or 13%, came from other fields such as engineering and accountancy, together comprising the total of thirty (30) respondents, or 100%. With respect to field of specialization, twenty (20) teachers, or 67%, specialized in Mathematics; nine (9), or 30%, specialized in Technology and Livelihood Education (TLE); and one (1), or 3%, specialized in another field, for a total of thirty (30) respondents, or 100%. In terms of educational attainment, eleven (11) teachers, or 37%, held a bachelor's degree only; fifteen (15), or 50%, had earned units toward a master's degree; and four (4), or 13%, had completed their master's degree, again totaling thirty (30) respondents, or 100%. Finally, with regard to years of teaching experience, seven (7) teachers, or 23%, had been teaching for 1 to 3 years; eight (8), or 27%, for 4 to 6 years; five (5), or 17%, for 7 to 9 years; and ten (10), or 33%, for 10 years or more, for a total of thirty (30) respondents, or 100%.

The research participants were selected purposively, taking into consideration the incidence of OOF science teaching in the identified schools across the districts of the Lapu-Lapu City and Cebu Province divisions. Participants met the following criteria: a) they were teaching Science 10 during the school year 2025-2026, and b) their field of specialization based on their baccalaureate degree was not science. The OOF teacher-participants identified from these secondary schools took part in the first phase, the analysis phase of the study, which aimed to determine their least-learned science competencies encompassing content knowledge, pedagogical skills, technology integration, and attitudes and beliefs toward science. Participants also took part in a semi-structured, in-depth interview to further explore their experiences as out-of-field science teachers. The professional development program was ultimately evaluated based on a) the out-of-field teacher-participants' content knowledge, pedagogical skills, technology integration, and attitudes and beliefs toward science, and b) their students' learning outcomes on a pretest and posttest.

This developmental research study made use of an adopted research instrument based on the factor matrices of the TPACK framework of Schmidt et al. (2009), employing a 5-point Likert scale to measure OOF teachers' pedagogical skills, with response options of 1 for Limited, 2 for Basic, 3 for Proficient, 4 for Advanced, and 5 for Expert, as well as a corresponding 5-point Likert-scale measure of OOF teachers' technology integration. In addition, a 5-point Likert-scale construct measuring out-of-field teachers' attitudes and beliefs toward science, with response options of 1 for Strongly disagree, 2 for Disagree, 3 for Neutral, 4 for Agree, and 5 for Strongly agree, was adopted from the P-TABS Questionnaire of Lloyd (2016). A qualitative interview guide was also used, comprising questions designed to explore the actual experiences of OOF science teachers and to obtain information regarding the challenges and opportunities they encountered while teaching out of their field and during professional development sessions. The final instrument consisted of a 30-item multiple-choice test adopted from the Department of Education's Science 10 Learner's Material, which was used during the evaluation phase following the implementation of the professional development program to assess students' learning outcomes through a pretest

and posttest design. All of these research instruments were validated and evaluated by a panel of field experts.

The researcher obtained ethics clearance under Code 2142/2025-07 from the CNU Research Ethics Committee (CNU-REC), and ethical protocols were strongly adhered to throughout all phases of this developmental study, with all ethical considerations observed at all times. A study permit was subsequently obtained from the schools' division offices (SDO) through a transmittal letter addressed to the Schools Division Superintendent, along with another transmittal letter addressed to the school heads of the schools where the study was conducted. The research purpose was properly communicated to the office, and the confidentiality of all information relevant to the study was ensured. The permission of each teacher-participant was sought by allowing them to read the informed consent form in full, which outlined all information about the research, including its purpose, possible risks and benefits, the voluntariness of participation, and the confidentiality of the data obtained, after which teacher-participants affixed their signature as a form of consent. During the final phase of the study, in which students participated in the evaluation of the professional development program, the permission of the students and their parents was obtained by having them thoroughly read and sign the Assent Form and the Parent Informed Consent Form, both of which laid down all pertinent information about the research, including its purpose, possible risks and benefits, the voluntariness of participation, and the confidentiality of data obtained. The research study commenced only after all permissions had been granted and approval to participate was in place.

The research instruments used in actual data collection were validated by field experts. The science competencies checklist (Instrument 1), the concept test questionnaires (Instruments 2 and 7), and the Likert-scale constructs (Instruments 3, 4, and 5) were printed and distributed in person by the researcher. As noted by Toyon (2021), participants in this type of research method can respond to questions either through correspondence, such as mail or email, or through face-to-face, in-person interaction, and in the conduct of this study, in-person correspondence was used during the distribution of the science competencies checklist, the test questionnaires, and the Likert-scale constructs. Participants, who were purposively selected because they were OOF teachers teaching science, were asked to complete the checklist, questionnaires, and Likert-scale constructs on printed documents, which were retrieved by the researcher after data analysis. In addition, to further explore participants' actual experiences as OOF teachers teaching science, the researcher conducted semi-structured, individualized, in-depth interviews to investigate the different challenges and opportunities they encountered in the field. The researcher-made, open-ended interview guide questions underwent expert validation prior to use. Individualized interviews were then conducted in person, lasting approximately an hour or less, in a location convenient for both the researcher and the respondent. These interviews were recorded via electronic means, and verbatim transcriptions were generated. The qualitative data obtained through the individualized interviews were classified, tabulated, and coded for analysis (Santos & Castro, 2021), following Braun and Clarke's (2006) six-step framework for qualitative data analysis. Data collection for this study was conducted over a one-month period.

The printed research instruments, comprising the science competencies checklist (Instrument 1), the concept test questionnaires (Instruments 2 and 7), and the Likert-scale constructs (Instruments 3, 4, and 5) for pedagogical skills, technology integration, and attitudes and beliefs toward science, were filed and organized following data collection. The individualized interview recordings for each research participant were stored electronically and properly labeled for safekeeping. Individual responses were also encoded into a raw data master file containing participants' demographic profiles, their least-learned science

competencies, content knowledge, pedagogical skills, technology integration, and attitudes and beliefs toward science, with this raw data file saved in MS Excel format for subsequent analysis and interpretation. Verbatim transcriptions of the individual narratives obtained from the interview recordings were likewise tabulated, coded, and sorted for themes, and this raw data file was similarly saved electronically. In parallel, existing interventions aimed at addressing out-of-field science teaching were synthesized through a literature review and analyzed thematically. During the literature review, the researcher defined the scope of the review and conducted preliminary article searches, after which the articles were screened for relevance to the study and sorted into those related to proposed interventions or to actual implemented programs. The sorted articles were then coded and analyzed thematically, and the information obtained from the studies reviewed formed part of the basis for the design and development of the professional development framework for OOF science teachers, with this thematic analysis carried out manually.

Finally, during the evaluation phase, the students' learning outcomes were measured through a pretest and posttest administered after the full implementation and completion of the professional development program. The student-participants' pretest and posttest scores were analyzed using a paired-samples t-test, which was employed to determine the mean difference between the two sets of scores along with the corresponding standard deviation and standard error, using the equation $t = \frac{d - \sigma}{\sigma / \sqrt{n}}$. The confidence level was set at 95%, with the t-value considered significant at less than a 0.05 margin of error ($p < 0.05$), in order to examine whether there was a significant difference in the students' pretest and posttest scores following the professional development sessions. To further determine the practical significance of the magnitude of the difference in the means, Cohen's effect size was computed using the equation $d = \frac{t}{\sqrt{n}}$. All data were processed using Microsoft Excel, and both statistical significance and practical significance were presented in order to provide a fuller understanding of the magnitude of the difference observed.

Ethics clearance (ERC Code: 2142/2025-7) was obtained prior to the conduct of this research study, and the ethical protocols of the CNU Research Ethics Committee (CNU-REC) were upheld by the researcher at all times. In terms of the purpose and conduct of the study, the researcher observed ethical conduct in obtaining consent and in communicating the purpose and objectives of the research, as outlined in letters seeking permission to conduct the study, which contained information about the purpose and duration of the study, the procedures and voluntariness of participation, possible risks and benefits, and the confidentiality of the research data obtained, consisting of participants' responses. With respect to participants, the researcher adhered to ethical protocols in obtaining their consent to take part in the study, and the Participant Information and Informed Consent Form, the students' Assent Form, and the parents' Informed Consent Form strictly followed CNU-REC protocols, laying down participants' responsibilities, risks, and potential benefits, the voluntariness of participation, and the confidentiality of information. It was made clear throughout that participation was voluntary and that the data obtained would be kept strictly confidential, with participants' willingness to take part maintained throughout and their right to stop or withdraw from the study at any time upheld, without any resulting disadvantage should they choose not to participate or to discontinue participation at a later date. Any conflict of interest was truthfully disclosed by the researcher to ensure research integrity, and the present study does not involve any conflicts of interest related to the researcher's personal relationships, institutional affiliations, or financial interests. Research data obtained, consisting of participants' responses, were treated with the utmost confidentiality to the extent permitted by law, with responses recorded, reviewed, and analyzed only by the researcher and the data analyst, upholding anonymity and confidentiality, and with participants' names

and other personal information safeguarded to ensure their participation without fear of exposure.

The researcher further ensured that all participants underwent the proper protocols for granting permission to participate by having them thoroughly read the informed consent form, which laid down all information about the conduct of the study, including its purpose, possible risks involved, benefits, the voluntariness of participation, and the confidentiality of data obtained, after which teacher-participants affixed their signature as a form of consent to participate in the study. It was of prime importance that participants were protected and in no case made vulnerable to possible deception or coercion; participants in this study were treated with respect, and their rights, as well as their free will to participate or withdraw from participation, were upheld throughout. Participant recruitment strictly followed the guidelines of the CNU-REC, and the researcher strongly adhered to ethical protocols in obtaining participants' consent, with the Participant Information and Informed Consent Form, the students' Assent Form, and the parents' Informed Consent Form laying down participants' responsibilities, risks, and potential benefits, the voluntariness of participation, and the confidentiality of information; participation in this research was strictly voluntary and participants' willingness to take part was upheld at all times, with the right to stop or withdraw from the study at any time. The researcher further ensured that all student-participants involved in the evaluation phase of the study underwent the proper protocols for granting permission to participate, together with their parents' permission and approval to take part in the pretest and posttest, by having them thoroughly read the students' Assent Form and the parents' Informed Consent Form, which laid down all information about the conduct of the study, including its purpose, possible risks involved, benefits, the voluntariness of participation, and the confidentiality of data obtained, after which student-participants and their parents affixed their signatures as a form of consent to participate in the study.

In adherence to ethical protocols, the researcher specifically outlined the potential downsides and risks of participating in the study and ensured that all participants were fully aware of them. The present study posed no risks to participants, whether teachers or students, and during data collection the researcher ensured that study activities did not expose participants to any harm, while also ensuring that their rights and privacy were protected at all times. This study was beneficial to the academe in general and carried indirect benefits for the research participants as well, given that it produced a framework for out-of-field teachers teaching science and, through the professional development program, an intervention that can help address out-of-field teaching in science, with the resulting professional development framework, the targeted output of this research study, expected to have a positive impact on science education. Finally, participation in this research study was accompanied by an incentive in the form of a token provided by the researcher, given in recognition of the time and effort of all participants in the study.

RESULTS AND DISCUSSION

This present study involved two (2) out-of-field (OOF) science teachers purposively selected from two (2) different public secondary schools, who served as the teacher-participants in the actual implementation and evaluation of the Acquisition-Capacitation-Optimization (ACO) Professional Development Framework. The professional development (PD) program was rolled out to these OOF science teachers handling Grade 10 Science during the 4th quarter of school year 2025-2026, following a needs-specific and context-responsive design anchored on the three interrelated phases of Acquisition, Capacitation, and

Optimization. Data were gathered through a thirty (30) item multiple-choice test adopted from the DepEd's Grade 10 Science Learner's Material to determine content knowledge proficiency, a 5-point Likert scale instrument adapted from the factor matrices of the TPACK of Schmidt et al. (2009) for pedagogical skills and technology integration, and the P-TABS Questionnaire of Lloyd (2016) for attitudes and beliefs toward science, complemented by a structured interview using guide questions to capture the actual experiences of the OOF teacher-participants. The same 30-item multiple-choice test was likewise used to evaluate students' learning outcomes through pretest and posttest scores, which were analyzed using the paired t-test to determine whether statistically significant differences existed between the two measurement points. The discussion that follows is grounded strictly on the data gathered from these instruments and is interpreted directly in relation to the objectives of the study, specifically the implementation and evaluation of the ACO Framework in improving OOF science teachers' content knowledge, pedagogical skills, technology integration, attitudes and beliefs, and consequently their students' learning outcomes.

Profile of the out-of-field teacher-participants

Two out-of-field science teachers participated in the actual implementation of the professional development sessions anchored in the ACO Framework, and both came from schools previously identified during the analysis and design phase of the study. Participant 1 held a bachelor's degree in education with a specialization in mathematics, had earned several master's units in Mathematics Education (MaEd-Math), and had only one (1) year of teaching experience. She was assigned to a small junior high school based on student population and was the sole teacher handling Grade 10 Science in that school. Participant 2 likewise finished a baccalaureate degree in education majoring in mathematics, had earned some master's units in MaEd-Math, and had four (4) years of teaching experience. She was assigned to a larger school where she taught Science 10 alongside other science teachers. Both participants were trained and mentored by an experienced in-field subject-matter expert throughout the PD sessions, and this contrast in their institutional contexts, particularly in terms of experience, school size, and access to peer support, later proved relevant in interpreting differences in their affective outcomes.

Content knowledge outcomes of OOF science teachers

The pretest and posttest scores of the OOF teacher-participants across the three targeted competencies, namely investigating the relationship between volume and pressure at constant temperature (C1), investigating the relationship between volume and temperature at constant pressure (C2), and explaining these relationships using the kinetic molecular theory or KMT (C3), revealed a clear improvement in content knowledge following the PD sessions. Participant 1 obtained a total pretest score of 20 ($C1 = 5$, $C2 = 8$, $C3 = 7$), interpreted as Nearly Proficient, which increased to a total posttest score of 28 ($C1 = 8$, $C2 = 10$, $C3 = 10$), interpreted as Highly Proficient. Participant 2 obtained a total pretest score of 16 ($C1 = 3$, $C2 = 9$, $C3 = 4$), also interpreted as Nearly Proficient, which increased to a total posttest score of 23 ($C1 = 8$, $C2 = 9$, $C3 = 6$), interpreted as Proficient. Notably, Participant 2's score in Competency 2 remained unchanged between the pretest and posttest at 9 and then decreased slightly to 9 is not the case as the posttest value was recorded at 9 for C2 as well, while gains were observed in C1 and C3, still indicating an overall gain in content knowledge after the PD sessions. These proficiency-level interpretations were based on D.O. 55, s. 2016. The consistent upward movement in scores across both participants, particularly in the areas where scaffolded discussion, guided inquiry, and hands-on experimentation were employed

during Sessions 3, 4, and 5, suggests that the structured Capacitation steps of the ACO Framework directly addressed the conceptual gaps that OOF teachers initially held regarding gas behavior, pressure-volume relationships, and the kinetic molecular theory. This finding aligns with the work of Kenny et al. (2019), who found that the Professional Learning Initiative (PLI), a structured PD program funded by the Australian state for OOF teaching in Mathematics and Science, enabled OOF teachers to strengthen their content understanding, and is similarly consistent with Perry, de Winter, and Hartley (2024) and Rutgers et al. (2024), who reported that the Science Additional Specialism Programs (SASP) and the Subject Knowledge Enhancement (SKE+) program supported OOF teachers in acquiring deeper content knowledge in Chemistry and Physics. Taken together, these results indicate that the PD sessions structured through the ACO Framework yielded a meaningful increase in the content knowledge of OOF science teachers, underscoring the importance of systematically and diagnostically addressing knowledge gaps rather than relying on generic training approaches.

Changes in pedagogical skills, technology integration, and attitudes and beliefs

Beyond content knowledge, the ACO-anchored PD sessions also produced measurable gains in the OOF teachers' pedagogical skills, technology integration, and attitudes and beliefs toward science. In terms of pedagogical skills, Participant 1's rating increased from 3.7 (Advanced) before the PD sessions to 4.6 (Expert) after, while Participant 2's rating increased from 4.4 (Expert) to 4.8 (Expert). Similarly, in technology integration, Participant 1's rating rose from 3.9 (Advanced) to 4.5 (Expert), while Participant 2's rating rose from 4.5 (Expert) to 4.8 (Expert). These improvements can be attributed to the instructional modeling of effective teaching strategies during Sessions 3 and 4, where hands-on demonstrations and experiments for Boyle's Law and Charles' Law, respectively, were modeled by the subject-matter expert before being practiced by the participants, as well as to the introduction of the PHET Colorado online simulation during Session 5, which allowed the OOF teachers to purposefully and meaningfully integrate ICT tools into science instruction. With regard to attitudes and beliefs toward science, Participant 1 registered a shift from 3 (Neutral) to 4 (Very Positive), whereas Participant 2 remained constant at 4 (Very Positive) both before and after the PD sessions. This differential pattern is explainable by the contrasting institutional and experiential contexts of the two participants: Participant 1, with only one year of teaching experience, was the sole science teacher in a smaller school lacking a functional science laboratory and without the support of a master teacher, conditions that plausibly contributed to her initial apprehension and lower self-esteem in teaching science out-of-field; in contrast, Participant 2, with four years of experience, was situated in a larger school with a functional (though basic) science laboratory, other in-field science teachers, and a master teacher who could provide mentoring and peer support, conditions that likely sustained her already positive disposition throughout the PD implementation. The consistent gains in pedagogical skills and technology integration across both participants, together with the notably positive shift in Participant 1's attitudes and beliefs, affirm that the ACO Framework's Capacitation phase, through its combination of instructional modeling, hands-on workshops, one-on-one mentoring, and post-session consultation, addressed not only the cognitive and instructional domains but also the affective domain of OOF teaching. This is consistent with Schueler et al. (2015), who found that both the cognitive and affective competencies of OOF mathematics teachers changed significantly following a qualification program, reflecting improvements in action-related competence and beliefs, and with Kenny et al. (2019), who reported that the government-funded PLI promoted changes in pedagogical

content knowledge that positively influenced OOF teachers' ability and confidence to try new pedagogical approaches. These findings suggest that when OOF teachers are given structured and needs-responsive support, they become more capable, more confident, and more positively disposed toward the discipline they are teaching out-of-field.

Actual experiences of OOF teachers during the PD sessions

Thematic analysis of the OOF teacher-participants' narratives yielded three (3) themes that further evaluated the impact of the professional development sessions. The first theme, "PD sessions improved OOF teachers' knowledge and provided a 'roadmap' to teaching strategies," emerged from codes such as better content understanding, additional knowledge and strategies, accurate knowledge of gas laws, and roadmap to teaching, and reflected how the sessions functioned not only as a mechanism for content mastery but as a structured guide for instructional decision-making, consistent with the first Capacitation step of identifying teaching gaps. This finding parallels the Cross-specialization training for OOF junior high science teachers (NCR_RM_s2018_145; DM1195 09-14-18; RM No. 110, s. 2018), which similarly enhanced teacher competence across science disciplines, and the SASP and SKE programs described by Perry et al. (2024), which improved content knowledge and deepened conceptual understanding among OOF teachers of chemistry and physics. The second theme, "Developed OOF teachers' confidence to teach and explain science concepts and competence to utilize ICT tools and simulations," was drawn from codes including the ability to explain difficult concepts, increased confidence to teach, and utilization of the PHET simulation as an ICT tool, and captured the participants' movement from feelings of inadequacy toward confident instructional ownership, corresponding to the second and third Capacitation steps of translating content into teachability and authoring their own instruction. This is consistent with Abrantes and Bargamento (2024), who found that out-of-field physical science teachers demonstrated notable enthusiasm and willingness to embrace new technologies such as online simulations and virtual laboratories to foster student curiosity and engagement. The third theme, "OOF teachers yearn for training sustainability and institutional support for facilities and supplies," was derived from codes such as follow-up trainings, support group for OOF teachers, and additional supplies in the laboratory, and revealed that while the PD sessions strengthened content knowledge, pedagogical competence, and confidence, the sustainability of these gains was perceived by the participants to depend on continued institutional reinforcement, including access to facilities, laboratory materials, and ongoing mentoring structures. This finding is consistent with Tenorio (2022), who found that OOF teachers given opportunities for further study, training, and professional development activities gained overall self-efficacy in teaching, and with Castro et al. (2023) and Torcino and Villocino (2023), who argued that since out-of-field teaching cannot be entirely prevented, OOF teachers must be given ongoing technical assistance and continuing professional development support. Collectively, these three themes illustrate a dynamic process in which the OOF science teacher-participants improved their content knowledge, strengthened their pedagogical strategies, enhanced their technology integration, shifted very positively in their attitudes and beliefs, and reframed their professional identity from implementers of an assigned subject to empowered facilitators of science instruction, while simultaneously articulating a clear need for sustained institutional support.

Effects on students' learning outcomes

The effectiveness of the ACO Framework was further evaluated by examining students' pretest and posttest performance across two class groups taught by the OOF

teacher-participants, analyzed through the paired t-test at the 0.05 level of significance. In Class 1, Competency 1 (Boyle's Law, 9-item test) showed a mean pretest score of 3.36 ($\sigma^2 = 3.18$) increasing to a mean posttest score of 7.03 ($\sigma^2 = 1.47$), a mean difference of 3.67, with $t(32) = -11.19$, $p < 0.01$ (two-tailed), and a Cohen's effect size of $d = 1.95$, interpreted as an exceptionally large effect. Competency 2 (Charles' Law, 11-item test) in Class 1 showed a mean pretest score of 5.09 ($\sigma^2 = 2.52$) increasing to a mean posttest score of 8.30 ($\sigma^2 = 2.09$), a mean difference of 3.21, with $t(32) = -10.91$, $p < 0.01$ (two-tailed), and a Cohen's $d = 1.90$, also a very large effect. Competency 3 (kinetic molecular theory, 10-item test) in Class 1 showed a mean pretest score of 4.15 ($\sigma^2 = 3.20$) increasing to a mean posttest score of 7.97 ($\sigma^2 = 4.28$), a mean difference of 3.82, with $t(32) = -9.97$, $p < 0.01$ (two-tailed), and a Cohen's $d = 1.74$, again a very large effect. Since the computed t-values for all three competencies exceeded the critical t-value at the 0.05 level of significance, the null hypothesis of no significant difference between pretest and posttest scores was rejected for all three competencies in Class 1, indicating that the observed improvements were not due to chance but reflected meaningful conceptual learning gains attributable to the classroom instruction delivered by the OOF teacher following the PD sessions.

In Class 2, Competency 1 showed a mean pretest score of 4.06 ($\sigma^2 = 2.73$) increasing to a mean posttest score of 7.06 ($\sigma^2 = 2.66$), a mean difference of 3.00, with $t(30) = -8.80$, $p < 0.01$ (two-tailed), and a Cohen's $d = 1.58$, a very large effect. Competency 2 showed a mean pretest score of 5.61 ($\sigma^2 = 4.51$) increasing to a mean posttest score of 8.71 ($\sigma^2 = 3.95$), a mean difference of 3.10, with $t(30) = -7.19$, $p < 0.01$ (two-tailed), and a Cohen's $d = 1.29$, a large effect. Competency 3 showed a mean pretest score of 4.32 ($\sigma^2 = 2.76$) increasing to a mean posttest score of 6.84 ($\sigma^2 = 5.21$), a mean difference of 2.52, with $t(30) = -5.82$, $p < 0.01$ (two-tailed), and a Cohen's $d = 1.05$, also a large effect. As with Class 1, the computed t-values for all three competencies in Class 2 exceeded the critical value at the 0.05 level of significance, leading to the rejection of the null hypothesis in each case and confirming that the improvements in posttest scores represented statistically significant and academically meaningful gains rather than random fluctuation. Across both class groups, students exhibited increased engagement and participation during discussions and hands-on activities, as reflected in the OOF teachers' own observations that students became more active, asked more questions, and were more willing to participate, particularly during experiments and simulation-based group work. These results are consistent with Oleg et al. (2015), who found that even a relatively short four-hour content knowledge workshop for beginning teachers effectively changed their pedagogical content knowledge and subsequently improved their students' academic performance, and with Gess-Newsome et al. (2016), whose Project PRIME intervention demonstrated that OOF teachers' gains in knowledge and pedagogical skill had a statistically significant positive influence on student learning. These findings support the broader assertion of Jacob et al. (2020) that improving OOF teachers' content knowledge and pedagogical competence is likely to enhance instructional practices and, in turn, positively influence students' academic achievement.

Refinement of the ACO framework

The convergence of the findings on OOF teachers' content knowledge, pedagogical skills, technology integration, attitudes and beliefs, actual experiences, and students' learning outcomes provided the empirical basis for refining the ACO Framework by explicitly embedding "Support and Sustainability" as the core around which the three phases of Acquisition, Capacitation, and Optimization revolve. The Acquisition phase, focused on identifying learning competencies and diagnosing the baseline needs and challenges of OOF

teachers, requires support in the form of diagnostic assessments, such as pretest and posttest instruments for content and structured self-assessments for skills, framed as tools for growth rather than accountability, given that OOF teachers may feel vulnerable about their content expertise. The Capacitation phase, which strengthens content knowledge and pedagogical competence through its four essential steps of surfacing teaching gaps, translating content into teachability, authoring one's own instruction, and reframing identity and readiness, requires practice-based support such as consistent coaching and feedback as well as content-specific models and exemplars, including live demonstrations, video lessons, online simulations, and annotated lesson guides crafted by subject-matter experts. The Optimization phase, which involves the refinement of instructional practice through independent application and professional reflection, requires support for reflective practice, such as professional reflections and guided post-instructional analysis, as well as continuous improvement opportunities through peer collaboration structures such as Professional Learning Communities (PLCs), which parallel the Learning Action Cell (LAC) sessions already mobilized in Philippine public schools. This embedding of support and sustainability across all three phases reframes sustainability not as an isolated outcome but as an inherent, continuous, and dynamic component of the entire framework, ensuring that the professional growth of OOF teachers, and the corresponding academic gains of their students, can be reinforced and extended well beyond the formal duration of the PD sessions.

In synthesis, the findings of this study demonstrate that the implementation of the Acquisition-Capacitation-Optimization Framework in a professional development program for out-of-field science teachers produced statistically and practically meaningful improvements across multiple interrelated dimensions: OOF teachers advanced from Nearly Proficient to Highly Proficient and Proficient levels of content knowledge in gas laws and the kinetic molecular theory; their pedagogical skills and technology integration both progressed to the Expert level; their attitudes and beliefs toward science shifted toward, or remained at, the Very Positive level; their personal narratives revealed a reframed professional identity from feeling inadequate to feeling confident and capable; and their students, across two independent class groups, exhibited statistically significant and large-effect gains in learning outcomes across all three targeted competencies, as evidenced by paired t-test results with p-values below 0.01 and Cohen's d values ranging from 1.05 to 1.95. These convergent findings directly address the objectives of the study by demonstrating that a needs-specific, context-responsive, and process-based professional development framework can simultaneously strengthen the cognitive, pedagogical, technological, and affective dimensions of out-of-field science teaching while producing measurable downstream benefits for student achievement. The refinement of the ACO Framework to explicitly embed support and sustainability at its core further contributes to the field by offering a structurally reinforced, replicable model that school administrators, division offices, and teacher-training institutions may adopt or adapt to address the persistent challenge of out-of-field teaching in science education. These results, taken together, set the empirical and theoretical foundation for the concluding chapter, which synthesizes the study's overall contributions, articulates its implications for policy and practice, and offers recommendations for the sustained institutionalization of the ACO Framework in professional development programs for out-of-field teachers.

CONCLUSION

Out-of-field science teaching has been a perennial problem in education. In an effort to help address this practice of out-of-field teaching, this study aimed to design and develop a professional development framework for OOF science teachers. The Acquisition-Capacitation-Optimization (ACO) professional development framework that was designed

and developed to address the needs and challenges of OOF science teaching, was able to promote OOF teachers' instructional competence and students' performance. The implementation of the professional development sessions anchored in the ACO framework produced significant improvements for out-of-field science teachers. OOF teachers have improved content knowledge, enhanced pedagogical skills, demonstrated competence in the utilization of ICT tools such as online simulation, and made meaningful shifts in their positive attitudes and beliefs toward science. Consequently, the improvement in out-of-field teachers' competence was translated into the significant gains in their students' learning outcomes. This confirmed that the ACO Framework professional development sessions produced not only measurable but substantial improvements in student achievement. These validated that the framework improved OOF teachers' knowledge, enhanced pedagogical skills and technology integration, and positively shifted their attitudes and beliefs, all of which directly and greatly influenced student learning.

However, an important limitation of this present study was derived in its limited generalizability due to the small number of out-of-field teacher participants and the highly specific needs and challenges that came from their personal attributes, professional backgrounds, and unique teaching experiences. While the significant results of the study in the utilization of the ACO framework in the professional development program proved to be remarkable and very promising, the limited number of participants in the study may constrained the extent to which the findings can be extrapolated to a wider population of OOF science teachers. The diversity of teaching contexts, differences in school resources and administrative support, and varied student demographics across other institutions and educational setting, may not be adequately represented in this study. This limitation potentially narrowed the contextual scope as variations in institutional cultures, leadership practices, and the different OOF teacher population across other schools may influence the outcomes of similar professional development programs anchored in the ACO framework. Although the study was able to promote out-of-field science (OOF) teachers' competence and students' performance and provided valuable insights into their experiences and development, generalizing these results to other settings was limited, as it may not hold true, particularly in those with different organizational structures, resource conditions, and cross-cultural variation. It is recommended that there is a cross-cultural validation of the ACO Framework in order to examine the ACO framework's applicability across diverse educational contexts. Moreover, for future research and validation of the ACO framework, it is recommended that a longitudinal study be conducted to further examine and establish the relevance of each phase of the framework. With repeated observations for the same out-of-field teacher participants over an extended time frame, their progression for each phase will be extensively analyzed to capture developmental and long-term change and to better establish a cause-and-effect relationship over a period of time.

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