

## Best Practices to Foster Pre-service Teachers' Science Content Knowledge

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### Abstract

Understanding the science instruction approaches to pre-service teacher preparation is important to identify the effective features of these experiences and apply them to the design of new learning experiences. The main idea is that teachers often feel not prepared to teach science, and there are several research reports that teachers need opportunities to continue learning science as they prepare to teach it. Thus, it is important to identify the best practices and science learning experiences that can inform the preparation of teachers. Additionally, it is possible to understand the factors that include usefulness and perceived ease of technology as a special case in teacher preparation. Moreover, the focus of the literature review and revision of research work is to understand the affordances and limitations of different learning environments to support and provide a positive science learning experience to teachers with the intersection of science and technology as a particular case.

*Keywords:* pre-service teachers, teacher preparation, science, inquiry, technology

### Introduction

The analysis of the different models and methods in teacher preparation can shed light on their effectiveness, affordances, and limitations in teachers' science learning process. It is also important to detailly analyze the usefulness of technology in science education to determine the efficacy of innovation in learning instruction. The use of technology has become essential in pre-service and in-service teaching instruction.

In this manuscript, I present the results of a literature review conducted to identify the research and approximations to teach science and science with technology to pre-service teachers. The purpose is to identify the best practices to continue supporting the scientific knowledge of pre-service teachers and its intersection with using technology.

To conduct the literature search for the review, I utilized the educational database 'ERIC' and 'Dissertations & Theses Global (ProQuest)' with the key words: "pre-service teachers inquiry learning", "pre-service teaching and technology", "pre-service and in-service teaching", "technology in science education", etc. The main research that has been conducted and primary findings identified during my research process include such keywords that recognized efficacy and effectiveness of pre-service and in-service science teaching instruction.

This literature review is organized around three topics, that include the use of inquiry-based methods and technology in pre-service and in-service teaching, the impact of pre-service teacher's perspectives in science education, and pre-service teacher experiences with science education to evaluate quantitative and qualitative scientific approaches that affect education science learning instruction.

### Using Inquiry-Based Methods and Technology in Teacher Preparation

The articles selected documents on various approaches to prepare pre-service teachers, including the Itakura model, inquiry-based learning methods and curriculum, technology and virtual learning implementation, and teaching sound, waves, and communication methods. Such approximations include a clear explanation of pre-service preparation teaching programs and approaches from every author.

Isabelle and de Groot (2008) describe inquiry functionality through the "Itakura method" technique for pre-service teachers who teach science and other related STEM majors. This method consists of hypothesis-experiment-instruction (HEI). As part of this method, students predict the outcome of an experimental setup, work in collaborative groups to discuss their predictions, experiment, and create an explanation based on their observations. Finally, the instructor facilitates a discussion to achieve a common explanation and make connections to everyday phenomena. Thus, the Itakura method utilizes peer discourse to address pre-service teachers' science misconceptions.

During the 3-month research, pre-service teachers enrolled in a methods course were exposed to the Itakura model. Data collected for this research included pre-service teacher predictions and explanations. This study revealed that participants demonstrated learning gains and knowledge retention with a non-significant lower retention level after three months of exposure to the Itakura model.

The research conducted by Bell and colleagues (2013) focuses on the intersection of learning and science with technology. The researchers conducted a qualitative study to identify pre-service teachers' approaches to incorporate technology in the instruction and develop

technology efficacy. Moreover, the study provides guidelines for such different approaches to determine how technology incorporates in science instruction programs.

The study is based on McLellan's situated learning perspective (2013) to incorporate and introduce technology smoothly into in-service teaching instruction. The author examined technology integration in different courses of the teacher preparation program, for instance, Science Methods course, Seminars, Student Teaching assignments. Data sources included lesson plans, observations, and interviews.

One of the main factors that are discussed in the study were the data collection of the study and the ability of teachers to adapt to technology innovation. The science methods to incorporate technology are analyzed to obtain data and behavior in teaching engagement. This, in order to obtain observations and report data on technology-enhanced science instruction. Also, the level of understanding and teaching behavior are crucial when incorporating learning technologies.

Further, the focus was to explore the extent to which participants who are exposed to a preparation program aligned to McLellan's situated theory framework used technology during their student teaching experiences. The resulting finding was that pre-service teachers used technology for reform-based science instruction during student teaching and that pre-service teachers incorporated technology in student-centered ways. Also, the results in the research demonstrated that the hypothesis conducted justifies the experiment by the results acquired which facilitates learning science instruction as well as the level of adjusting in in-service teaching.

Nuangchalerm (2012) focuses on the motivation aspect of students and content mastery on scientific content of pre-service teachers. This research paper mainly focuses on teacher preparation programs and inquiry learning to increase teaching knowledge.

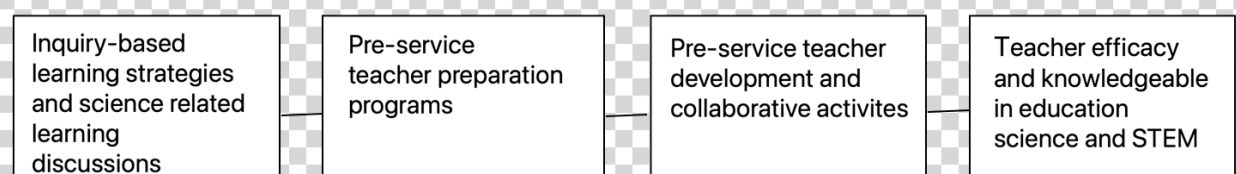
Further, this article goes over the teaching standards and subject mastery when it comes to teaching science in primary and secondary education systems. The author also emphasizes the evolution of science in pedagogical material as pre-service teachers integrate the science subject content into classrooms.

Some of the data sources utilized in this study to evaluate the inquiry-based instruction include videos, journal entries, classroom discussion, and interviews, journal reflections, and school visits in inquiry science. All these were evaluated in detail in this study to analyze qualitative data on education science.

This data was helpful for this research since the results of such activities allowed to examine pre-service teachers' learning development. Another factor that played an essential role in this study involves a discussion of how to prepare teachers efficiently through collaboration efforts, activities, innovative teaching approaches, and inquiry-based learning strategies (Figure 1).

**Figure 1**

*Strategies to improve pre-service teaching efforts in science-related courses*



### Science Education Curriculum for Pre-service Teachers

There has been useful research content found that explains pre-service teachers that were exposed to multiple learning strategies and techniques that have influenced science education. Such, as described in the articles included in this section to provide evidence of multiple effective strategies that impact pre-service science teachings. The factors that intervene teacher development include the utilization of science kits, utilization of micro-teaching methods, inquiry-based learning, and teamwork activities through virtual classroom settings.

Awad and Barak (2018) designed and evaluated a curriculum to teach sound, waves, and communication systems to pre-service teachers. This study examines the level of comprehension that pre-service teachers have and challenges based on their science learning experiences using qualitative and quantitative data sources. The multiple experiences that pre-service teachers have in STEM contribute to student development and exposure of science field related material. In context, education programs in the science field such as inquiry have allowed for technology and education science to grow significantly in primary and secondary grade levels.

Moreover, this article also goes over the effect of the teaching of sound, waves and communication systems (SWCS) curriculum and how that affects pre-service teachings as well as education science as a whole. Because STEM education is growing significantly, this article pursues how this curriculum facilitates learning science and encourages engagement in classroom settings.

This research study consists of a semester course for pre-service teachers in primary schools to get additional preparation to teach STEM content to students. The idea of utilizing sounds and waves encourages pre-service teachers to take a new approach to be cognizant of sound in physics and math-related courses and spread knowledge in a scientific context.

The methods utilized in this source include different sound and vibration equipment that incorporates math, science, physics, and technology in signals and waveform created from sound. This is to create experiments in STEM to analyze and understand the different scientific approaches to solve multiple science-related projects and experiments. For the other part of the research, data from assignments, exams, questionnaires, and pre-service teacher interviews were used to analyze the teacher behaviors and thoughts on the multiple activities.

This investigation allowed the author to obtain quantitative and qualitative data to analyze pre-service teacher learning. The study findings show that even when pre-service teachers presented challenges in understanding key sound and wave concepts, they showed content learning gains and elevated their levels of self-efficacy in STEM-related coursework.

Murphy and Smith (2012) suggest that some factors affect teaching science and are analyzed throughout. This includes scientific content knowledge, pedagogical knowledge, classroom management, and resources. The author examines and studies the effectiveness of a year-long course on pre-service teachers' scientific content and pedagogical content knowledge.

This study also provides detailed descriptions of scientific approaches and technology that can be implemented to improve students' learning journey. This study also provides student feedback by questionnaires to measure the level of student understanding and attitudes towards science. The positive attitudes that students have towards science courses also greatly affect the student performance when it comes to understanding scientific concepts.

Sherman and MacDonald (2008) addressed the impact and difficulties of science teaching in elementary settings by creating a ten-week teaching module utilizing "science kits" that contain guidelines for classrooms. The elementary science classroom kit includes specific activities, materials, and modules monitored by pre-service teachers. These kits are used to keep

students engaged, understand the science course in depth, and be a resource aid for each instructor.

This research also notes all the benefits that this project results on based on the project of the kits presented to each professor for student learning purposes. The outcomes of this project were satisfactory and engaging to integrate science. The “impact on teacher thinking” as described in the article, has been positively demonstrated with the results and testimonies of the teachers who were exposed to this process. The kits seem to also be a great way for teachers to engage and communicate with their students rather than traditional lectures.

Moreover, this approach of utilizing kits seems to also be more relevant to students since they seem to comprehend the information in an easier and more accessible way. Elementary teachers seem to be more comfortable with teaching as well since they believe it keeps students involved. The authors show clear evidence that such works efficiently and demonstrates to be improving student performance in the overall student scores.

Long et al. (2019) use micro-teaching lessons to develop pre-service teachers’ physical science content knowledge. This article also discusses ways to interpret different teaching experiences and observations on teacher preparation programs through pedagogical certification assessments. Further, test scores in such pedagogical certification exams are examined to determine the level of knowledge and understanding each pre-service instructor has. This source bases their research on the research question, “How does lesson plan design instruction and student microteaching of physical science concepts contribute to PSETs content knowledge?” (Long et al., 2019, p.17), to evaluate the functionality of teacher intervention and the level of comprehension that a pre-service teacher has.

This source also discusses physical science since it has been proven to be challenging for pre-service teachers since the concepts are shown to be difficult to understand because of the science content that is analyzed and taught. The approaches that are mentioned throughout the article to improve the understanding of physics science encompass the perception of scientific conceptions under scientific methods.

Another approach that encompasses the development of incorporating physical science through courses involves microteaching to obtain student examinations. The results in this study demonstrate the different scientific approaches taken and microteaching have a tremendous impact on the potential knowledge obtained by pre-service teachers on physical science.

Santau and colleagues (2014), the level of insufficiency that instructors have in scientific inquiry. The relevance of this research is based on the long-term impact of underprepared teachers that affects education and which is further demonstrated in an extensive data analysis provided by this article. Moreover, this article focuses on the level of “science content knowledge (SCK)” that teachers possess and its importance to teach science effectively.

Scientific inquiry has also a great impact in primary teaching since this study shows that there is not a lot of engagement when it comes to teaching science concepts in such levels nor enough teacher preparation, but the article does contrast how important science is for lower levels of education for student development to be incorporated and evaluated.

The practice of scientific inquiry has been shown to allow teachers to efficiently teach and comprehend science teaching and learning to increase teacher and student comprehension. This can also be accomplished through understanding of science content knowledge (SCK) and evaluating ways to incorporate STEM in instruction to enhance student learning.

The study focused on redesigning and implementing a Science Methods Course to develop a theoretical framework of teaching science through inquiry, a repertoire of teaching strategies, and a deeper understanding of science.

The researchers used the “Science Knowledge Test” to measure the level of knowledge of each teacher and the possible areas of growth.

Nicholas and Wang (2009) examined the use of online environments to foster the construction of science knowledge of pre-service teachers working in virtual groups. They report positive collaboration experiences in an innovative learning environment.

Moreover, this source emphasizes the correlation between technology and science education since innovation plays an important part of online learning instruction. Participating pre-service teachers completed a two-week task for online coursework involving collaborative learning methods.

Participants also completed collaborative online assignments during five weeks to evaluate the interaction and effectiveness of virtual scenarios. Pre-service teachers’ experiences and behaviors were analyzed to examine their participation in the online environment. After this evaluation was completed, the data collection and analysis indicated that virtual means projected a positive impact on collaboration, teamwork, and successful assessment behaviors as described in the article.

### **Pre-service Teachers Experiences**

This section includes articles that report pre-service teachers’ experiences through inquiry-based learning coursework, education modules, course evaluations, and pre-service teaching assessments. This, to describe the perspectives and interactions that pre-service teachers approach in multiple scenarios through analysis, examination, and evaluation in science education.

Lewis (2019) conducted a qualitative study to identify the aspects of the elementary pre-service teaching preparation programs relevant to educate students on the science field accurately. Further, the author conducted collaborative interviews, collected information from coursework, and important learning content instructed during the fall 2015 evaluation periods. Data shows that pre-service teachers benefit from experiences that reflected the development of science and STEM related field programs that help students understand science concepts. The examination in this research also highlights the importance of incorporating science material in detail on elementary schools and primary education classrooms.

Kazempour and Amirshokohi (2013) engaged in an action research project to examine the science learning experiences of pre-service teachers participating in inquiry-based instruction. The researchers examine the different methods for lesson planning utilized for elementary teachers in the education science field. This, to analyze the learning process and the different patterns of pre-service teachers through data collection, video observation, student reflections, data analysis, and results obtained by the study.

The article also lists the different hardships that students face in traditional classroom settings and ways to overcome such.

Learning opportunities is one of the concerning factors that students encounter when analyzing implications and instruction difficulties. Online resources and research data patterns are also discussed to show the important factors that affect education based on the different techniques utilized in pre-service teaching when it comes to science education content. This to



demonstrate the student learning experiences and perspectives to improve teaching and learning instruction in the elementary and high school levels.

Sherman & MacDonald (2007) address a project created by scholars to describe the experiences of pre-services teachers who participated in a ten-week teaching module (p. 526).

The study examined relationships between increased science content and understanding of appropriate science teaching, explore whether the learning environments used in the study promoted collegiality and cooperation amongst beginning teachers, and enhance pre-service teachers' levels of confidence and ownership of the learning and teaching experiences that are part of the intervention (p. 528).

This is done to compare the magnitude of self-efficacy and if this has to do with a related bachelor's degree in science. The author in this paper encourages teachers to take an active role in science learning instruction to engage with their students. Sherman also discusses the importance of teaching strategies that can affect learning content for student achievement.

Moreover, different models of inquiry are analyzed to show the different perspectives that teachers have about the multiple challenges that influence students. Also, the factors that alter instruction include strategies, skills, and dialogue utilized in the education process.

Discussing through team building activities supports and enhances pre-service teaching comprehension techniques. This is important since teachers must understand the different teaching methods and approaches that relate to science content which could be integrated into their own teaching styles.

In the 10-week experiment conducted by the researchers, the main idea was to enhance pre-service teaching skills and make them work through team-building activities, planning, and organizing resources. Sherman and MacDonald (2007), created "science unit plans... in partnerships and presented to their pre-service colleagues. Through these activities and processes we covered outcomes related to planning and presentation normally covered in both the science course and the foundations course." (p. 527).

Campbell (2011) designed a 40-day training course named the "Science Additional Specialisms Programme (SASP)" that allows in-service secondary teachers with no prior experience to be trained for physics disciplines. Some of the components that were examined in this research study include the benefits of the completion of this training program from which the goal was to achieve proficient skills and completion of teacher preparation in the science field.

The objective of this course also includes the development of teachers under education science fields to allow teachers to become proficient in the science curriculum targeted specifically in the chemistry, mathematics, and physics subjects as mentioned in the article. Participants collaborated in groups for questions and discussion. There is also a diagnostic exam and different assessments to measure the level of understanding and comprehension that teachers have as they try to complete a given task or assignment.

Then, this research provides the reader with the feedback that is acquired through course evaluation and gathering opinion from each participant (pre-service teachers). Moreover, the results and the completion of those teaching evaluations and surveys from the 40-day training course called Science Additional Specialisms Programme (SASP) showed to have a positive impact for teachers who teach physics since it elevated teacher confidence and improve knowledge in the subject as well as willingness to learn more about education science courses.

### **Conclusion**

The literature review showed that inquiry-based teaching and learning conducted in science methods courses is the main approach to support the development of teachers' science knowledge. The implementation of the courses and curriculum reported in this review demonstrated positive outcomes related to pre-service teachers' content knowledge. Research demonstrated the relevance of analyzing the use of technology for pre-service teachers, the teacher's experiences and perceptions of the best practices to support science learning, and the curricular approaches to prepare teachers to teach science. The primary inquiry-based methods reported include technology, science kits, and the 'Itakura' method.

The review presented indicates that the studies focused on the continuous development of pre-service teachers are scarce, even though it is recognized the relevance of content knowledge to teach science effectively.



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