International Journal of Engineering, Science and Humanities
An international peer reviewed, refereed, open access journal
Impact Factor: 8.3 www.ijesh.com ISSN: 2250 3552

Predictors of Science Teaching Effectiveness: A study of PCK, Attitude and Self-efficacy

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Abstract
Students' scientific literacy, conceptual grasp, and interest in science education are all significantly influenced by the efficacy of science instruction. Pedagogical content knowledge, scientific teaching self -efficacy, and teachers' attitude toward science education have regularly been found to be important teacher- related variables among the many factors impacting effective science instruction. In order to investigate the individual and interaction roles of PCK, scientific teaching self -efficacy, and attitudes toward science teaching in improving instructional effectiveness, this systematic qualitative review synthesizes recent empirical investigations published between 2020 and 2026. The Preferred Reporting items for systematic reviews and Meta-Analyses (PRISMA 2020) framework is used in the review to find, filter, and evaluate peer -reviewed research that has been retrieved from significant scholarly databases such as Scopus, Web of Science, ERIC, and Google Scholar. Four major themes emerge from the review's thematic synthesis: 1) Pedagogical content knowledge as the cornerstone of successful science instruction; 2) The impact of science teaching self-efficacy on instructional practices and classroom engagement; 3) The contribution of positives attitudes towards science teaching to learner centered pedagogy and professional commitment; 4) The dynamic interaction among these three constructs in fostering teaching effectiveness. The results show that teachers with strong self -efficacy beliefs, well-developed PCK, and good professional attitudes are more likely to use inquiry -based teaching tactics and successfully resolve students' misconceptions.

Keywords: Science Teaching Effectiveness, Self-efficacy, PCK, Attitude, Teacher Education

Introduction

The quality of teaching and learning in modern educational systems is increasingly recognized as a multifaceted construct influenced by teachers' professional settings, knowledge, beliefs, and competencies. Teacher self-efficacy and pedagogical content knowledge (PCK) are two of the most important concepts in this field. They are both universally acknowledged as key factors that influence both student accomplishment and the efficacy of instruction. Understanding how these constructs interact has become crucial for enhancing teacher preparation, professional

development, and student outcomes as education systems around the world adapt to the rapid advancement of technology, changing societal expectations, and the need for twenty-first-century skills (UNESCO, 2021; OECD, 2020). Teachers' beliefs in their capacity to plan and carry out the actions necessary to successfully complete particular teaching tasks are referred to as teacher self-efficacy, which was first conceptualized by Bandura (1997). This belief system is a potent psychological process that affects motivation, perseverance, instructional decision-making, and resilience in the face of difficulties rather than just being a reflection of confidence. According to Bandura's social cognitive theory, mastery experiences, vicarious learning, social persuasion, and physiological states—all of which are extremely pertinent in educational settings—all influence self-efficacy views. Even in difficult learning circumstances, teachers who have high levels of self-efficacy are more likely to implement creative teaching techniques, run their classrooms efficiently, and encourage student participation. Their research demonstrates the strong correlation between self-efficacy and student motivation, classroom management, and instructional quality. These results have been supported by more recent systematic reviews, which show that teacher self-efficacy is strongly linked to student achievement and teacher performance in a variety of educational contexts (Xu et al., 2026; Genek & Ding, 2026).

The idea of pedagogical content knowledge, which was first presented by Shulman (1986, 1987) and serves as a fundamental framework for teacher education, is closely linked to self-efficacy. PCK stands for the specialized knowledge that educators have that allows them to present material in ways that are both pedagogically effective and understandable to students. It combines pedagogical techniques, such as an awareness of student misunderstandings, curriculum design, instructional representations, and assessment procedures, with content knowledge. By highlighting the fact that effective teaching takes more than subject-matter expertise—rather, it requires the capacity to make knowledge relevant and accessible to a wide range of learners—Shulman's work signaled a paradigm shift in educational research. The understanding of PCK has been broadened and improved by recent study, especially in the teaching of science and math. PCK is closely linked to both teacher effectiveness and student performance results, according to systematic reviews and meta-analyses (Fukaya et al., 2025). Furthermore, it is becoming more widely accepted that PCK is a dynamic and malleable concept that changes as a result of professional cooperation, reflective practice, and focused professional development initiatives (Park & Chan, 2025). PCK and teacher self-efficacy have a very important relationship. Teachers with high self-efficacy are more likely to participate in activities that advance their pedagogical knowledge, and teachers with good PCK are more likely to feel secure in their ability to educate. Teachers must have both excellent topic understanding and high levels of instructional confidence in order to successfully navigate the particular obstacles presented by the integration of science, technology, engineering, and mathematics. According to systematic reviews, teachers' desire to use interdisciplinary and inquiry-based learning approaches is significantly influenced by their STEM

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self-efficacy (Genek & Ding, 2026). Instructional strategies and student outcomes are significantly influenced by teachers' attitudes toward science and math. According to a meta-analysis by Guo et al. (2021), there is a positive correlation between students' academic performance and teachers' attitudes toward science, indicating a direct connection between affective elements and cognitive and instructional processes. Another important component affecting PCK and self-efficacy is professional development. Sustained duration, active learning opportunities, topic focus, and coherence with teachers' instructional settings are characteristics of high-quality professional development programs (Darling-Hammond et al., 2020). It has been demonstrated that these programs greatly improve teachers' teaching strategies, subject-matter expertise, and self-assurance when instructing difficult material. In order to improve educational quality at the systemic level, the OECD (2020) further highlights the importance of treating teachers as professionals and offering chances for ongoing learning.

In contemporary education, digital capabilities have grown in significance alongside conventional professional development. Teachers must acquire new pedagogical expertise and confidence in order to incorporate digital tools into their lessons. Teacher professional development, self-efficacy, attitudes, and digital competences are closely related, especially in technology-enhanced learning environments, according to Gui et al. (2026). Teachers who are self-assured in their digital abilities are more likely to successfully incorporate technology, improving learning outcomes and student engagement. Recent studies have also focused on the growth of self-efficacy in higher education settings. According to Xu et al. (2026), professional learning environments, teaching experience, and institutional support all have an impact on students' self-efficacy in higher education. According to their systematic study, raising teachers' self-efficacy in higher education may result in better instruction and more successful learning outcomes for students. In conclusion, the increasing amount of research emphasizes how crucial it is to incorporate professional, pedagogical, and psychological aspects into teacher development. Enhancing teacher self-efficacy and pedagogical topic knowledge is essential to raising educational quality and fairness as educational systems continue to change in response to global issues. The dynamic relationships between these dimensions should be further investigated in future research and policy initiatives, with a focus on how supportive educational environments and efficient professional development may promote them.

Review of Literature

Bjerke et al. (2026) examined a comprehensive review of teacher’s self- efficacy in science and math this review verified that teacher’s efficacy views are considerably strengthened by professional development, peer collaboration, mastery experiences, and institutional support. Higher self-efficacy teachers were more confident in their ability to teach, more persistent, and more open to using new teaching techniques, all of which increased classroom effectiveness.

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Chan and Park (2026) conducted a study on markers of high quality among science instructors they discovered that in order to support meaningful science learning, effective teachers incorporate pedagogy, evaluation, content understanding, and student knowledge. The review also underlined that contextual teaching, reflective practice, and adaptive competence are critical traits of successful science instructors in modern classrooms.

Fukaya et al. (2025) conducted a meta-analysis and systematic review to investigate the connection between educational outcomes and pedagogical content knowledge in science and mathematics. Stronger PCK was found to be favorably correlated with student achievement, teacher competency, and instructional quality. However, the study also indicated that without taking contextual and motivational factors into account, PCK cannot adequately explain teaching efficiency.

Genek and Ding (2026) studies on STEM self-efficacy Turkish pre-service and in-service teachers were thoroughly evaluated according to this review, instructors who had higher efficacy beliefs were more innovative in their education, engaged in the classroom, and eager to use inquiry-based STEM teaching. Opportunities for professional development and encouraging learning environments were found to be important factors in raising instructor's self-efficacy.

Gui et al. (2026) compiled data on attitudes, digital competency, self-efficacy and teacher professional development. The review came to the conclusion that ongoing professional development boosts teachers' self-esteem, fortifies their positive teaching attitudes, and promotes their capacity to successfully integrate digital technology. In the end, these enhancements lead to better instructional quality and more successful science instruction.

Tepner et al. (2026) conducted the relationship between science instructor's pedagogical topic knowledge, self-efficacy, and instructional methods was examined. The results showed a consistent correlation between self-efficacy and classroom discipline, constructive classroom assistance and adaptive teaching. The impact of PCK, on the other hand, was contingent upon school contextual factors, underscoring the significance of supporting institutional contexts in augmenting the efficacy of instruction.

Zhang et al. (2026) conducted global research on teacher's self-efficacy, that was published between 2019 to 2025 was thoroughly examined. According to the review, instructors who have higher levels of self-efficacy have better teaching practices, are more resilient, have better teaching quality, and experience less burnout. The authors also highlighted how organizational support and school culture affect teacher's self-efficacy.

Misol and Lajium (2025) used a systematic quick review to investigate teacher self-efficacy in implementing STEM-TPACK. Their results demonstrated that educators with higher levels of self-efficacy felt more comfortable incorporating tec technology inti their pedagogy and subject-matter expertise. According to the review's findings, self-efficacy is essential for using creative scientific teaching strategies in classrooms with more technology.

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Park and Chan (2025) conducted the Pedagogical Content Knowledge (PCK) in science education was methodically compiled. According to this review, PCK has a favorable impact on students' conceptual knowledge, lesson planning, assessment and instructional quality. The authors further contended that in order to further explain differences in the efficacy of science instruction, future studies should incorporate PCK with motivational factors like self-efficacy and professional attitudes.

Menon et al. (2024) used a qualitative meta-analysis to compile 88 studies on the teaching of self-efficacy in science and engineering. According to the review, professional development, classroom experiences, and teacher education programs all have a favorable impact on self-efficacy. The authors suggested more longitudinal research in a variety of educational contexts; however, they found insufficient data supporting the long-term sustainability of these benefits.

Mutlu and Bayasal (2022) conducted a meta-analysis looked at how professional development programs affected teacher's self-efficacy in teaching science. Teachers' confidence in teaching science is greatly increased by structured professional development, according to the studys moderately positive findings. The authors came to the conclusion that ongoing professional development improves instructional competency, encourages creative teaching methods, and increases the efficacy of science instruction.

Malhotra and Masih (2022) conducted research on PCK for teaching the Nature of Science (NOS) was reviewed, many teachers have little knowledge of NOS and frequently find it difficult to incorporate it into their lesson plans. In order to create topic- specific PCK and enhance students' scientific literacy and inquiry abilities, the authors suggested bolstering teacher education programs.

Guo et al. (2021) conducted a three level meta- analysis to investigate the connection between science achievement and students' attitudes toward science. The results showed a strong positive correlation, suggesting that good attitudes improve academic achievement, motivation, and involvement. Additionally, the study indicated that students' attitudes are influenced by teachers' excitement and instructional strategies, highlighting the importance of cultivating positive attitudes in order to improve science teaching effectiveness and meaningful learning outcomes.

Darling-Hammond et al. (2020) conducted a review on effective teacher professional development, came to the conclusion that teacher's pedagogical knowledge, instructional competence, and classroom performance are greatly enhanced by ongoing, collaborative, and content focused professional learning. The review emphasized that professional development enhances teachers' self-assurance and pedagogical abilities, which are essential elements of successful scientific instruction and sustained professional development.

Objectives

(1) To explore the interrelationships among PCK, science teaching, self-efficacy, attitudes toward science teaching, and science teaching effectiveness reported in recent empirical

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studies.

(2) To identify the major themes, trends, methodological approaches, and theoretical perspectives adopted in studies published between 2020 and 2026.

(3) To identify research gaps and propose directions for future research and science teacher education.

Research Questions

The study is guided by the following research question:

(1) What evidence does the recent literature (2020-2026) provide regarding the influence of Pedagogical Content Knowledge (PCK) on science teaching effectiveness?

(2) How are PCK, science teaching, self -efficacy and attitudes toward science teaching interconnected in influencing science teaching effectiveness?

(3) What common themes, trends, and methodological patterns emerge from studies examining these constructs?

(4) What research gaps exist in the current literature, and what recommendations can be made for future research, teacher education, and education policy?

Research Methodology

The present study used a qualitative systematic literature review design to synthesize existing evidence related with PCK, Attitude & Self-Efficacy in science teaching effectiveness according to the Preferred Reporting Items for Systematic Reviews and Meta- Analysis (PRISMA) was followed for the review of literature to ensure transparency, replicability, research gap, rigor.

Data Sources

Scopus, Web of Science, Eric, Science Direct, Springer link, Taylor &Francis, Google Scholar and Research Gate.

In this study the review of literature from 2020 to 2026 was covered, mainly focused on the studies included peer-reviewed journal, articles, or policy documents written in English and gave an empirical and conceptual evidences and understanding with relevant to the objectives of the study.

Findings and Discussion

Main findings of the study are followings:

The contribution of positives attitudes towards science teaching to learner centered pedagogy and professional commitment

One of the best indicators of how well science is taught is pedagogical content knowledge (PCK), according to the analyzed studies. Through appropriate teaching strategies, analogies, classroom demonstrations, inquiry- based activities, and formative assessment, teachers with well- developed PCK exhibit a deeper understanding of scientific concepts and possess the ability to transform complex idea into meaningful learning experiences. Effective PCK, according to recent systematic evaluations, goes beyond topic mastery to incorporate understanding, of students' misunderstandings, curriculum, assessment, and context -specific instructional decisions (Park &

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Chan, 2025; Chan & Park, 2026). Additionally, studies show that teachers with higher PCK are more likely to help pupils develop their conceptual knowledge, scientific reasoning, and problem-solving abilities. These results corroborate Shulman's theoretical claim that successful instruction relies on the integration of pedagogy and subject knowledge rather than rote learning.

The impact of science teaching self-efficacy on instructional practices and classroom engagement

The important role that science teacher self-efficacy plays in enhancing classroom instruction is another prevalent conclusion. Teachers with higher effectiveness views showed more assurance when putting inquiry-based learning into practice, carrying out lab exercises, incorporating technology, and attending to a variety of learning requirements, according to the evaluated studies. High self-efficacy also fostered reflective practice and ongoing professional development, as well as perseverance when faced with obstacles in the classroom. Teachers' efficacy beliefs are strengthened by mastery experiences, professional learning opportunities, collaborative contexts, and institutional support, according to systematic reviews by Bjerke et al. (2026) and Genek and Ding (2026). These results are consistent with Bandura's Social Cognitive Theory, which suggests that motivation, effort, resilience, and professional success are all directly impacted by efficacy beliefs. Therefore, increasing teachers' self-assurance through ongoing professional development is crucial to increasing the efficacy of science instruction.

The contribution of positives attitudes towards science teaching to learner centered pedagogy and professional commitment

The body of research also shows that instructors' perspectives on teaching science have a big impact on the quality of education. Positive views towards science make teachers more passionate about teaching, more open to implementing cutting-edge teaching techniques, and more dedicated to encouraging student participation, experimentation, and inquiry. Additionally, cooperative learning, classroom management, and reflective teaching methods are all promoted by positive attitudes. Negative attitudes, on the other hands, hinder students' prospects for genuine scientific inquiry and diminish instructional inventiveness. According to recent research, professional development programs enhance instructors' knowledge and instructional competency while also fostering favorable attitudes toward teaching science, which in turn improves teaching effectiveness. These results support earlier research showing the importance of affective and motivational traits in science education.

The dynamic interaction among these three constructs in fostering teaching effectiveness

PCK, Scientific teaching self-efficacy, and attitudes towards science education do not function separately, which is significant conclusion drawn from this analysis. Instead, they serve as mutually reinforcing and complimentary constructions. Because they are better equipped to explain scientific concepts and handle learning challenges, teachers with excellent pedagogical knowledge frequently express higher levels of confidence in their classroom instruction. In a similar vein, greater self-efficacy motives educators to makes better use of their pedagogical

expertise, try out novel teaching strategies, and involve students in active learning. In spite of contextual difficulties, teachers are further inspired to maintain teaching method by positive attitudes. Therefore, rather than being a single professional quality, scientific teaching efficacy should be viewed as the result of an integrated system of cognitive, motivational, and affective abilities.

Overall, this research offers compelling evidence that enhancing the efficacy of science instruction necessitates a comprehensive strategy that concurrently enhances teachers' pedagogical content knowledge, science teaching self-efficacy, and attitudes toward science instructions. The quality of scientific education can be significantly raised and student learning outcomes can be improved by incorporating these factors into professional development programs, teacher preparation programs, teacher preparation and education policy.

Conclusion

In conclusion, the results indicate that by concurrently improving Pedagogical Content Knowledge, science teaching self-efficacy, and positive teaching attitudes, teacher education institutions, legislators, and educational leaders should take a comprehensive approach to science teacher preparation and professional development. An integrated strategy like this is expected to increase science education in a variety of educational situations, enhance instructional quality, and encourage meaningful student learning. In order to create complete models of scientific teaching effectiveness that are sensitive to current educational reforms and the changing needs of science education in the twenty-first century, future research should make use of longitudinal, mixed-methods, and cross-cultural designs.

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