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Students' Perception of Teachers' Technological, Pedagogical, and Content Knowledge and Motivation to Learn Science: The Moderating Role of Physics Anxiety

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ABSTRACT

This study examined the relationship between students' perception of teachers' Technological, Pedagogical, and Content Knowledge (TPACK) and motivation to learn science, with physics anxiety serving as a moderating variable. Using a descriptive-correlational quantitative research design, the study involved Grade 12 senior high school students as respondents. Data were analyzed using Pearson Product-Moment Correlation, multiple regression, and moderation analysis through simple slope analysis. The findings revealed that students perceived their teachers' TPACK to be very high and that their motivation to learn science was also high. However, students also demonstrated high levels of physics anxiety. Correlation and regression analyses showed that Instructional Representation and Strategies (IRS) and Knowledge of Students' Understanding (KSU) positively predicted motivation, while Technology Integration and Application (TIA) negatively predicted motivation. Furthermore, moderation analysis revealed that physics anxiety significantly moderates the relationship between perceived teachers' TPACK and motivation to learn science. Specifically, the positive effect of teachers' TPACK on motivation weakened as students' physics anxiety increased. The study concluded that effective technological, pedagogical, and content instructional competencies enhance students' motivation, but high physics anxiety may diminish the positive impact of teachers' TPACK on motivation to learn science. These findings indicate that even though the enhancement of teachers' TPACK alone might not be enough to maintain the motivational level of students for science, there is also a need for the adoption of instructional and psycho-social approaches that assist in minimizing the students' anxiety about physics, thus creating a conducive environment for efficient teaching.

Keywords: Technological Pedagogical and Content Knowledge (TPACK), motivation to learn science, physics anxiety, science education, moderation analysis, senior high school students

INTRODUCTION

The decline in students' motivation to learn science has become a growing concern, particularly in cognitively demanding disciplines such as physics. Motivation is a critical affective factor that influences students' engagement, persistence, participation, and willingness to learn scientific concepts. Students with low motivation often exhibit reduced classroom participation, limited effort, poor conceptual understanding, and low academic performance in science subjects (Capunitan et al., 2023). In physics education, this problem becomes more evident because students are expected to understand abstract concepts, mathematical relationships, and scientific reasoning simultaneously.

Low student motivation has also been associated with ineffective instructional practices and limited instructional clarity in science classrooms. Krishan & Al-Rsa'i (2022) explained that poor instructional delivery contributes to weak academic performance and learner disengagement. In physics education, instructional clarity—through coherent explanations, organized discussions, and responsive teaching—has been shown to influence students' confidence and motivation positively. A secondary analysis of TIMSS 2019 data revealed that clearer, well-structured physics instruction significantly predicted higher motivation and self-confidence among students learning physics (Pečiuliauskienė, 2023). These findings suggest that effective teaching practices can improve students' motivation and learning experiences in science.

Globally, students continue to demonstrate low achievement and declining interest in science learning. The Trends in International Mathematics and Science Study (TIMSS) reported weak performance in scientific concepts among many participating countries, emphasizing the importance of affective and instructional factors in science learning outcomes (Mullis et al., 2020). One instructional factor strongly associated with positive science learning outcomes is teachers' Technological, Pedagogical, and Content Knowledge (TPACK). According to Herwanto et al. (2024), teachers with strong TPACK can effectively integrate technology, pedagogy, and content, making science lessons more interactive, engaging, and meaningful. TPACK-based instruction also promotes active learning, improves visualization of abstract concepts, and enhances students' interest and motivation toward science.

At the same time, students' emotional experiences in physics learning may influence how instructional practices affect their motivation. One important affective factor is physics anxiety, which refers to students' feelings of fear, tension, worry, and apprehension when engaging with physics concepts, laboratory activities, problem-solving tasks, or assessments. Moroki & Lahamendu (2024) emphasized that poor instructional design and unsupportive learning environments can intensify students' anxiety. In contrast, organized and technology-supported instruction can reduce stress and improve students' confidence in learning physics. This indicates that teachers' TPACK may influence students' anxiety levels by helping simplify abstract concepts and improving students' understanding of lessons.

Previous studies further revealed that anxiety negatively affects students' motivation and engagement in science learning. Simón et al. (2024) found that higher anxiety levels are associated with lower academic engagement. In contrast, students with greater confidence and self-efficacy are better able to sustain motivation despite academic challenges. Similarly, Malespina et al. (2025) explained that students with high levels of physics anxiety often avoid difficult tasks, doubt their abilities, and exhibit reduced intrinsic motivation for learning physics. Limbaga & Borlio (2025) also reported that science anxiety significantly and negatively affects students' academic performance and willingness to participate in science-related activities. These findings imply that physics anxiety may weaken or strengthen the influence of perceived teachers' TPACK on students' motivation to learn science.

Understanding students' motivation to learn science is essential because motivation influences students' engagement, persistence, academic achievement, and participation in STEM-related learning activities. Motivation drives students to put in effort, stay engaged, and actively participate in challenging science tasks. Soriano-Sánchez et al. (2025) emphasized that motivation serves as a foundation for meaningful learning and academic achievement in science education. Research further indicates that students with moderate to high levels of motivation tend to perform better academically because motivation enhances cognitive, behavioral, and emotional engagement in learning scientific concepts.

Conversely, declining motivation in science has been associated with disengagement, poor conceptual understanding, and lower achievement. Chan & Che Hassan (2017) found that motivation toward science significantly influences students' academic performance and conceptual understanding. Despite the recognized importance of motivation, many students continue to experience low interest and engagement in science due to unengaging instruction, lack of relevance, and emotional barriers such as anxiety. This highlights the need to investigate instructional factors, such as teachers' TPACK, and emotional factors, such as physics anxiety, that may influence students' motivation to learn science.

Research has consistently established teachers' TPACK as an important factor in effective science instruction and technology-enhanced learning environments. Teachers with strong TPACK are better able to integrate digital tools, instructional strategies, and content knowledge to create meaningful and engaging science lessons. Recent studies continue to affirm that TPACK positively influences student engagement, classroom interaction, and motivation in science learning. However, most TPACK studies remain instruction-centered, focusing primarily on teachers' competencies rather than on students' affective conditions that may influence motivational outcomes.

Similarly, recent studies on physics anxiety have shown that anxiety negatively affects students' engagement, persistence, confidence, and motivation in science learning, especially in subjects involving abstract concepts and mathematical reasoning (Luo & Luo, 2022; Tze et al., 2022). However, most studies examine anxiety only as a predictor or outcome variable, rather than as a moderator within instructional frameworks. Consequently, there is limited empirical evidence on whether physics anxiety changes the strength or direction of the relationship between teachers' TPACK and students' motivation to learn science.

The lack of studies examining physics anxiety as a moderating variable creates a significant research gap in science education. Although previous studies separately explored teachers' TPACK, students' motivation, and science anxiety, few studies have integrated these variables into a single framework. This gap is particularly important in the Philippine educational context, especially in private schools, as they adapt to technology-integrated instruction and the MATATAG curriculum. Understanding whether physics anxiety weakens or strengthens the relationship between perceived teachers' TPACK and students' motivation to learn science may provide valuable insights for improving instructional practices, student engagement, and science learning outcomes.

The objective of this study is to examine the correlations between students' perception of their teachers' Technological, Pedagogical, and Content Knowledge (TPACK) and Motivation to Learn Science, and to investigate the moderating role of Physics Anxiety among STEM students in General Physics.

This study specifically aims to: (1) assess the level of students' perception of teachers' Technological Pedagogical and Content Knowledge (TPACK) in terms of subject-matter knowledge, instructional representation strategies, knowledge of students' understanding, and technology integration and application; (2) assess the level of students' motivation to learn science in terms of self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation; (3) identify the level of students' physics anxiety in terms of course/test anxiety, lack of physics knowledge anxiety, mathematics anxiety, and physics laboratory anxiety; (4) examine the significant relationship between students' perception of teachers' TPACK and students' motivation to learn science; and (5) determine whether physics anxiety significantly moderates the relationship between students' perception of teachers' TPACK and students' motivation to learn science.

This study is grounded in the TPACK Framework by Mishra and Koehler (2006) as an extension of Shulman's Pedagogical Content Knowledge framework. It explains how technology, pedagogy, and content knowledge integrate to support effective teaching. Teachers with strong TPACK are capable of designing technology-integrated lessons that improve instructional clarity, interaction, and conceptual understanding. Also, the study is anchored in Pekrun's Control-Value Theory (2006), which posits that students' emotions and motivation are influenced by their perceived control over learning tasks and the value they attach to them. Science Anxiety Theory, rooted in Mallow (1981), also supports the study by explaining that students develop fear, apprehension, and tension toward science learning because of negative experiences, lack of confidence, and difficulty understanding scientific concepts. Lastly, Self-Determination Theory, developed by Deci and Ryan (1985), which explains that students become more motivated when learning environments support autonomy, competence, and relatedness.

METHODS

Research Design and Procedure

This study utilized a descriptive-correlational quantitative design, which is appropriate for examining relationships among variables without active manipulation. To address the specific interaction of student emotions, the study employs a moderation analysis. As emphasized by Zhang & He (2024), incorporating a moderating variable allows the researcher to qualify a relationship by indicating the conditions under which an effect is strengthened, weakened, or reversed, rather than implying a strict causal sequence. Specifically, this approach enables investigation into how physics anxiety affects the strength of the relationship between teachers' TPACK and students' motivation to learn science.

Furthermore, the researcher employs a cross-sectional design with respect to the time dimension, as TPACK, motivation to learn science, and physics anxiety are measured at a single point in time using adapted survey questionnaires. The mean was used to determine the level of teachers' Technological, Pedagogical, and Content Knowledge (TPACK), students' motivation to learn science, and physics anxiety among Grade 12 Senior High School STEM students. Pearson Product–Moment Correlation Coefficient (r) was used to assess significant relationships between the dimensions of teachers' TPACK and students' motivation to learn science. Multiple regression analysis was further utilized to identify which TPACK dimensions significantly predict students' motivation to learn science. Lastly, moderation regression analysis and simple slope analysis were conducted to determine whether physics anxiety significantly moderates the relationship between teachers' TPACK and students' motivation to learn science.

Accordingly, in the methodical approach to data acquisition, the researcher has sought authorization from the Dean of the Professional Schools to conduct the study. The researcher has also sought permission from the Principal and Academic Head of the respondent's school to conduct the study. The researcher obtained ethical clearance from the University of Mindanao Ethics Review Committee (UMERC). As part of a courtesy call, the researcher promptly met with the academic head and explained the intention to survey all respondents and to determine appropriate schedules for questionnaire administration. Informed parental consent was obtained before participation, and respondents were informed of the study's purpose, the confidentiality of their responses, and their right to withdraw at any time without academic consequences.

The participants were oriented to their roles in the study, including its purpose, procedures, risks, benefits, confidentiality measures, and their rights as participants. They were given 24 hours to review the consent forms and consult their parents or guardians before deciding to participate. Consent forms were collected confidentially via a sealed drop box to ensure privacy during the distribution of the survey questionnaire. The researcher personally distributed the research instrument to the respondents from February 2026 to April 2026. With the help of the STEM Department Head and teachers, all questionnaires were retrieved. The data were retrieved and encoded. Lastly, the data were analyzed and interpreted using appropriate statistical methods.

During data collection, ethical issues and considerations arose.

Voluntary Participation. Participation in the research was absolutely voluntary, and only qualified subjects were selected for the research. All respondents were oriented on the purpose, rights, and their option to refuse participation in the research without any penalty on their grades. Their decision to participate in the research was made voluntarily, without any form of coercion. The respondents were told that teachers would not know whose answers they were receiving, and that their answers would be kept confidential. Additionally, a neutral third party handled the recruitment and data collection process, particularly in the researcher's affiliated institution, to ensure objectivity and protect participants' autonomy. Lastly, the teachers will not directly handle or administer the questionnaires to their own students; only the researcher will, to ensure that participation remains voluntary and free from pressure.

Privacy and Confidentiality. The study strictly upholds the principles of privacy and confidentiality in accordance with the Data Privacy Act of 2012. To protect participants' identities, the questionnaire was designed without direct identifiers; any optional name field was removed to ensure full anonymity. Responses were coded using numerical identifiers, and no personally identifiable information was collected or linked to the data. Access to both physical and digital data was strictly limited to the researcher to prevent unauthorized use or disclosure. Data will be retained for a specified period of three (3) years solely for academic and research purposes. After this period, all data will be securely disposed of: paper documents will be shredded, and electronic files will be permanently deleted, including any backup copies. Any coded data and related files will be destroyed in a manner that prevents their retrieval or reconstruction.

Informed Consent. The study used separate informed consent forms for adult and minor participants, ensuring that ethical standards for each age group are appropriately addressed. To strengthen the protocol, the informed consent process is clearly defined. Consent will be obtained by the researcher before data collection, before any questionnaires are distributed. Participants were given a day to read and understand the consent form, ask questions, and decide whether to participate without pressure. For minor participants, parental or guardian consent was secured first, followed by the students' assent. The assent of minors will be documented through a signed assent form, indicating their willingness to participate. Both consent and assent will be obtained before administering the survey to ensure ethical compliance. Lastly, the researcher's contact details will be kept consistent across all documents, including the informed consent forms, the manuscript, and the permission letters, to ensure transparency and ease of communication.

Recruitment. The recruitment process was carefully designed to minimize the risk of perceived coercion, particularly since teachers and administrators approached participants in the school setting. To address this concern, it was clearly emphasized that participation in the study was entirely voluntary and that students' decisions to participate or decline would have no effect on their academic standing, grades, or relationship with their teachers and school. Teachers and school personnel assisted only in disseminating information about the study and did not influence, monitor, or be involved in students' decisions to participate. They were not informed of who chose to participate, ensuring that students could decide freely without fear of judgment or pressure. Any class lists used solely for identifying qualified respondents were handled with strict confidentiality. Access to such information was limited to the researcher, used only for recruitment purposes, and not recorded in the final dataset. These lists were securely stored and disposed of after use to prevent unauthorized access.

Risks. As participants evaluate their teachers' TPACK and reflect on their motivation and experiences of physics anxiety within a school-based context, discomfort, self-consciousness, or emotional unease may occur among some respondents. Participants were informed that they may skip any question they find uncomfortable and withdraw from the study at any time without negative consequences. The questionnaire was also designed with neutral, non-threatening language to reduce the likelihood of distress. A clear referral mechanism was established for participants who may experience discomfort during or after completing the survey. They will be advised to seek support from the school's guidance office or designated counselor if needed. The researcher also coordinated with the school to ensure that appropriate support services are available and accessible to participants.

Benefits. The study offered participants a small, tangible token of appreciation for their voluntary involvement. While participation is entirely voluntary and not contingent on receiving this token, it acknowledges the time and effort students dedicate to completing the survey. In addition to this direct benefit, participants may gain indirect benefits by reflecting on their motivation to learn science and their experiences with physics anxiety, thereby increasing self-awareness and personal insight.

Plagiarism. The researcher ensured that the materials used were paraphrased and expressed in the researcher's own words. No portion of the study used another person's ideas or words; if it did, the person has been given appropriate credit for their work and study. As part of the process, the research paper underwent a plagiarism check at the university using Turnitin to ensure that no plagiarism occurred throughout the study.

Fabrication. The study underwent the standard research procedure established by the Professional School of the University of Mindanao. There was no trace or indication of deliberate distortion of what was done. There was no fabrication of data and outcomes, nor any intentional presentation of false conclusions. There were no discrepancies between the material in the text and the current literature.

Falsification. There was no evidence that the study was intentionally misrepresented to match a model or theoretical assumption. There was no indication of fabrication or over-claiming. To prevent scientific misconduct, such as falsification, the correction mechanism was strengthened, and researchers sought to accord peer review the importance it deserved. This ensured accuracy. Also, collaboration among research institutions, journals, authors, and co-authors was needed to improve research standards and procedures, thereby prioritizing knowledge over economic benefits and prestige.

Conflict of Interest. The study had no conflicts of interest, as the researcher had no relationship with the study's respondents. The researcher is a grade school teacher at Precious International School of Davao. However, this potential concern is mitigated by the fact that the study's respondents are senior high school students, while the researcher's teaching responsibilities are limited to the grade school level. To further manage any perceived conflict, the researcher does not directly recruit or administer surveys to any students from the senior high school.

Consent and survey instructions are communicated clearly to participants, emphasizing voluntary participation and confidentiality, and teachers or staff do not influence students' decisions to participate.

Deceit. This study did not include any deception. Everything that was said and reflected was accurate and had been extensively verified by many research professionals. The researcher and his paper maintain a commitment to honesty, integrity, and transparency.

Permission from the Organization. Prior to the commencement of data collection, the researcher secured formal approval from the University of Mindanao Ethics Review Committee (UMERC). Any data collected before obtaining this approval will be considered null and void, ensuring full compliance with ethical standards. An approved letter from the Dean of the Professional Schools at the University of Mindanao was obtained, along with any other necessary authorizations to conduct the study. The Principal and Academic Head of each school were the recipients of the letter.

Authorship. No person was authorized to publish or present this paper except the researcher or the adviser without the researcher's consent. If the organization wants a copy of the study results, it can access them to create programs and policies within the organization, with the researcher's, adviser's, and university's permission. For publication, the adviser becomes the co-author of the study.

Research Participants

The respondents in this study were the Grade 12 STEM students enrolled in the Senior High School Strand of Precious International School of Davao, Philippine Academy of Sakya Davao, and Holy Cross College of Calinan for the Academic Year 2025-2026. The respondents were 326 students enrolled in the General Physics course who shared their academic experiences. These students share characteristics essential to the study's objectives: they are at a comparable developmental stage, have prior exposure to foundational science and physics concepts, and are taught by science teachers who employ varying levels of integration of technology, pedagogy, and content in instruction. As senior high school learners, they are expected to engage in more abstract scientific reasoning and problem-solving, making them particularly susceptible to fluctuations in learning motivation and physics anxiety.

All Grade 12 Senior High School STEM students from intact sections in the three selected private schools were included as respondents in this study, resulting in a total sample of 326 participants. The inclusion of all available respondents from the three schools ensured broader representation of STEM learners within the study locale. It provided an adequate sample size for examining the relationships among students' perceptions of their teachers' TPACK (independent variable), motivation to learn science (dependent variable), and the moderating effect of physics anxiety. This sample size also ensured sufficient statistical power for both correlational and moderation regression analyses, yielding more stable and precise estimates while reducing sampling error. According to Hayes (2018), larger sample sizes are particularly important when testing interaction effects in regression models because they increase the likelihood of detecting significant moderation effects.

In addition, the researcher employed purposive sampling to select students who met specific criteria. Purposive sampling was adopted to ensure that participants were most relevant to the research objectives and possessed unique context-specific data and characteristics, such as instructional strategies, content, and subject-related learning tasks, that were essential to the study's purpose (Ahmad & Wilkins, 2024). Furthermore, because the population of students taking General Physics is exclusive to the STEM strand, the researcher involved the entire group (total enumeration). This approach was adopted to minimize sampling bias and ensure that the data provide a comprehensive representation of the instructional strategies and pedagogical integrations used by their science teachers.

Research Instruments

This study utilized three (3) standardized instruments to measure the key variables: (1) Students' Perceptions of their Teachers' Technological Pedagogical and Content Knowledge (TPACK), (2) Students' Motivation to Learn Science, and (3) Physics Anxiety. The Students' Perceptions of Science Instructors' TPACK questionnaire was adapted from Jang & Chen (2013) and comprises four subcategories: subject matter knowledge (SMK), instructional representations and strategies (IRS), knowledge of students' understanding (KSU), and technology integration and application (TIA). Meanwhile, the Students' Motivation Towards Science Learning questionnaire was adapted from Tuan, Chin, & Shieh (2005) with six subcategories: self-efficacy, active learning strategies, science learning value, performance goal, achievement goal, and learning environment stimulation. Lastly, the Physics Anxiety Rating Scale was adapted from Şahin (2014) with four subcategories: physics course/test anxiety (C/TA), lack of physics knowledge (LPKA), mathematics anxiety (MA), and physics laboratory anxiety (PLA).

RESULTS AND DISCUSSIONS

Students' Perceptions of Their Teachers' Technological, Pedagogical, and Content Knowledge

The results of the gathered data are presented in this section. The order of the presentation is based on the objectives of the study.

Table 1 Level of Students' Perceptions of Their Teachers' Technological, Pedagogical, and Content Knowledge

	Mean	**SD**	**Interpretation**
Subject-Matter Knowledge	4.29	0.464	Very High
Instructional Representation Strategies	4.15	0.537	High
Knowledge of Students' Understanding	4.16	0.506	High
Technology Integration and Application	4.33	0.641	Very High
Overall	4.23	0.377	Very High

Table 1 shows that students' perceptions of teachers' technological, pedagogical, and content knowledge were very high, with an overall mean score of 4.23 (SD = 0.377). It indicates that the students viewed their physics teacher as highly competent in subject matter and the use of technology. As for the indicators, Technology Integration and Application obtained the highest mean score ($\bar{x}$ = 4.33), indicating that students perceived their teachers as very skilled in using technological resources in teaching. On the other hand, the lowest mean score was attained by Instructional Representation Strategies ($\bar{x}$ = 4.15), yet it remained at a high level of interpretation.

These findings indicate that the high perceived value of teachers' TPACK helps create a positive learning experience for learners and motivates them to learn science. The high mean scores across all indicators suggest that respondents' answers were consistent and that teachers can teach meaningfully by using the right combination of pedagogy, content, and technology. The low standard deviations further indicate consistency in students' responses, suggesting that most respondents held similar positive perceptions of their teachers' competencies.

This study's findings further confirm the theoretical underpinnings of the Technological Pedagogical and Content Knowledge (TPACK) framework proposed by Mishra & Koehler (2006), which posits an interwoven relationship among technology, pedagogy, and content knowledge to achieve effective instruction. The very high overall perception ratings of students of their teachers' competence suggest that teachers with high TPACK competence are better able to design meaningful and engaging science lessons. This idea aligns with the findings of Absari et al. (2020), who argued that combining technological, pedagogical, and content knowledge is crucial for enhancing instruction and providing meaningful learning experiences for students. Likewise, in their work on science teachers, Mohamad (2021) emphasized that teachers with higher TPACK competencies were more effective at integrating technology, thereby positively impacting students' learning experience.

Students' Motivation to Learn Science

Table 2 Level of Students' Motivation to Learn Science

	Mean	**SD**	**Interpretation**
Self-efficacy	3.80	0.625	High
Active Learning Strategies	4.09	0.542	High
Science Learning Value	4.19	0.578	High
Performance Goal	3.52	0.872	High
Achievement Goal	4.21	0.557	Very High
Learning Environment Stimulation	4.04	0.515	High
Overall	3.97	0.307	High

Table 2 presents the level of motivation to learn science, showing that students were highly motivated, with an overall mean score of 3.97 (SD = 0.307). This indicates a positive level of motivation among the respondents regarding science learning. The Achievement Goal indicator had the highest mean ($\bar{x} = 4.21$, SD = 0.557), which was interpreted as "Very High." This implies that students are very motivated to perform well in their science subjects. On the other hand, the Performance Goal indicator had the lowest mean ($\bar{x} = 3.52$, SD = 0.872), but the interpretation remains the same: "High."

These findings show that the students have both intrinsic and academic motivation to study science. The very high mean score for achievement goals indicates that students are motivated to master science concepts, improve their academic performance, and achieve individual success. It also means that they are not preoccupied with beating their peers. Similarly, the high mean scores for active learning approaches, science learning value, and environmental stimulation indicate that students understand the significance of science learning and feel encouraged in interactive, supportive environments.

On the other hand, the relatively low mean self-efficacy score could indicate that some students have doubts about their self-confidence in science learning. These findings align with self-determination theory, which is also anchored in this study and was introduced by Deci & Ryan (1985). It highlights that learners become more motivated to learn when they are supported, value the learning process, and are encouraged to accomplish meaningful objectives. This study is also consistent with several previous studies indicating that a positive learning environment, effective teaching techniques, and learner-centered instruction play important roles in enhancing learners' motivation to learn science subjects.

The findings are also in consonance with the results obtained by Ceylan & Kesici (2022), which indicate that students exposed to supportive learning methods and allowed to engage actively have higher levels of motivation, persistence, and a positive attitude towards their science learning. In other words, motivated students engage in class activities, persist through difficult assignments, and adopt a positive attitude towards learning science. Consequently, it becomes crucial to support learners' interest in studying science through supportive teaching practices.

Physics Anxiety

Table 3 Level of Physics Anxiety

	Mean	**SD**	**Interpretation**
Physics Course/Test Anxiety	3.53	0.622	High
Lack of Physics Knowledge	3.56	0.743	High
Mathematics Anxiety	3.62	0.886	High

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Physics Laboratory Anxiety	3.63	0.650	High
Overall	3.59	0.592	High

In Table 3, it is evident that the level of anxiety among students studying physics was high, with an overall mean score of 3.59 (SD = 0.592). It can be noted that there is quite a lot of anxiety among students studying physics. Among the various dimensions of anxiety, the highest mean values were Physics Laboratory Anxiety ($\bar{x}$ = 3.63, SD = 0.650) and Mathematics Anxiety ($\bar{x}$ = 3.62, SD = 0.886), both rated as "High." At the same time, the lowest mean value was observed for Physics Course/Test Anxiety ($\bar{x}$ = 3.53, SD = 0.622), though it was also rated at the "High" level.

Based on the findings above, students often encounter challenges and stressful moments when engaging with physics concepts, calculations, lab work, and assessments. High laboratory anxiety might mean that students feel stressed when conducting experiments, using lab instruments, or applying theoretical knowledge in practice. In addition, high mathematics anxiety means that the math-oriented aspect of physics is what creates the fear among the students. Furthermore, these findings suggest that stress may hinder students' engagement, understanding, and motivation to study physics.

Moreover, the research findings validate Mallow's (1981) Science Anxiety Theory. The Science Anxiety Theory is premised on the idea that anxiety towards science subjects has the capacity to influence motivation, academic performance, attitudes, and the overall learning process. Learners experiencing science anxiety often fear, become tense, and avoid science-related activities, especially those involving advanced mathematics and laboratory experiments.

In addition, the findings also align with those of Kaya & Yildirim (2021), who found that anxious students in physics and math have difficulty maintaining focus. The abstract nature of physics and the complex calculations associated with it led many learners to develop anxiety. The importance of applying various teaching techniques to reduce students' anxiety when problem-solving and participating in their science classes. It seems that the abstract nature of physics and the complex calculations it entails lead many learners to develop an aversion to studying it. Hence, it is crucial to emphasize the importance of applying various teaching techniques to reduce students' anxiety when learning physics.

Correlation Analysis between Independent and Dependent Variables

Table 4 Correlation Analysis of IV and DV

DV	**IV**				
	Subject- Matter Knowledge (SMK)	Instructional Representation & Strategies (IRS)	Knowledge of Students' Understanding (KSU)	Technology Integration & Application (TIA)	**Overall**
Self-efficacy	-0.314 < .001	-0.037 0.503	-0.04 0.47	-0.32 < .001	-0.259 < .001
Active Learning Strategies	0.112 0.043	0.18 0.001	0.184 < .001	0.044 0.428	0.179 0.001
Science Learning Value	0.24 < .001	0.221 < .001	0.174 0.002	0.143 0.01	0.272 < .001
Performance Goal	-0.309	-0.059	-0.117	-0.357	-0.307

	< .001	0.289	0.035	< .001	< .001
Learning Environment Stimulation	0.15 0.007	0.201 < .001	0.157 0.004	0.058 0.299	0.195 < .001
Achievement Goal	0.224 < .001	0.196 < .001	0.235 < .001	0.226 < .001	0.313 < .001
Overall	-0.035 0.532	0.197 < .001	0.155 0.005	-0.135 0.014	0.054 0.332

The correlation analysis between students' perceptions of their teachers' TPACK and their motivation to learn science is presented in Table 4. The figures appearing in this table indicate the correlation coefficients (r) and their respective probability levels (p). Positive correlations mean that when students' perceptions of teachers' abilities go up, so does their motivation, while negative correlations imply that increased perceptions correspond to decreased motivation. Statistically significant correlations are those for which $p < 0.05$.

Self-Efficacy has shown a significant negative correlation with Subject-Matter Knowledge ($r = -0.314$, $p < .001$), Technology Integration & Application ($r = -0.320$, $p < .001$), and an overall score ($r = -0.259$, $p < .001$). These results indicate that even though students perceive their teacher as competent in subject-matter knowledge and in the application of technology in teaching, they still are likely to exhibit low levels of self-efficacy regarding their science performance. It can be argued that such a perception could lead to high intimidation among students, particularly those affected by physics anxiety and difficulties in understanding science. In this regard, it appears that the Instructional Representation & Strategies and Knowledge of Students' Understanding do not affect students' confidence in science, since these two dimensions did not show a significant relationship with self-efficacy.

On the other hand, Active Learning Strategies has shown a significant and positive correlation with Subject-Matter Knowledge ($r = 0.112$, $p = 0.043$), Instructional Representation & Strategies ($r = 0.180$, $p = 0.001$), Knowledge of Students' Understanding ($r = 0.184$, $p < .001$), and an overall score ($r = 0.179$, $p = 0.001$). The above findings suggest that students who perceive their teachers as competent are more likely to be actively involved in learning science. These findings indicate that the teacher's use of appropriate teaching practices and knowledge of students' learning needs would lead to better classroom participation and learning activities. However, Technology Integration & Application was not significantly correlated with active learning strategies ($r = 0.044$, $p = 0.428$).

The Science Learning Value variable demonstrated strong significant and positive correlations with all TPACK constructs, such as Subject-Matter Knowledge ($r = 0.240$, $p < .001$), Instructional Representation & Strategies ($r = 0.221$, $p < .001$), Knowledge of Student' Understanding ($r = 0.174$, $p = 0.002$), Technology Integration & Application ($r = 0.143$, $p = 0.010$), and an overall score ($r = 0.272$, $p < .001$). These results imply that students who have positive attitudes towards their teachers are likely to consider science learning important. This study revealed that effective teaching strategies and the use of technology in teaching can enhance students' understanding of science.

Moreover, a significant negative correlation was identified between Performance Goal and Subject-Matter Knowledge ($r = -0.309$, $p < .001$), Knowledge of Students' Understanding ($r = -0.117$, $p = 0.035$), Technology Integration & Application ($r = -0.357$, $p < .001$), and an overall score ($r = -0.307$, $p < .001$). The results imply that learners who see themselves as having highly competent teachers tend to focus less on the external outcomes of their learning, such as grades, competitions, and beating other students to achieve high results. Instead, they may be more concerned with grasping the lesson content and acquiring scientific knowledge. Instructional Representation & Strategies was not significantly correlated with performance goals ($r = -0.059$, $p = 0.289$).

Learning Environment Stimulation has shown a significant positive correlation with Subject-Matter Knowledge ($r = 0.150$, $p = 0.007$), Instructional Representation & Strategies ($r = 0.201$, $p < .001$), Knowledge of Students' Understanding ($r = 0.157$, $p = 0.004$), and an overall score ($r = 0.195$, $p < .001$). This implies that teachers' skills play a role in shaping a more stimulating and supportive science learning environment. Learning science might appear more appealing to students when teachers use effective instructional methods and demonstrate their pedagogical skills. Nonetheless, there was no significant correlation between TIA and learning environment stimulation ($r = 0.058$, $p = 0.299$).

Additionally, Achievement Goal has shown a significant and positive correlations across all dimensions of TPACK, including Subject-Matter Knowledge ($r = 0.224$, $p < .001$), Instructional Representation & Strategies ($r = 0.196$, $p < .001$), Knowledge of Students' Understanding ($r = 0.235$, $p < .001$), Technology Integration & Application ($r = 0.226$, $p < .001$), and an overall score ($r = 0.313$, $p < .001$). This implies that learners who recognize their teachers' competence tend to feel more motivated to accomplish their academic objectives in science. Positive correlations can be interpreted as indicating that effective learning practices motivate learners to be academically achievement-oriented.

Finally, the overall correlation analysis revealed a very weak positive relationship between students' overall perceived TPACK and overall motivation to learn science ($r = 0.054$). However, the relationship was not statistically significant ($p = 0.332$). This indicates that overall perceived TPACK does not significantly influence students' overall motivation to learn science. Therefore, the null hypothesis that there is no significant relationship between teachers perceived TPACK and motivation to learn science is retained. Nevertheless, certain dimensions of TPACK demonstrated significant relationships with specific motivational factors.

Moderation Analysis of the relationship between the Independent Variable and the Dependent Variable

Table 5 Moderation Analysis (MV) towards the relationship between IV and DV

95% Confidence Interval						
	Estimate	**SE**	**Lower**	**Upper**	**Z**	**P**
IV	0.0465	0.0459	-0.0434	0.1364	1.01	0.311
MV	0.1320	0.0276	0.0779	0.1860	4.78	< .001
IV ✻ MV	-0.1624	0.0584	-0.2769	-0.0479	-2.78	0.005

The results in Table 6 highlight the impact of Physics Anxiety as a moderator of the association between teachers' Technological, Pedagogical, and Content Knowledge (TPACK) and students' motivation to learn science. It was observed that the relationship between TPACK and the motivation to learn science (as the direct effect) was insignificant (Estimate = 0.0465, $p = 0.311$) if the moderating factor was considered in the model. Nevertheless, Physics Anxiety had a significant impact on students' motivation to learn science (Estimate = 0.1320, $p < .001$).

The most critical part, however, is that the interaction between the perceived TPACK and physics anxiety was statistically significant (Estimate = -0.1624, $p = 0.005$). In other words, physics anxiety was a significant moderator of the association between TPACK and motivation to study science. The negative coefficient suggests that physics anxiety attenuates the effect of teachers' TPACK on the motivational aspect under discussion. Given that the p-value for the interaction was less than 0.05, the null hypothesis can be rejected.

These results indicate that, despite students' perception of their instructors as very good at integrating technology into instruction, using effective teaching strategies, and demonstrating strong subject-matter knowledge, high levels of physics-related anxiety might limit students' confidence, engagement, and participation in scientific learning activities. In other words, physics anxiety may undermine students' cognitive engagement and responsiveness to instruction, thereby minimizing the positive influence of teachers' TPACK on students' motivation to learn science.

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Putwain (2021) stated that academic anxiety is highly influential in how engaged learners are and in their academic behavior and motivation, especially in science courses, where there tends to be considerable anxiety and fear of failure among learners. In addition, according to Loderer et al. (2020), anxiety might weaken the impacts of instructional support and environments on learners' academic motivation. This suggests that increasing teachers' instructional competencies alone will not be effective unless learners' anxiety is considered.

Additionally, the simple analysis below further explains the moderating effect of physics anxiety on the relationship between students' perception of teachers' Technological, Pedagogical, and Content Knowledge (TPACK) and their motivation to learn science.

		95% Confidence Interval				
	Estimate	SE	Lower	Upper	Z	P
Average	0.0465	0.0462	-0.0440	0.1370	1.007	0.314
Low (-1SD)	0.1425	0.0479	0.0486	0.2364	2.974	0.003
High (+1SD)	-0.0495	0.0662	-0.1792	0.0802	-0.748	0.454

Note. shows the effect of the predictor (IV) on the dependent variable (DV) at different levels of the moderator (MV)

As reflected in the findings, there was a positive and significant relationship between perception of TPACK and motivation to learn science at low levels of physics anxiety (-1SD) [Estimate = 0.1425, $p = 0.003$]. This suggests that students with low physics anxiety are likely to increase their motivation to learn science when they perceive their teachers as having strong knowledge of how to integrate technology, pedagogy, and content. However, this relationship was non-significant among students at average levels of physics anxiety [Estimate = 0.0465, $p = 0.314$]. Similarly, in the case of high physics anxiety levels (+1SD), there was a negative and insignificant relationship between the two variables (Estimate = -0.0495, $p = 0.454$). Such results show that the positive effect of teacher TPACK on learners' motivation diminishes as physics anxiety increases. Because the probability figure at the low level of anxiety was below the 0.05 significance level, the null hypothesis is accepted in the case of students with low physics anxiety levels, but not high.

The results suggest that students tend to derive greater benefits from effective instructional practices when they experience less anxiety about physics. Students with low physics anxiety seem to be more sensitive to teachers' instructional competencies that help them engage in their studies, build their confidence, and become motivated to acquire scientific knowledge. High anxiety towards physics, in turn, might lead to fear or pressure among learners, preventing them from benefiting from teachers' technical, pedagogical, and content competence. The high level of students' physics anxiety could affect their cognitive involvement, sensitivity to instructional activities, and result in decreasing the positive influence of teachers' TPACK on students' motivation in learning science. As argued by Putwain (2021), high academic anxiety is likely to negatively affect learners' engagement, confidence, and sensitivity to instructional techniques.

The simple slopes plot and slope estimates provide additional support for how Physics Anxiety moderates the association between students' perception of teachers' Technological, Pedagogical, and Content Knowledge (TPACK) and motivation to learn science. The chart shows three regression lines corresponding to low, medium, and high levels of physics anxiety.

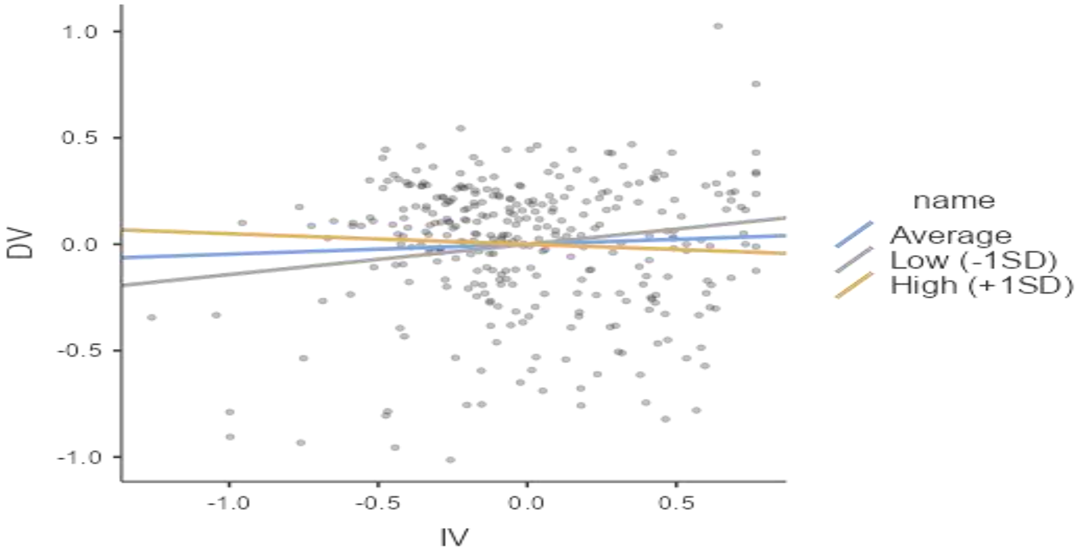

Figure 2. The Moderating Effect of Physics Anxiety on the Relationship between TPACK and Motivation to Learn Science

According to the slope estimates, only students with low physics anxiety showed a statistically significant positive association between the two variables under investigation (Estimate = 0.1425, p = 0.003). Thus, students with low anxiety towards physics are more likely to feel motivated when their teachers have strong TPACK. As for the probability value of the low anxiety group, it was less than 0.05; hence, the null hypothesis can be rejected among students with low anxiety towards physics.

Students who reported moderate levels of physics anxiety showed a positive, although statistically insignificant, correlation between perceived TPACK and science learning motivation (Estimate = 0.0465, p = 0.314). Students with high levels of physics anxiety showed a slightly negative and statistically insignificant correlation between TPACK and science learning motivation (Estimate = -0.0495, p = 0.454). It can be concluded from the above data that students with high anxiety have a slight inverse correlation between TPACK and science learning motivation, meaning that despite a favorable perception of their teachers, high levels of anxiety diminish the motivational impact that their perceived competencies have on the process of students' science learning.

Overall, the results reveal that physics anxiety plays a crucial role in shaping the impact of perceived teachers' TPACK on students' motivation to learn science. The positive relationship between teachers' skills and students' motivation in learning is enhanced by low levels of anxiety in students but weakens at higher levels of anxiety. This finding indicates that psychological aspects like physics anxiety play an essential role in determining students' reactions to instructional activities and processes in science instruction. In conclusion, academic anxiety can undermine students' engagement, confidence, and responsiveness to instructional support, thereby reducing their motivation and participation in academic activities.

Implications And Concluding Remarks

Implications for Practice

There are significant implications for science teachers, school administrators, curriculum developers, and teacher education institutions that have been highlighted in the findings of this study. Although the level of perceptions of students in their teachers' Technological, Pedagogical, and Content Knowledge (TPACK) is at a very high level, the presence of high physics anxiety indicates that instructional competence is insufficient to fully develop and enhance the motivation of students in learning science. Teachers should therefore integrate emotional support instructional practices, effective pedagogy, and technology use in the classroom. Creating an emotional and psychologically safe environment encourages students to participate without fear of failure, be provided with constructive feedback, and use anxiety-reducing teaching strategies, which help students develop greater confidence and competence in learning physics.

Moreover, the positive and predictive influence of instructional representation and strategies, knowledge of students’ understanding, emphasizes the importance of a learner-centered instruction approach in the classroom. Science teachers should constantly assess the prior knowledge, misconceptions, and emotional readiness of students to learn, specifically in the subjects that are highly abstract in nature, such as physics. This will enable them to design lessons that are responsive to the cognitive and affective needs of the students. Similarly, the integration of technology should be implemented purposefully to ensure that the digital tools aim to enhance conceptual understanding rather than merely increasing technological exposure.

Lastly, the findings underscore the important roles of school administrators in providing continuous professional development programs that strengthen teachers’ TPACK while equipping them with strategies for addressing students’ emotional well-being, particularly in physics anxiety. The teacher institutions may also incorporate training on anxiety-sensitive instructional approaches and socio-emotional learning into the science curriculum to produce educators who are competent in both instructional delivery and learner support.

Implications for Future Research

The findings of the study highlight several important directions and aspects for future research. Since the study focused on Grade 12 STEM students, future researchers may replicate the study across different educational levels, academic strands, subject areas, and school settings to determine whether similar relationships exist among diverse learner populations. Comparative studies between public and private schools or across different regions may also provide broader evidence regarding the influence of TPACK and physics anxiety on student motivation.

Future studies may investigate additional variables that could explain students' motivation to learn science beyond teachers' TPACK, such as science self-efficacy, academic resilience, classroom climate, teacher-student relationships, parental support, learning resources, and students' prior academic achievement. Considering the weak overall relationship between perceived TPACK and motivation, examining these factors may provide a more comprehensive understanding of students' motivational development.

Researchers are also encouraged to employ qualitative or mixed-methods approaches to gain deeper insights into students lived experiences of physics anxiety and how instructional practices influence their motivation. Longitudinal and experimental studies may further establish causal relationships and evaluate the effectiveness of intervention programs designed to reduce physics anxiety while enhancing science motivation through improved instructional practices.

Concluding Remarks

This study contributes to the growing body of knowledge on science education by demonstrating that teachers' Technological, Pedagogical, and Content Knowledge remains an essential component of effective science instruction, particularly in fostering specific dimensions of students' motivation to learn science. However, the findings also reveal that instructional competence alone cannot fully overcome the adverse effects of physics anxiety. The significant moderating role of physics anxiety highlights that students' emotional experiences substantially influence how they respond to even high-quality instruction.

Ultimately, meaningful science learning requires a balanced integration of instructional competence and emotional support. Teachers who effectively combine sound pedagogical practices, appropriate technology integration, strong content knowledge, and sensitivity to students' emotional needs are more likely to cultivate motivated, confident, and engaged science learners. As science education continues to evolve in the digital age, addressing both the cognitive and affective dimensions of learning will remain essential in promoting students' academic success and lifelong interest in science.

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