Self-efficacy, Epistemological Beliefs, and Academic Performance in Physics: A Mediation Analysis

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ABSTRACT. Self-efficacy and epistemological beliefs are focal figures in enhancing academic performance in learning Physics. This paper investigates the mediating role of epistemological beliefs about physical science (EBAPS) on the effect of Physics self-efficacy (PSE) on academic performance in Physics (APP) of 456 grade 12 senior high school students enrolled in Science, Technology, Engineering, and Mathematics (STEM) track. A correlational research design was used to analyze, interpret, and propose a statistical model predicting the APP based on the empirical data gathered. The adapted research instruments obtained an excellent reliability index, encoded in a web-based program, and distributed through online platforms. Mediation analysis using PROCESS v3.5 was used to examine the mediating role of EBAPS between PSE and APP. Findings revealed that EBAPS significantly mediated the association between PSE and APP. This indicates that their self-efficacy beliefs can enhance their epistemological beliefs, eventually translating to higher academic performance.

1.0. Introduction

Physics is recognized as one of the most difficult subjects in secondary high school because of its highly abstract and mathematical nature (Chala et al., 2020; Panergayo, 2020). Physics as a subject provides an avenue to foster quantitative reasoning and problem-solving skills using the context of science. The main aim of this subject is to enhance the appropriate understanding of the essential ideas, facts, concepts, and principles in Physics and apply them in real-life settings to understand how the world works (Panergayo et al., 2023). To quantify students' achievement in understanding physics, academic performance is used to numerically report students' level of learning acquisition. Academic performance measures the learners' achievement in a given subject. It is a combination of various components but not limited to results from performance tasks, written tasks, and examinations. It also pertained to the knowledge acquired aligned with the educational goals and learning objectives marked by the teachers and set to the students on a given period (Narad & Addullah, 2016; Vilia et al., 2017). Likewise, academic performance is an aggregate of cognitive and non-cognitive components considering the socio-cultural context of the learning environment (Panergayo et al., 2022). It further serves as input in evaluating curriculum and instituting educational reforms (Almerino et al., 2020).

Previous research suggests that intrinsic and extrinsic factors influence academic performance in Physics (APP). It is an interplay among the learning environment, teachers, and student factors. The classroom environment can affect the quality of learning in physics through the availability of appropriate learning materials, such as quality learning textbooks, the physical condition of the classroom (Garzon-Agudelo et al., 2020), laboratory rooms, and adequate scientific equipment. Teaching methods teachers employ further explain the APP (Garzon-Agudelo et al., 2020). Moreover, the teaching experience and the professional ranking of the teachers also play a vital role in APP. In terms of the student factor, a lack of prior knowledge in fundamental mathematics and physics (Garzon-Agudelo et al., 2020) is important in understanding the lessons in physics. Students' prior knowledge and conception of physics largely affect their learning of physics. Similarly, students' beliefs (Panergayo et al., 2023; Vecaldo, 2017) about physics and their capability to perform (Kapucu, 2017; Sağlam & Toğrol, 2018; Fidan & Tuncel, 2021) physics-related tasks predicts APP. This suggests that epistemological belief is a popular theme in explaining academic performance. Likewise, self-efficacy beliefs also serve as motivational factors and sources of self-

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confidence in learning physics that can improve their academic performance.

Epistemological beliefs pertain to the student's understanding of the characteristics of knowledge and the nature of knowing (Lee & Chan, 2018). Specifically, epistemological beliefs about physical science (EBAPS) (Elby et al., 2023) pertain to the views of students in physical science, such as physics and chemistry. EBAPS has a critical role in students' academic performance. This belief provides a structure for how students will approach learning, engage in content, and resolve challenges in teaching and learning science (Ongowo, 2022; Orleans & Palomar, 2018; Panergayo et al., 2023). This theme provides valuable input in developing instructional materials and interventions, allowing them to raise their understanding of physics as a form of knowledge (Panergayo et al., 2023). Likewise, epistemological beliefs were indicated to be correlated to interest and reflective thinking, which in turn affect scientific identity. This insight can be valuable in fostering reflective thinking and forming a scientific identity (Guo et al., 2022). Similarly, EBAPS is closely related to learning gains. Hence, facilitating conceptual change can be initiated by exploring the EBAPS of the learners. Epistemological beliefs emerged as significant determinants of science achievement (Ongowo, 2022). This indicates that teachers are vital in designing a learning environment engenders epistemological beliefs. This can be actualized by directing knowledge-construction activities using the relevant and meaningful experiences of the learners.

Self-efficacy is a construct based on the social cognition theory of Bandura (1977). It is defined as the individuals' beliefs and perception of their capability to perform a certain action (Andal et al., 2020; Panergayo & Mansujeto, 2021; Malagsic et al., 2021). The same description was provided by Bandura (1977) about self-efficacy. It refers to *beliefs in one's capabilities to organize and execute the course of action required to produce given attainments".* Physics self-efficacy (PSE), in particular, indicates self-confidence in one's capacity to accomplish physics-related tasks. Numerous scales were developed designed to measure the beliefs that one's actions are responsible for successful outcomes (Selcuk et al., 2018; Gurcay & Ferah, 2018; Fidan & Tuncel, 2021). Furthermore, academic scholars established a strong association between self-efficacy in physics and their academic performance and learning motivation (Sağlam & Toğrol, 2018). This implies that motivation and self-confidence can significantly enhance students' learning performance in physics. Students have ideas about their capacities for learning science. It has been demonstrated that these self-perceptions about their capacities to promote science learning directly influence success through motivation and their capacity to function in a certain science learning environment (Fidan & Tuncel, 2021). Such self-efficacy attitudes are crucial for enhancing science instruction. Similar to this, learning content has an impact on how self-efficacy develops.

The interplay of self-efficacy, epistemological beliefs, and academic performance in physics can serve as valuable inputs in designing instruction to enhance the student's performance. This relationship can provide tailored feedback and support for students by recognizing their beliefs that influence their motivation and persistence toward academic improvement. Sadi and Dagyar (2015) structurally model epistemological beliefs, the conception of learning, and self-efficacy for learning biology. The study found that epistemological beliefs directly affect the conceptions of learning and indirectly influence self-efficacy through the mediation of the conception of learning. These results served as inputs in designing a comprehensive and effective teaching and learning plan for biology education. Kapucu and Bahcivan (2015) further proved the substantial impact of epistemological beliefs on self-efficacy in physics learning and attitude towards physics. Hence, positive and significant relationships can be observed in the epistemological beliefs, self-efficacy in physics learning, and attitudes toward physics. The standing relationship among the variables prompted the investigation of further interrelation to model their influence on one another. This also provides an avenue to explore interacting effects among the study variables that best fit the context of the study and target research sample and site.

This present study highlighted the role of PSE and EBAPS in enhancing APP at the senior high school level since most of the previous studies are situated in the context of higher education. The scholarly literature also revealed a gap in the active role of epistemological beliefs in academic performance (Panergayo et al., 2023). This prompted the researcher to examine the mechanism of how self-efficacy and epistemological beliefs influence the performance of the students. Limited studies consider these variables in the Philippines compared with other countries (Orleans & Palomar, 2018). Thus, investigating Filipino SHS learners can provide a more responsive and appropriate groundwork for teaching and learning to enhance the student's academic performance. In this regard, this study aimed to describe the connection among PSE, EBAPS, and APP of the Senior High School (SHS) students in one schools division office in Laguna, Philippines. It describes the direct influence of PSE and EBAPS on the APP of the SHS STEM learners. It further aimed to determine

the mediating role of EBAPS in the cause-and-effect relationship between PSE and APP. The results of the study provided salient inputs in designing instructional materials, classroom environments, and learning plans to address APP banking on PSE and EBAPS.

2.0. Methodology

Research Design. This study adopted a correlational research design to answer the research objectives. This non-experimental design involves no manipulation while examining the relationships among study variables (Creswell, 2014). This study aimed to model the causal relationship of PSE, EBAPS, and APP to understand the interaction among these variables.

Sample. The study selected SHS students as participants of this study as they exhibit a wide range of beliefs about learning and knowledge, including self-efficacy and epistemological beliefs. The relevance of the SHS STEM curriculum further made them appropriate target participants as they have two courses in Physics, suggesting their active engagement in Physics learning. Likewise, since the SHS level is a preparatory stage for higher education, they are more likely to demonstrate a critical development stage where cognitive beliefs are becoming more sophisticated for a higher level of learning. In this study, a convenient sample of 456 respondents was used. These are students enrolled in the 2nd semester, academic year 2021 to 2022, in Grade 12 SHS and taking up the STEM strand at SHS level in one school's division in Laguna Province. The sample was selected through a convenience sampling technique since the data collection was administered via a web-based program. In terms of age, most respondents are 17 years old (33.6%) and 18 years old (60.3%), while the remaining percentage is older than 18 years old. Furthermore, respondents are mostly female (56.6%). There are fewer males (43.4%) who participated in the study. The respondents were obtained from 4 private (34.4%) and 5 public (65.6) SHS.

Instrument. This study used adapted research instruments to measure the PSE and EBAPS of the target respondents. To measure the students' PSE, the researcher adopted the Self-efficacy in Physics Instrument (SEPI) developed and validated by Shaw (2004). SEPI has 8 items in a 5-point Likert scale to measure the students' confidence about their capability to carry out classroom-specific tasks in physics. On the other hand, EBAPS was assessed using the instrument developed by Elby (2001). The instruments aimed to examine the epistemological stances of students in physical science, including introductory physics. The instrument has 30 multiple-choice items measuring the five non-orthogonal dimensions - the structure of scientific knowledge, nature of knowing and learning, real-life applicability, evolving knowledge, and source of the ability to learn. The instruments were assessed and gained excellent reliability of Cronbach's alphas of 0.841 and 0.893, respectively. For the APP, the researcher obtained the self-reported students' performance, in the form of percentage grades, from the General Physics 1 class taken by the respondents. The researcher asked permission regarding the use of the instrument via email before the data collection and received consent from the respective authors.

Data Collection. The researcher asked permission to conduct the study in the Schools Division Superintendent and was channeled appropriately to school heads and teachers. The instruments were encoded in a web-based program and were distributed through online media. The researcher asked the assistance of Physics teachers of SHS to disseminate the online form and secure the responses of the students. The online form came with an Informed Consent Form (ICF), which specified the study rationale, objectives, and procedures. The ICF declared that the participation of respondents is entirely voluntary, and they can withdraw anytime without stating a valid reason. The response rate was monitored weekly to ensure adequate data to answer the research problems. The data collection lasted for one month.

Data Analysis. The data were organized and analyzed using the SPSS v25 following the suggested protocol of Hayes (2017). The PROCESS v3.5 was utilized to initiate mediation analysis to model the mediating role of EBAPS in the relationship between PSE and APP. Mediation analysis is a statistical method used for testing suppositional mechanisms through which an antecedent, X, might induce n outcome variable, Y, indirectly through the mediator, M (Baron & Kenny, 1986; Hayes, 2017). It quantifies the extent to which a mediating variable participates in the transmittance of a cause-and-effect relationship between independent and independent variables. The results generated a statistical model predicting APP, model summary information, and mediating effect.

3.0. Results and Discussion

Direct Effect of Physics Self-efficacy to Academic Performance in Physics

In this study, the direct and indirect effects of PSE on APP considering EBAPS as a mediator were used to generate linear regression models, which in turn were used to develop the statistical model predicting APP. The direct effect of PSE represented to the APP can be summarized using the equation . Likewise, the direct effect of PSE on EBAPS can be represented

using the equation . The equation, , represents APP estimation from EBAPS, where X is the independent variable PSE, Mi is the mediating variable EBAPS, and Y is the dependent variable APP. Figure 1 presents the statistical diagram explaining the APP of the respondents estimated by PSE and EBAPS. This model was developed from a simple mediation analysis using Hayes's (2017) PROCESS v3.5 path analysis. The figure shows that PSE significantly explains the EBAPS. This indicates that a one-unit change in PSE can institute a .0826-unit change in the EBAPS. Similarly, a one-unit change in EBAPS *(*, the model predicts a 3.8749-unit change in APP. On the other hand, PSE emerges as not a significant predictor of APP based on the study results since the result is not statistically different from zero based on lower and upper limits of class interval -0.1425 to 1.7500. These findings are based on the standardized coefficient and p-values computed from Table 2, assuming all other factors are held constant.

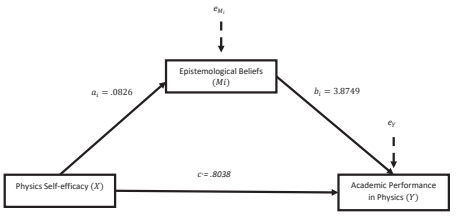

Figure 1. Statistical Model Predicting Students' Academic Performance in Physics

Table 1 shows the direct effect of PSE and EBAPS on APP using a regression approach. The direct effect quantifies the estimated difference in APP based on the one-unit change of PSE to EBAPS. It can be noted that the path coefficient of PSE to EBAPS is positive, suggesting that the higher self-efficacy in Physics learning translates to a more positive outlook about the nature of Physics. Likewise, a positive path coefficient was also computed for path EBAPS to APP, indicating that more desirable beliefs about the knowledge of Physics result in higher academic performance in Physics. The table further revealed that PSE can explain 11.2% variance in EBAPS, while 9.04% variance of APP can be explained in combination by PSE and EBAPS, holding other variables constant.

The study revealed that PSE did not emerge as a significant predictor of APP. This shows that self-efficacy in learning physics does not readily translate to higher academic performance. Considering the study results, the researcher infers that self-confidence about performing a certain activity is not enough to enhance the learners' academic achievement. This belief must be able to translate into actions with favorable outcomes. It can also be noted that the academic performance measured in this study is based on the grades they obtained in the previous grades. Thus, other factors, such as the grading system, teachers' standards, and environmental settings, may influence the current results. Nevertheless, the study indicates that an individual's belief about the ability to accomplish learning tasks in Physics is insufficient to develop the students' learning attainment. The teachers must also source out other determinants of the academic performance of the learners that contribute to the improvement of their grades.

This result is relevant to the results uncovered by Ahmed and Jabeen (2011); while self-efficacy was found to impact the perceived academic performance of the students, a weak association between the two variables was detected. This suggests that perceived academic performance has a weak dependency on learning self-efficacy. Talsma et al. (2019) argued that self-efficacy is not a self-fulfilling prophecy. The study described that self-efficacy beliefs can be imprecise, often resulting in under- or over-efficacious. It also explained that overrated self-efficacy among students may experience an adverse impact on both academic regulation and performance. On the other hand, numerous studies have established a significant relationship between self-efficacy and academic performance (Al-Abyadh & Abdel Azeem, 2022; Doménech-Betoret, 2017; Hayat et al., 2020; Köseoğlu, 2015; Nasir & Iqbal, 2019). Self-efficacy in learning has been considered a strong predictor of the student's academic performance. Given this, it can be inferred that a factor can transmit the effect of self-efficacy on academic performance in the study context. It follows that PSE can transmit its effect to APP through an intervening variable. Hence, mediation analysis was initiated, considering EBAPS as a mediator.

Table 1
Model Summary Information

		Consequent						
		M_i (EBAPS)				Y (APP)		
Antecedents		**Coeff.**	**SE**	**P**		**Coeff.**	**SE**	**P**
X (PSE)	a_i	.0826	.0364	.0240	**c'**	.8038	.4185	.0958
M_i (EBAPS)					b_i	3.8749	.6165	.0000
constant		2.0502	.1186	.0000		76.2663	2.0058	.0000
		R^2=0.112				*R^2=0.0904*		
		F=5.1319, p=.0240				*F=22.5042, p=.0000*		

Mediating Effect of Epistemological Beliefs between Self-efficacy and Academic Performance in Physics

Table 2 shows the mediating effect of EBAPS on the cause-and-effect relation between PSE and APP. It verifies that EBAPS can significantly mediate the relationship between PSE and APP. This indirect effect was computed to be statistically different from zero based on the bias-corrected bootstrap confidence interval using 5,000 samples, as shown by the lower and upper limits. The results suggest that EBAPS can transmit the effect of PSE to APP. It shows that higher confidence about their skills and ability to perform in a Physics classroom influences their belief in the truth and knowledge of Physics, which affects their academic performance. It clearly shows that EBAPS mediating effect of 0.3199. This indirect effect means that the respondents who differ by one unit in their PSE are estimated to vary by 0.3199 units on their APP.

Table 2
Mediating Effect of Epistemological Beliefs about Physical Science between Physics Self-efficacy and Academic Performance in Physics

Indirect Effect	Effect	SE	LLCI	ULCI
PSE→EBAPS→APP	0.3199	.1497	.0620	.6458

The present study uncovered that EBAPS emerged to mediate the relationship between PSE and APP. This indicates that students who reported higher PSE are inclined to have higher EBAPS, which tend to exert more effort to learn, eventually achieving a higher academic achievement. Kapucu and Bahçivan (2015) found a significant and positive association between self-efficacy in learning physics and scientific epistemological belief. Specifically, the study claimed that students who demonstrate more sophisticated beliefs about the source of knowledge and their justification for knowing have higher self-efficacy in learning physics. This indicates that students who are more self-efficacious in Physics learning produce a more sophisticated knowledge of the characteristics of knowledge and how knowledge is acquired in Physics. This, in turn, affects the academic performance in Physics grounded on epidemic beliefs. Panergayo et al. (2023) revealed that epistemological beliefs statistically determine the academic performance of the students. This shows that epistemological beliefs can be used as a basis for developing instructional materials to enhance students' performance. The design of instructional materials and classroom environment must emphasize the students' views about the nature of learning Physics and its structure.

In the same manner, Orlean and Palomar (2018) further argued that epistemological beliefs in Physics have a pivotal role in the cultivation of academic performance in the teaching and learning of Physics. The mediation model developed, as presented in Figure 1, shows how PSE can statistically predict APP through EBAPS. This provides salient inputs to reinventing the teaching and learning of Physics, crafting learning plans anchored on self-efficacy and epistemological beliefs, and designing classroom environments to address the low performance in the subject.

4.0. Conclusion

Enhancing academic performance in Physics is a long-term goal in science education. This prompted researchers to explore the factors affecting academic performance in Physics learning. While many studies identified self-efficacy and epistemological beliefs as significant determinants of students' achievement, a new structural model is needed to explain how these factors impact performance in Physics learning. Hence, this study performed a mediation analysis to understand the interrelationship among PSE, EBAPS, and APP. The study revealed that PSE does not directly affect APP but influences it through EBAPS. It can be concluded that EBAPS is a significant mediator in the cause-and-effect relationship between PSE and APP. It shows that higher confidence about their skills and ability to perform in a Physics classroom influences their belief in the truth and knowledge of Physics, which affects their academic performance.

5.0. Practical Value

In view of this, senior high school Physics teachers may examine the beliefs of the students about their capability and the subject to develop responsive interventions in enhancing their learning. Since beliefs are highly subjective, teachers must consider the social learning context and individual background of the students. This will provide an avenue to identify their strengths and weaknesses based on their beliefs. Likewise, senior high school administration should underscore the cultivation of motivation and persistence of the students in learning Physics as it is grounded on their self-efficacy and epistemological beliefs.

6.0. Limitations of the Findings

This study encountered several limitations to produce a generalizable result given the context of

the study. The selection of participants was through convenience sampling, which indicates that the target population has no equal chance of participating in the study. This also limits the collection of maximum data since there is no complete access to the whole research site, apart from the fact that the data-gathering period only lasted one month. The research instruments used were also self-reported surveys, which can be affected by the feelings and emotions of the respondents while answering the survey. Likewise, another perceived limitation was the collection of grades as a representation of academic performance in physics, which solely relies on the honesty of the students. Since the data were collected from different schools, teachers' influence on the students' grades was not considered. The researcher relied on the idea that the participating schools strictly follow the guidelines for the computation of the grades of the students in Physics as prescribed by the Department of Education (DepEd). The results could be more valid and reliable if a standardized test was used to determine the academic performance of the students.

7.0. Directions for Future Research

For future research directions, differences in students' SLES, EBAPS, and APP can be investigated in terms of demographic factors such as age, gender, socioeconomic status, and academic rank. Furthermore, demographic factors can also act as moderating variables, which will further uncover interesting statistical relationships on the variables under study. In light of the limitations of the study, qualitative research designs and methods can be conducted and employed respectively to gain more extensive information regarding their beliefs and their effect on academic performance.

8.0. Declaration of Conflict of Interest

The authors have no conflict of interest to declare.

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