RELATIONSHIPS AMONG HIGH SCHOOL STUDENTS' PHYSICS-RELATED SENSE OF BELONGING, PERSONAL EPISTEMOLOGIES, AND ACHIEVEMENT ACROSS SCHOOL TYPE, GRADE, AND GENDER

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ABSTRACT

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Abstract

This study explores the relationships among students' physics-related sense of belonging, personal epistemologies, and physics achievement (PA) across grade levels (9th-11th) and gender, specifically focusing on variations among school types: Anatolian High School (AHS) and Science-Oriented High School (SHS) students. The sample of the study was drawn by convenience sampling, including students from an AHS and a SHS in the Küçükçekmece district of Istanbul. The study participants included 529 (315 Female, 214 Male) high school students. The Physics-Related Personal Epistemology Questionnaire was administered to assess students' physics-related personal epistemologies (PPE) including five subdimensions (structure of knowledge, justification of knowledge, changeability of knowledge, source of knowledge, quick learning and effort) and the Students' Sense of Physics Belonging Survey was applied to assess students' sense of belonging to physics

(SoBP). The correlation analysis indicated that PA is consistently and positively associated with PPE across various grade levels and school types, particularly among tenth-grade students in AHS and male students in SHS. While PA showed a positive relationship with the sub-dimensions of PPE—most notably quality of learning QL—SoBP was moderately correlated with PA among certain male students in SHS. The Multivariate Analysis of Variance (MANOVA) further demonstrated significant effects of grade level, gender, and school type on key outcome variables, with notable differences in JK, and CK across grades. Males reported higher SoBP overall, whereas females tended to exhibit stronger SK, especially in SHS. Interaction effects emerged between grade level and school type for PA, and between gender and school type for CK.

Keywords: Comparative Study, Epistemic Cognition, Personal Epistemology, Physics Education, Sense of Belonging

ÖZ

OKUL TÜRÜ, SINIF DÜZEYİ VE CİNSİYET BAĞLAMINDA LİSE ÖĞRENCİLERİNİN FİZİKLE İLGİLİ AİDİYET DUYGUSU, KİŞİSEL EPİSTEMOLOJİLERİ VE FİZİK BAŞARILARI ARASINDAKİ İLİŞKİLER

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Tez Özeti

Bu tez çalışması, öğrencilerin fizikle ilişkili aidiyet duygusu, kişisel epistemolojileri ve fizik başarıları arasındaki ilişkiyi 9. 10. ve 11. sınıf düzeyleri ile cinsiyet açısından inceleyerek, özellikle Anadolu Lisesi (AL) ve Fen Lisesi (FL) öğrencileri arasında gözlenen farklılıklara odaklanmaktadır. Çalışmanın örneklemi, İstanbul'un Küçükçekmece ilçesindeki bir AL ve bir FL'deki öğrencilerden oluşmuş ve kolayda örnekleme yöntemiyle seçilmiştir. Araştırmaya toplam 529 (315 kız, 214 erkek) öğrenci katılmıştır. Öğrencilerin fizikle ilişkili kişisel epistemolojilerini değerlendirmek amacıyla, bilginin yapısı, bilginin gerekçelendirilmesi, bilginin değişebilirliği, bilginin kaynağı ve çaba sarf etme olmak üzere beş alt boyutu içeren 'Fizikle İlgili Kişisel Epistemoloji Anketi' uygulanmıştır. Ayrıca, öğrencilerin fizikle ilişkili aidiyet duygusunu belirlemek amacıyla 'Fizik Aidiyet Duygusu Anketi' kullanılmıştır. Korelasyon analizi, öğrencilerin fizik başarısının epitemolojileri arasında anlamlı bir ilişki olduğunu gösterirken, özellikle AL'deki

10. sınıf öğrencileri ve FL’deki erkek öğrenciler arasında bu ilişkinin daha belirgin olduğunu ortaya koymuştur. Fizik başarısı ile aidiyet duygusu arasında anlamlı bir ilişki bulunmamıştır. Epistemolojinin alt boyutları—özellikle çaba sarf etme—ile fizik başarısı arasında pozitif bir ilişki gözlenirken, aidiyet duygusuyla bazı FL’li erkek öğrencilerde ise orta düzeyde bir korelasyona sahiptir. Çok Değişkenli Varyans Analizi (MANOVA), temel değişkenler üzerinde önemli etkiler olduğunu ortaya koymuş; özellikle bilginin gerekçelendirilmesi ve bilginin değişebilirliği alt boyutlarında sınıflar arasında anlamlı farklılıklar saptanmıştır. Erkek öğrenciler genel olarak daha yüksek aidiyet duygusu bildirirken, özellikle FL’deki kız öğrencilerin bilginin yapısı boyutunda daha sofistike inaçlara sahip olduğu görülmektedir. Ayrıca, fizik başarısı üzerinde sınıf düzeyi ile okul türü arasında, bilginin değişebilirliği alt boyutu üzerinde ise cinsiyet ile okul türü arasında etkileşim etkileri ortaya çıkmıştır.

Anahtar Kelimeler: Karşılaştırmalı Çalışma, Epistemik Biliş, Kişisel Epistemoloji, Fizik Eğitimi, Ait Olma Hissi

To my students, whose unwavering strength I have always felt by my side, even when I stumbled and made mistakes, rising and learning together.

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ABBREVIATIONS

AHS : Anatolian High School

CFA : Confirmatory Factor Analysis

CK : Changeability of Knowledge

EQ : Equations in Physics

JK : Justification of Knowledge

MoNE : Ministry of National Education

PA : Physics Achievement

PI : Physics Identitity

PPE : Physics-Related Personal Epistemology

PPEQ : Physics-Related Personal Epistemology Questionnaire

QL : Quick Learning and Making Effort

SHS : Science Oriented High School

SKC : Coherent Structure of Knowledge

SKH : Hierarchical Structure of Knowledge

SOB : Sense of Belonging

SoBP : Sense of Physics Belonging

Source : Source of Knowledge

SPSS : Statistical Package for the Social Sciences

STEM : Science, Technology, Engineering and Mathematics

LIST OF SYMBOLS

SYMBOLS

% : Percentage

CHAPTER 1

INTRODUCTION

Physics and physics-related careers play a critical role in advancing science and technology. A comprehensive understanding of physics not only explains the basic principles behind many technological innovations and engineering encountered daily (Redish, 1994) but also fosters problem-solving, analytical thinking, and science process skills in scientific inquiry. The report, '*Physics in Demand: The Labour Market for Physics Skills in the UK and Ireland'* (Emsi Burning Glass, 2022), emphasizes a growing demand for physics expertise in positions not typically linked to the discipline. A strong understanding of physics is crucial in various sectors, such as healthcare, education, engineering, construction, and manufacturing, and there is an increasing demand for skilled professionals in fields like data science, software engineering, computer science, and quantitative analysis (Holgate, 2023). In this context, physics education is not just about learning facts about how the world works but about developing a mindset that lays the groundwork for students to excel in physics and all 'Science, Technology, Engineering, and Mathematics (STEM)' fields (Bao & Koenig, 2019).

Secondary education is pivotal in shaping students' academic trajectories, and students' attitudes toward science, interests, and career aspirations are primarily formed during this critical phase (Dare & Roehrig, 2016; Hazari et al., 2010). Notably, the physics course is crucial in guiding students toward careers in science and engineering (Hazari et al., 2013). Increasing high school students' interest in physics and their success in this field ensures the development of individuals who will contribute to future scientific and technological advancements (DeWitt & Archer, 2015). However, it is important to recognize that motivation often dwindles over time in educational programs. In the worst-case scenario, this decline may lead to students dropping out (Wild, 2023).

Beyond cognitive factors, non-cognitive social and interpersonal skills have been considered as catalysts that trigger cognitive capacities' emergence and development (Kautz et al., 2014). One factor that significantly impacts student learning and ‘academic achievement’ is the ‘personal epistemologies of the students’, which refers to their beliefs about the nature of knowledge (Hofer, 2012; Lodewyk, 2007). Several studies indicated that students' beliefs about knowledge and knowing in physics, in other words, their ‘physics-related personal epistemologies’ are related to their learning performance (Alpaslan et al., 2016; Özmen & Özdemir, 2024; Stathopoulou & Vosniadou, 2007; Yerdelen-Damar & Eryılmaz, 2021). Individuals have distinct methods of learning and comprehending information, and these methods can be influenced by factors such as culture, experience, and motivation (Hofer, 2012; Alpaslan, 2019).

On the other hand, students' perceptions of their educational environments and social factors, such as their SOB, play a decisive role in their ‘academic success’ (Eccles & Wigfield, 2002). Belongingness signifies not just a physical attachment but also a more profound and spiritual connection, helping to understand individuals' commitments to a community or environment and how these bonds shape their experiences (Ada et al., 2016). Because academic pursuits do not happen in isolation but instead involve intricate social interactions and connections, it is crucial to recognize and comprehend the impact of belonging on ‘academic achievement’ and continued effort (Lewis et al., 2016). Pittman and Richmond (2007) noted that students' SOB in formal education significantly influences their current ‘academic performance’ and psychological well-being, even when accounting for other demographic and relational factors.

Cwik and Singh (2022) provided comprehensive evidence that students' ‘sense of belonging in physics’ classes significantly impacts their overall course outcomes. Students with a strong SOB are likely to perform better and pursue future careers in physics and science. However, the findings also highlighted a gender gap, in which female students feel less of a SOB compared to their male peers. Stout et al. (2013) emphasize the gender disparity in the SOB, indicating that female students' diminished SOB adversely impacts their ‘academic performance’ in physics classes. Li and Singh (2023) also emphasize the significance of a feeling of ‘belonging’ in predicting students' ‘academic performance’ in physics. They noted a consistent gender gap that put women at a disadvantage in both their SOB and ‘academic achievement’ throughout the course.

The SOB, especially in high school, is crucial for encouraging students to pursue STEM fields, and creating an inclusive and supportive environment significantly impacts students' engagement and persistence in STEM subjects (Feser et al., 2024; Mulvey et al., 2022). Rainey et al. (2018) reported that those who choose to stay in the science field report a greater SOB than those who leave. Although existing literature has confirmed a strong connection between students' ‘academic success’ and their SOB, more detailed research is necessary to comprehend the underlying mechanisms of this relationship and its impact on student's classroom performance (Trujillo et al., 2014). While several studies related to the ‘sense of belonging in physics’ (SoBP) conducted with university students (e.g., Cwik & Singh, 2022; Li & Singh, 2023; Stout et al., 2013; Whitcomb et al., 2023), the focus may be directed on high school students to comprehend more about the construct of SOB. However, the field of physics experiences the most significant impact from the decrease in female students' interest and motivation (Alpaslan, 2019). Studies have found that girls may have lower confidence in their abilities in physics and may experience more barriers to success in the subject than boys, leading to a lower SOB (Marchand & Taasoobshirazi, 2013).

Moreover, Feser and his colleagues (2024) reported that SoBP in secondary education affects undergraduate physics students’ decisions related to dropping out of physics, and this impact is mediated by how connected they feel to the field of physics and their university. Therefore, differences in educational institutions may provide different learning environments, affecting students’ SOB.

In the context of Turkey, the Ministry of National Education (MoNE) (2017) sets the general objectives for secondary education institutions (e.g., Anatolian high school (AHS) and science-oriented high school (SHS)) which aim to provide students with a shared general culture at the upper-secondary level to prepare them for higher education, professions, life, and the workforce. AHSs are institutions designed to equip students for advanced education pathways that match their talents, aspirations, and accomplishments. In contrast, SHS focuses on training students specifically in science and mathematics with the goal of nurturing future scientists. These differences in educational objectives for high schools may influence students' experiences in physics classrooms, potentially leading to a divergence in the development of various affective constructs.

Among the existing research examining the differences in these schools, there are no direct studies specifically related to the SOB and 'epistemology'. However, when we look at other studies on affective factors, it was found that there was a positive correlation between 'epistemic cognition' and 'self-efficacy' (e.g., Kapucu & Bahçivan, 2015; Chen & Pajares, 2010). These findings suggest that 'sense of belonging' and 'epistemology' may similarly have an impact on students' 'academic achievement' and differences between schools. Therefore, this study aims to directly examine the role of a SOB and 'epistemology' on differences between schools by filling the gap in the literature in this field.

To summarize, students' academic performances are closely linked with affective constructs such as a SOB and 'personal epistemologies'. Accordingly, this study aimed to establish the relationship between high school students' SoBP, 'physics-related personal epistemologies' (PPE), and their 'physics achievement' (PA). The second objective of the current study is to compare high school students' SoBP and their PPE due to type of school (AHSvs. SHS), grade level, and gender.

1.1 Research Questions

In line with previous studies research, this study seeks to explore two variables that may affect high school students' achievement in physics: students' ‘personal epistemologies’ related to physics and their SoBP. In this context, the research questions of this study are as follows:

Main Research Question for Correlation Analysis

RQ1: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology among Anatolian and Science High School students in Küçükçekmece, İstanbul?’

Research Questions for Correlation Analysis by Group

RQ2: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for male students in Anatolian and Science High Schools in Küçükçekmece, İstanbul?’

RQ3: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for female students in Anatolian and Science High Schools in Küçükçekmece, İstanbul?’

RQ4: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 9th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul?’

RQ5: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 10th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul?’

RQ6: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 11th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul?’

RQ7: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for students in Anatolian High Schools in Küçükçekmece, İstanbul?’

RQ8: ‘Are there significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for students in Science High Schools in Küçükçekmece, İstanbul?’

RQ for Differences

Main Effect

RQ1: ‘Are there significant differences in the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—based on grade level, gender, and school type among Anatolian and Science High School students in Küçükçekmece, İstanbul?’

Specific Effects

RQ2: ‘Are there significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology across different grade levels among Anatolian and Science High School students in Küçükçekmece, İstanbul?’

RQ3: ‘Are there significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology between male and female students among Anatolian and Science High School students in Küçükçekmece, İstanbul?’

RQ4: ‘Are there significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology based on school type among Anatolian and Science High School students in Küçükçekmece, İstanbul?’

Interaction Effects

RQ5: ‘Do grade level and gender interact to influence the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul?'

RQ6: 'Do grade level and school type interact to influence the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul?'

RQ7: 'Do gender and school type interact to influence the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul?'

RQ8: 'Do grade level, gender, and school type interact in a three-way interaction to influence the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul?'

1.2 Significance of the Study

The majority of research on the 'sense of belonging in physics' courses has concentrated on university students and older age groups (e.g., Cwik & Singh, 2022; Hazari et al., 2020; Ladewig et al., 2020; Kang et al., 2023; Ladewig et al., 2023; Lewis et al., 2016; Whitcomb et al., 2023). One noteworthy aspect of this research is its specific focus on high school students. Examining students at the high school level is crucial before they make career decisions or transition to university. According to the results of this study, we also have a chance to locate where the specific changes occur in students' SOB by analyzing the data at different grade levels.

To comprehensively address the impact of students' engagement in school science classes on their personal epistemology within the school environment, it is necessary for science education to establish a link between cognitive (e.g., PA) and affective (e.g., SoBP) variables. Previous studies reported that students' sophisticated 'epistemological beliefs' positively correlate with 'academic achievement' (e.g., Alpaslan et al., 2016; Pamuk et al., 2017). High school students' conceptions of knowledge and its origins significantly impacted their performance in physics class (Alpaslan et al., 2016). Pamuk et al.'s (2017) study results showed that elementary school students' perceptions of the constructivist learning environment significantly predicted their performance in science (e.g., course grade). As AHSs and SHSs offer different learning environments and curricula in Turkey, students' achievement in science may differ. Accordingly, in this study, the primary goal is to investigate the strength of association between high school students' PPE, their SoBP, and their PA. These associations will be separately addressed by type of school (AHS vs SHS), grade level (9 to 11th), and gender to determine if any differences occur between groups.

The results will provide some opportunities for decision-makers to tailor educational policies and interventions that enhance students' SoBP and PPE. Through an analysis of the specific variables impacting student engagement and performance in different school types, grade levels, and gender groups, educational practitioners and policymakers can adopt targeted interventions to more effectively address the diverse needs of students. For instance, schools may develop programs that foster a more inclusive classroom environment, offer professional development for teachers to recognize and address students' affective needs, and design curricula that connect with students' personal interests and experiences in physics. Ultimately, these insights aim to improve academic outcomes, increase retention in physics courses, and encourage more students to pursue careers in the sciences.

The second aim of the study focuses more on individual differences among high school students, especially in terms of their epistemologies related to physics and their SoBP. In this context, particular focus was given to the variables of gender and grade level. Revealing the feelings of belonging of students studying physics in different types of schools and grade levels and how these feelings relate to ‘academic achievement’ can help educators and policymakers develop more effective teaching strategies and curricula.

Understanding possible variations in students' SOB and achievement in physics across genders can be an essential step in designing interventions to achieve gender equality. Such information can help to make necessary adjustments to increase female students' interest in STEM fields. How students approach and process knowledge can profoundly affect their learning processes, and this study reveals how students construct knowledge and how these constructions affect their ‘academic achievement’. In addition, exploring the effects of socio-cultural factors such as school type on student achievement can provide essential data to ensure equal opportunities in education.

1.3 Important Terms and Definitions

This study included the variables of sense of physics belonging, physics-related personal epistemology, and physics achievement.

Below are the definitions of these variables:

- The sense of physics belonging is a concept that encompasses how accepted, supported, and valued students feel in the course environment and the effects of these feelings on their ‘academic success’ and interactions with the physics course (Cwik & Singh, 2022; Whitcomb et al., 2023). The scores of the students’ sense of belonging to the physics course were obtained with the Sense of Physics Belonging Survey (Cwik & Singh, 2022).
- Physic-related personal epistemology involves individual's beliefs and understanding of the nature of knowledge and the process of learning within the field of physics (Özmen & Özdemir, 2024). High school students' epistemologies about physics were measured with the Physics-Related

Personal Epistemology Questionnaire (PPEQ) developed by Özmen and Özdemir (2019).

- Physics achievement refers to the level of proficiency or competence demonstrated by students based on their physics-related performance. The first written exam grades of the students, which were administered in their schools according to the school's own examination system and entered into the e-school system, were used.

CHAPTER 2

LITERATURE REVIEW

This chapter reviews the studies on both the ‘sense of belonging’ and ‘personal epistemology related to physics’. It includes the theoretical aspects of key concepts and studies regarding how a ‘sense of belonging’ is related to students' learning performance and career choices. The studies related to the nature of ‘physics-related personal epistemology’ and its relations to other variables are also reviewed.

2.1 Belonging

The concept of belonging has been acknowledged as a significant factor that has influenced human conduct for a long time (Lewis & Hodges, 2015). As outlined in Maslow's (1943) hierarchy of needs theory states that the first level focuses on satisfying essential physical and safety needs. Subsequently, individuals often seek deeper emotional and social connections, such as love, affection, and a ‘sense of belonging’ (SOB) At the heart of these needs lies the fundamental concept of being part of something greater: belonging. This involves feeling recognized as a valued part of a larger system or environment, which in turn motivates individuals to engage actively and contribute to the community (Hagerty et al., 1992). Literature suggests that a SOB is not just a fleeting sensation but has tangible impacts on an individual's well-being. Research indicates that a lack of belongingness can adversely affect an individual's mental and physical health (Dow-Fleisner et al., 2023; Foster et al., 2017).

Belonging extends beyond individual well-being as its effects are not merely superficial but deeply psychological. It plays a crucial role in building community, fostering mutual respect, and creating environments conducive to individual growth (Ma, 2003). Additionally, belongingness can affect the way individuals perceive and process information related to various aspects of social interactions (Baumeister & Leary, 1995). When individuals feel SOB, they are more likely to engage positively, make constructive contributions, and give importance to the well-being of society. On the other hand, not having SOB may contribute to experiencing loneliness, depression, and related physical physical ailments (Dutcher et al., 2022; Foster et al., 2017).

2.2 School Belonging

An individual's SOB significantly influences social adjustment and is a fundamental concept in academic environments. In education, ‘school belonging’ encompasses the genuine acceptance, appreciation, and acknowledgment of students by their peers, teachers, and the entire school community (Goodenow & Grady, 1993). According to Wilson et al. (2015), students who perceive themselves as essential members of their school community show greater commitment and involvement during classes. Furthermore, numerous studies have illustrated a correlation between a SOB and students' ‘academic success’ (Aker & Şahin, 2022; Anderman, 2002; Furrer & Skinner, 2003; Goodenow & Grady, 1993; OECD, 2013; Osterman, 2000; Stout et al., 2013).

In a significant study, Goodenow and Grady (1993) examined the relationship between ‘school belonging’, friends' values, and ‘academic motivation’ among urban adolescent students. The study utilized the ‘Psychological Sense of School Membership Scale (PSSM)’, an 18-item tool specifically designed for students in early and middle adolescence (Goodenow, 1993). The PSSM assesses perceptions of belonging through aspects such as personal acceptance, inclusion, and respect, featuring items like ‘Most teachers at this school are interested in me’ and ‘I feel like a real part of this school.’ It also includes elements of encouragement, for example, ‘People here notice when I’m good at something’ and ‘Other students in this school take my opinions seriously.' Each item was rated on a five-point Likert scale, and the mean of the responses was calculated to generate an overall scale score. With a Cronbach's α of 0.83 confirmed that the internal consistency reliability of the sample was robust.

The findings indicated that students' average scores on all scales were consistent across both schools and grade levels, with no significant differences detected. One notable and concerning outcome of the study was that, even with generally high levels of 'academic motivation', a significant number of students reported feeling a weak SOB. Students felt less assured that they were respected and valued by teachers and peers, that their friends valued 'academic success', or that being in school was worthwhile. Even though many students rated positively in terms of their SOB to school, alignment with friends' attitudes, and motivation, a notable number continued to have negative perceptions of school. Findings from the study indicated that 'school belonging' was closely linked to multiple aspects of motivation, such as success expectations, the importance of schoolwork, general motivation, and effort reported by students. Conversely, students' perceptions of their friends' academic values were less strongly correlated with these motivational outcomes. Importantly, the positive relationships between 'school belonging' and motivation-related measures persisted as statistically significant, even when accounting for the impact of friends' academic values. Additionally, the link between 'school belonging' and 'expectancy for success' appeared stronger in girls than in boys.

Korpershoek et al. (2019) conducted a meta-analysis study on the relationship between students' 'sense of school belonging' and their 'academic success'. Their comprehensive analysis covered eight years of research and examined how 'school belonging' influences secondary students' educational outcomes, interpersonal experiences, and psychological well-being across various cultural and national contexts. The meta-analysis encompassed studies published in English between 2000 and 2018 in peer-reviewed journals, sourced from online databases such as ERIC and PsycINFO. By examining the results of each study, the researchers utilized correlation coefficients to uncover the relationship between 'school belonging' and student outcomes. The study revealed a modest yet significant positive association between students' 'sense of school belonging' and their 'academic success', with those who felt a stronger connection to their school generally achieving higher grades. Furthermore, the study emphasized the equal impact of 'belonging to the school community' on middle and high school students. This highlights the crucial role of fostering a SOB in the educational environment during students' initial identity formation and academic journeys.

A study in China examining the correlation between students' SOB in school and their 'academic performance' during the transition to high school (Liu et al., 2011) presents findings that challenge commonly held beliefs in the field of educational research. The study discovered that neither the initial level of students' SOB to school nor its change over time significantly predicted 'academic achievement' during this transition period. These results suggest that while 'school belonging' is often considered essential for 'academic success' during the transition to high school, it may not have a direct or significant impact. The study's findings indicate a lack of a significant positive relationship between a student's SOB to the school and 'academic achievement' during this transition period, contradicting findings from other cultural and educational settings, which typically show a strong connection between a SOB and 'academic performance'. The data highlight the interplay of factors influencing 'academic achievement' and propose that the role of a 'sense of belonging' may vary across cultural, social, and educational contexts. This study underscores the necessity of re-evaluating the impact of a SOB on 'academic achievement' in different cultural contexts and emphasizes that this relationship is multifaceted.

Aker and Şahin (2022) conducted a study to explore the interconnectedness of academic burnout, students' SOB in their school, and 'academic success' among medical students. The cross-sectional study involved 601 students at the freshman, sophomore, and junior levels at a university in Samsun, Turkey. Data were collected through a comprehensive questionnaire covering sociodemographic details and two specific scales: the 'School Burnout Inventory' and the 'Psychological Sense of

School Membership Scale’. The latter, originally developed by Goodenow (1993) and adapted for Turkish culture by Alkan (2016), is an 18-item, five-point Likert-type scale where higher scores indicate a stronger ‘sense of school belonging’. The study's findings revealed a positive correlation between ‘school belonging’ and ‘academic achievement’, indicating that students' ‘academic performance’ improved as their SOB increased. Additionally, a stronger SOB was linked to reduced school burnout.

A cross-national study by Smith et al. (2022) focused on the correlation between senior secondary school students' attitudes toward physics courses and their ‘sense of school belonging’, considering gender differences. The study involved high school seniors from France, Italy, Lebanon, Norway, Portugal, Russia, Slovenia, Sweden, and the United States, totaling 24,380 students enrolled in advanced science or math courses. Data were collected from the ‘2015 Trends in International Mathematics and Science Study (TIMSS)’, specifically focusing on students taking advanced physics courses in grade 12. students’ SOB to school was assessed using the TIMSS non-cognitive scale, employing four Likert-type response options for each scale item. Multiple regression analyses were conducted to comprehend students' attitudes toward physics courses, with separate analyses performed for each country. The study also investigated the influence of gender, TIMSS physics performance scores, and parents' educational levels on students' perceptions of physics. The research findings revealed that students’ SOB to their school significantly predicts their interest and appreciation for physics. In most countries, a ‘sense of belonging’ was equally crucial as ‘academic achievement’. Notably, in Lebanon, the influence of school belonging was even more substantial than ‘academic performance’. This influence remained significant even after considering variables such as student's ‘academic performance’, parental education level, and gender. These results suggest that a student’s ‘sense of belonging’ to their learning environment can enhance their engagement with science subjects and the value they place on them. Students who feel unsafe at school or lack social support may be less likely to develop ‘interest and motivation’ in courses such as physics. The results also show the correlations between students' SOB to school and their 'interest in physics'. This correlation varies across different countries and genders. For example, in Norway and Sweden, male students' stronger SOB in school is associated with a greater interest in advanced physics. In France and Sweden, this SOB also correlates with perceiving advanced physics as more valuable. However, these effects tend to be less pronounced for female students compared to male students. Further research is needed to understand better how students of different genders, cultures, and family backgrounds are affected by this process. Table 2.1 presents a summary of the related studies.

Table 2.1 Studies related to the Sense of School Belonging

Study	Sample	Instrument	Key Findings
Goodenow and Grady (1993)	Urban adolescent students in early- and mid-adolescence	Psychological Sense of School Membership Scale (PSSM)	SOB positively correlated with motivation and effort, independent of friends' academic values. The relationship between SOB and success expectations was stronger among girls. Many students reported weak SOB despite high motivation. SOB scores were consistent across schools and grade levels, showing no significant differences. Despite positive ratings in SOB, motivation, and alignment with friends' attitudes, some students maintained negative perceptions of school.
Korpershoek et al. (2019)	Various secondary students from multiple cultural and national backgrounds	Meta-analysis of studies from online databases like ERIC and PsycINFO	The study found a modest but significant positive relationship between students' SOB and academic success. This relationship was equally significant for both middle and high school students. Furthermore, the findings emphasized the crucial role of fostering a SOB in educational environments, particularly during students' identity formation and academic journeys.
Liu et al. (2011)	567 Chinese high school students transitioning to high school	Quantitative surveys examining 'sense of belonging' and academic performance	They found no significant relationship between students' SOB and academic achievement during the high school transition, suggesting that cognitive factors may play a larger role in determining academic success during this period.

Table 2.1 (Cont'd)

Study	Sample	Instrument	Key Findings
Aker and Şahin (2022)	601 first-, second-, and third-year medical students at a university in Samsun, Turkey	School Burnout Inventory and Psychological Sense of School Membership Scale	Positive correlation between school belonging and academic achievement; stronger school belonging linked to reduced school burnout.
Smith et al. (2022)	24,380 senior secondary students from 9 countries (France, Italy, Lebanon, Norway, Portugal, Russia, Slovenia, Sweden, USA)	TIMSS 2015 non-cognitive scale for SOB; multiple regression analyses	SOB significantly predicts students' interest and appreciation for physics, with its impact comparable to academic achievement in most countries and even stronger in Lebanon. Male students in Norway and Sweden with stronger SOB show greater interest in physics, while in France and Sweden, SOB correlates with perceiving advanced physics as more valuable. However, these effects are less pronounced for female students. Additionally, unsafe school environments or lack of social support negatively affect students' interest and motivation in physics.

Recent studies have explored the complex relationship between students' SOB and their academic outcomes, offering diverse perspectives and findings. Goodenow and Grady (1993) demonstrated a strong correlation between SOB and academic motivation, highlighting its critical role in fostering success expectations and effort, particularly among female students. Similarly, Korpershoek et al. (2019) conducted a meta-analysis that revealed a modest but significant positive relationship between SOB and academic achievement across various educational settings and student groups. This analysis also connected SOB to improvements in motivational, social-emotional, and behavioral outcomes.

In contrast, Liu et al. (2011) found that SOB did not significantly predict academic achievement during the transition to high school in China. These findings emphasize the influence of cultural and contextual factors in determining the role of SOB in academic success. Expanding on this, Aker and Şahin (2022) examined medical students and observed that higher levels of SOB were linked to improved academic performance and reduced school burnout, underscoring the importance of SOB in higher education. Lastly, Smith et al. (2022) investigated SOB in relation to students' attitudes toward physics across nine countries. Their study highlighted that SOB significantly affects interest and appreciation for physics, with notable variations across gender and cultural contexts.

Existing studies demonstrate that SOB plays a vital role in shaping students' academic outcomes. While some research highlights its positive correlation with academic performance, others emphasize its broader influence on motivational, social-emotional, and behavioral factors. However, these studies also point to significant variations based on cultural, institutional, and individual differences, highlighting the complexity of this concept.

Understanding the multifaceted nature of SOB is crucial, as it extends beyond general academic success to influence students' engagement, attitudes, and perceptions across different educational contexts. In this study, the focus shifts toward exploring the intricate relationships between SOB, PPE, and PA. The following section, 'Sense of Belonging in Physics', delves into the specific role SOB plays within the context of physics education, drawing on previous research to provide a detailed understanding of this concept.

2.3 Sense of Belonging in Academic Domain: Physics

Lewis et al. (2016) defined 'academic belonging as the extent to which students subjectively perceive that they are valued, accepted, and legitimate members in their academic domain' (p.020110-2). They also pointed out that belonging can be assessed not only at the school level but also among peers in general. They emphasized that the specificity of the questions is crucial. Just as a SOB in school and academics is linked to overall 'academic success', belonging in specific domains is linked to outcomes in those specific areas (Lewis et al., 2016, p. 020110-3). The feeling of belonging among students in physics classes might be important in determining course results and impacting student determination and future career goals (Cwik & Singh, 2022).

The impact of students' SOB and 'academic achievement' is a significant area of research, particularly concerning gender differences (Lewis et al., 2016). Existing literature extensively explores the adverse effects of gender stereotypes and male-dominated educational environments on the SOB and 'academic success' of female physics students. Notably, the tendency of female students to disengage from physics education due to societal gender stereotypes and the detrimental effects of this situation on their SOB are crucial factors that hinder their academic accomplishments and career aspirations (Ladewig et al., 2020; Hazari et al., 2020; Li & Singh, 2021; Whitcomb et al., 2022; Cwik & Singh, 2022; Li & Singh, 2023; Santana & Singh, 2023; Bottomley et al., 2024).

A study by Ladewig et al. (2020) investigated the influence of stereotype threat experienced during the German Physics Olympiad on students' SOB within physics. This study is part of a larger project that assesses the factors influencing the success of students participating in science Olympiads in Germany. This research, involving students under the age of 20, revealed that female participants experienced lower levels of belonging than their male counterparts. By invitation, 282 students (30.3% participation rate) responded to the study (F:84, M:174, Not specified: 24). It was assumed that the participants had characteristics like those of the general Physics Olympiad students. The study evaluated participants' SOB to the field of physics, career goals, adoption of stereotypes, and other relevant characteristics. The SoBP was measured with a 15-item shortened and adapted version of the 'Sense of Belonging to Math Scale' (Good et al., 2012). Participants' expectations of a career in physics and their self-concept about physics were assessed using six items from the PISA questionnaire. Interest in physics was also included in the measurement. The findings revealed that fewer women participated in the Physics Olympiad than men. Additionally, women faced higher elimination rates in the advanced stages of the competition. The study showed that SOB of female students in physics is negatively affected by gender stereotypes. Female students, while showing interest and talent in physics, experienced a lesser SOB than their male peers. Girls' SOB decreased as they believed in gender stereotypes, but boys were not affected by this situation. The study highlighted that a SOB influenced students' aspirations to pursue physics at the university level and the importance they assign to the discipline, making it a crucial element in shaping their career decisions.

Emphasizing the significance of a SoBP, Hazari et al. (2020) conducted a study with undergraduate female physics students attending the 'American Physical Society's Women Physics Students' Conferences' in the United States. Survey data were collected from 1,422 female undergraduate physics majors that 223 were in their first year of university. The study focuses specifically on first-year and fourth/fifth-year students. The questionnaire consists of 23 questions designed to understand female physics students' thoughts about physics careers and physics identities, 3 of which are related to SOB. The questionnaire aimed to understand students' abilities in physics, whether they feel like physicists, their interest in physics courses, and how connected they feel to physics. The results showed that SoBP directly impacts physics identity, especially for final-year female students. This suggests that the importance of belonging to an academic discipline increases as they become more involved in the community. Moreover, while SOB influenced physics identity in senior students, it also directed the effect of the interest factor. For freshmen and seniors, SOB was found to move in tandem with performance/competence and recognition, meaning that feelings of belonging changed in parallel with these factors.

Li and Singh (2021) further highlighted the impact of the learning environment on students' motivation in physics courses, specifically focusing on first-year students from the engineering, science, and mathematics departments. The study explored how elements of the learning environment—such as SOB, 'peer interactions', and 'perceived recognition'—affect students' 'self-efficacy, interest, and identity in physics'. Motivational survey data were collected over two semesters from students taking an account-based Physics 1 course. A total of 1,203 students (F: 427 M: 776) were analyzed in the pooled data. The results revealed that SOB in the learning environment was the strongest determinant of ‘self-efficacy’ at the end of the semester and that ‘perceived recognition’ was the factor that most influenced physical identity. The researchers also found that variations in ‘peer interaction’ related to SOB and ‘perceived recognition’ explained a modest but significant percentage of the differences in motivational outcomes. The findings of the study reveal that SOB influences students' motivational beliefs in a calculus-based introductory physics course, with a particularly pronounced impact on 'self-efficacy' among female students.The differences in how male and female students perceive the learning environment made female students less motivated to learn.

The concept of SOB plays a crucial role in students' academic experiences, particularly in physics education, where it influences motivation and persistence. Whitcomb et al. (2022) conducted a study to explore how this sense evolves over time among different student groups, providing valuable insights into its dynamics. Whitcomb et al. (2022) investigated the variation in the development of students' SoBP over time across different student groups, including physics majors, non-physics majors, and PhD students. The study examined how physics majors' belonging progressed alongside factors such as ‘self-efficacy, interest, identity, perceived recognition, and peer interaction.’ In the first year, the survey included 123 physics majors and 3,591 non-physics students, most of whom were engineering students (70%), with the remainder from mathematics and chemistry departments. Physics courses were categorized based on the year of study, with first-year introductory courses labeled as ‘year 1’ and second-year modern physics courses as ‘year 2.’ Undergraduate and doctoral students were treated as distinct groups, with doctoral students serving as a comparative benchmark. Linear regression models were applied to assess the results concerning SoBP. The study found a slight decline in SoBP during the second year, attributed to the decrease in engineering students and the growing number of physics majors in the cohort. Additionally, the second year marked the lowest levels of belonging, linked to the challenges students faced in adapting to the rigor of advanced physics courses.

The relationship between students' ‘academic achievement’ in physics courses and their SOB stands out as an important issue in research in this field. In this direction, in a study conducted by Cwik and Singh (2022), the relationship between students’ SoBP course and their grades was examined. The research involved 814 students (36% male, 64% female) from a large public research university in the USA, all enrolled in an algebra-based physics course. A validated survey was administered at the start and end of the first semester to evaluate the SOB and its effect on grades. Adapted from earlier studies, the survey was revalidated using student interviews, exploratory and confirmatory factor analyses (EFA and CFA), Pearson correlation coefficients, and Cronbach’s alpha for reliability. The survey questions utilized a Likert scale. ‘Structural equation modeling (SEM)’ was employed to analyze the data and understand the relationship between a SOB and student grades, with gender as a variable. According to the SEM, students’ SOB plays a crucial role in forecasting their end-of-course grades in physics. The results indicated that female students had a lower SOB and grades than their male counterparts. Moreover, while males showed a significant increase in their SOB, females did not exhibit any significant change.

A new study examining students’ SoBP and the effect of this feeling on ‘academic achievement’ was added by Li and Singh (2023). This study examined SoBP and ‘academic achievement’ of male and female students taking physics courses at university. In 2018, a physics course for science and engineering students was organized with 4 hours of theoretical lectures and 1 hour of practical work per week. The research data were collected twice, at the beginning and end of the course, and 717 students participated. However, 533 students (F: 211 M: 322) who provided complete data at the beginning and the end of the course were included in the study. Most participants were from engineering (64.7%) and science faculties (32.6%), while the remaining belonged to other university faculties. The average age of the participants was 18.7 years, and most were between 18 and 19 years old. Study shows that female students tend to have higher high school GPAs compared to males. However, no significant difference was found in SAT mathematics scores between male and female students. The study found that female students' SAT math scores were similar to male students, but their SoBP and 'Force Concept Inventory (FCI)' test scores were lower than males. The level of understanding of physics concepts: FCI scores increased in female and male students during the course. However, at the end of the course, there was a decrease in SoBP for both genders. Female students scored lower on the FCI test than male students, but the gender difference in course grades was relatively small. The study reveals that although female students' course grades are similar to male students, their SoBP is lower on average. These findings suggest that the decline in female students' SoBP may be related to cognitive, emotional, and social factors. The role of gender difference in SoBP should continue to be investigated in more comprehensive and in-depth studies.

Santana and Singh (2023) conducted a qualitative study to examine the experiences of female students in physics departments, focusing on how gender inequalities shape their academic journeys. The researchers interviewed 16 undergraduate female students at a major U.S. research university, representing a significant portion of the women in the department. The study used semi-structured, empathetic interviews and hybrid coding methods to identify recurring themes related to gender-based challenges in physics education. The data were analyzed to identify themes related to discomfort and exclusion experiences caused by male peers and instructors. The results indicated that male-dominated environments led to feelings of isolation and discomfort among female students, negatively affecting their SOB and 'academic performance'. The findings showed that the male-dominated physics culture made female students feel excluded and reduced their motivation to succeed in the field. Moreover, the research indicated that the prevailing culture detrimentally influenced female students' achievements in physics courses and constrained their educational career goals.

Contrasting with the earlier studies (see Table 2.2) that highlight gender disparities affecting female students' SOB and 'well-being' in physics, Bottomley et al. (2024) presented different findings in their recent research conducted in the UK. This study involved 310 physics students (M: 205 and F: 105) across all years of study, representing 80% of the university's physics student population. Using questionnaires administered at the beginning of the academic year and analyzing the data through independent sample t-tests and hierarchical regression, the researchers examined the relationships between students' SoBP, their 'physics identity constructs, self-efficacy, and general well-being'. A hierarchical regression analysis was used to analyze the relationships between students' SOB, 'physics identity' (PI), and 'self-efficacy'. The results revealed that SoBP had a significant positive relationship with the well-being of male students, whereas no such relationship was found for female students. Interestingly, although there were gender differences in PI and 'self-efficacy'—with male and female students exhibiting different levels—the study found no significant gender differences regarding SoBP and overall well-being. This suggests that, in this context, female students did not experience a diminished SoBP or 'well-being'. This contrasts with previous research indicating that female students often feel isolated or less included in physics communities.

Table 2.2 Studies related to Sense of Belonging in Physics

Study	Sample	Instrument	Key Findings
Ladewig et al. (2020)	282 students (84 female, 174 male, 24 not specified) participating in the German Physics Olympiad	Adapted 15-item version of "Sense of Belonging to Math Scale"; PISA questionnaire items for career aspirations	Female students experienced lower levels of SOB compared to male peers. Gender stereotypes negatively impacted the SOB for females but not males. A stronger SOB positively influenced aspirations for physics careers.
Hazari et al. (2020)	1,422 female undergraduate physics majors (first-year and fourth/fifth-year students) from the United States	23-question survey, including 3 SOB-related items	SOB directly impacted physics identity, particularly for senior female students. SOB increased in importance as students progressed in their academic journey. SOB was found to vary by grade level, with senior students reporting a stronger relationship between SOB and physics identity compared to freshmen.

Table 2.2 (Cont'd)

Study	Sample	Instrument	Key Findings
Li and Singh (2021)	1,203 first-year engineering, science, and mathematics students (F: 427, M: 776)	Motivational survey over two semesters in a calculus-based Physics 1 course	SOB was the strongest determinant of self-efficacy at the end of the semester, particularly among female students. Peer interactions and perceived recognition were significant predictors of motivational outcomes. Female students perceived the learning environment differently, which reduced their motivation compared to male peers.
Whitcomb et al. (2022)	123 physics majors, 3,591 non-physics students (engineering, mathematics, and chemistry), and PhD students	Surveys on SOB, self-efficacy, interest, identity, recognition, and peer interaction	SOB slightly declined during the second year of physics education, attributed to the cohort composition shifting towards more physics majors and fewer engineering students. The second year marked the lowest SOB levels due to the challenges of adapting to advanced physics courses. SOB varied across groups, with doctoral students serving as a benchmark for comparison.
Cwik and Singh (2022)	814 students (M: 36%, F: 64%) in an algebra-based physics course at a public research university in the USA	Revalidated survey (EFA, CFA, Pearson correlations, Cronbach's alpha); Structural Equation Modeling	SOB significantly predicted end-of-course grades in physics, with gender as a key factor. Female students exhibited a lower SOB and lower grades compared to males. While males showed a significant increase in SOB during the semester, females did not show any significant change.
Li and Singh (2023)	533 students (F:211, M: 322) taking a physics course for science and engineering students in the USA	Force Concept Inventory; surveys administered twice during the course	SOB decreased for both genders by the end of the course, despite increases in FCI scores. Female students reported lower SOB and FCI scores than males, but course grades were similar. Gender differences in SOB may stem from cognitive, emotional, and social factors.
Santana and Singh (2023)	16 female undergraduate physics students at a major U.S. research university	Semi-structured empathetic interviews with hybrid coding	Male-dominated physics culture led to feelings of isolation and reduced motivation among female students, affecting their SOB and career aspirations.
Bottomley et al. (2024)	310 undergraduate physics students (M:205, F: 105) in the UK	Questionnaires SOB; Independent sample t-tests; Hierarchical regression	SOB positively correlated with the well-being of male students but not females. No significant gender differences were found in SOB or overall well-being, contrasting earlier studies. Gender differences were observed in PI and self-efficacy but not SOB.

SOB in physics education has been extensively studied, revealing its pivotal role in shaping students' motivation, persistence, and academic achievement. Across the literature, gender emerges as a key factor influencing SoBP, with numerous studies reporting disparities. For example, Ladewig et al. (2020) and Cwik and Singh (2022) demonstrated that female students consistently report lower SoBP than male students, often due to stereotypes and exclusionary practices within male-dominated physics environments. Santana and Singh (2023) further highlighted how cultural and social dynamics in physics departments exacerbate feelings of isolation among female students, negatively affecting both their SoBP and academic performance. However, contrasting findings from Bottomley et al. (2024) suggest that in certain contexts, gender differences in SoBP and well-being may be negligible, emphasizing the importance of the educational environment and institutional support in mitigating disparities.

The relationship between SOB and academic outcomes has also been a focus of research. Studies like those by Cwik and Singh (2022) and Li and Singh (2023) established that SoBP is a significant predictor of students' grades in physics, with gender differences playing a moderating role. While males often show improvements in SOB throughout their courses, females tend to experience stagnation or decline. Additionally, Whitcomb et al. (2022) revealed that SoBP is not static; it evolves over time, often declining as students progress into more advanced, rigorous physics courses. This finding underscores the challenges students face in maintaining a sense of community and inclusion as academic demands increase.

While these studies provide valuable insights, a significant gap exists in the literature regarding the high school age group. Most research focuses on university students, leaving the developmental and transitional period of high school largely unexplored. This is particularly critical, as high school is a formative stage where students make key decisions about their academic and career paths. It is during this period that students choose their future fields of study, and their experiences in physics can profoundly influence these decisions. High school students' SoBP is likely shaped by different factors compared to university students, such as their immediate school environment, teacher support, and peer dynamics.

This study addresses this critical gap by focusing on high school students and examining the interplay between their SoBP, academic achievement, and personal epistemology. By including students from diverse school types and grade levels, this research offers a comprehensive perspective on how belongingness in physics courses impacts students' academic trajectories at a pivotal stage in their lives. Moreover, by integrating the concept of personal epistemology, the study sheds light on how students' beliefs about knowledge and learning influence their SoBP and achievement. This work provides educators and policymakers with evidence-based strategies to foster inclusive and supportive learning environments, particularly for high school students, to nurture their engagement and success in physics.

2.4 Personal Epistemology

The study of epistemology examines 'the nature and justification of human knowledge' (Hofer & Pintrich, 1997, p.88). Epistemics uses ideas from the study of knowledge and provides ways to apply them to different areas of scientific and humanistic knowledge (Kelly, 2020). From this perspective, everyone has unique beliefs and understandings about knowledge shaped by the individual's education, experience, and cultural and social interactions, which is called personal epistemology. Researchers have studied how beliefs about knowledge and knowing develop over time and relate to other cognitive processes over sixty years (Hofer, 2016). Hofer and Pintrich (1997) recommended adopting the umbrella term 'personal epistemology' (PE) to align with philosophers' understanding of epistemology, which pertains to beliefs about knowledge and the process of knowing. The studies on PE, while lacking uniform terminology (e.g., epistemic beliefs, epistemic cognition), focus on the cognitive processes and convictions students hold about knowledge and understanding, specifically including the following: 'beliefs about the definition of knowledge, how knowledge is constructed, how knowledge is evaluated, where knowledge resides, and how knowing occurs' (Hofer, 2001, p.355). Later, Hofer (2016) defined epistemic cognition as 'a set of mental processes that involve the development and employment of one's conceptions of knowledge and knowing' (p.21).

Alternative conceptions of PE have evolved, beginning with holistic developmental models and advancing toward recognizing epistemological beliefs as a multidimensional construct. (Hofer, 2001, 2008; Lee et al., 2021a; Yang & Tsai, 2012). In the following sections, different phases of studies related to PE have been discussed.

2.4.1 Developmental Models

Perry's (1968, 1970) pioneering studies laid the foundation for understanding the stages of PE, encouraging further exploration in this area. According to these studies, individuals' epistemological views initially emerge as naive or dualistic approaches in which absolute truths are believed, usually divided into black and white. However, as individuals develop mentally and intellectually, their belief systems evolve into a relative and sophisticated perspective that recognizes more complex and contextual realities. This process involves a deeper understanding of the nature of knowledge and how it should be approached. Perry's framework initiated further research, leading scholars to expand the concept of personal epistemology (Baxter Magolda, 1987; Belenky et al., 1986). These researchers stated that the development of personal epistemology is often similar across different disciplines and is independent of a specific context. For this reason, researchers have continued examining PE by considering it an overarching and holistic construct.

Despite these foundational insights, further research exploring the relationship between PE and text comprehension has yielded mixed results. For instance, Ryan (1984) challenged the notion that epistemological beliefs are consistent across contexts. His studies on text comprehension revealed that individuals' views on knowledge could fluctuate significantly depending on the subject matter and situational factors. This evidence suggests a more complex and dynamic interplay between one's beliefs about knowledge and the specific contexts in which those beliefs are applied. Thus, PE may not always follow a straightforward, linear progression but exhibits a multifaceted nature that can adapt to varying scenarios.

Kuhn (1991) further developed this understanding by introducing a model that emphasizes the impact of general epistemological beliefs on individuals' cognitive processes, particularly in problem-solving. According to this model, people's capacity to reason and solve problems across different fields is shaped by their overarching beliefs about knowledge. This perspective suggests that individuals' epistemic frameworks influence their approach to complex, interdisciplinary issues, underlining the importance of developing sophisticated epistemological views.

Similarly, King and Kitchener's 'Reflective Judgment Model (RJM)' explored the progression of epistemic cognition by focusing on how individuals make judgments when confronted with uncertain or complex 'ill-structured' problems (King & Kitchener, 1994). The RJM posits that people's ability to conclude from incomplete information evolves through distinct stages, each reflecting a different epistemological perspective. This developmental process is closely tied to educational levels, providing educators with valuable insights into how to cultivate critical thinking skills. However, research has shown that even college graduates may not always reach the advanced levels of reflective judgment required to address complex adult issues effectively. A tool '(the Reflective Judgment Interview)' was designed to assess typical cognitive abilities, which could sometimes underestimate students' potential due to its challenging format. Encouragingly, when students received contextual feedback and support, they often demonstrated higher levels of reflective thinking. Nonetheless, there are still gaps in understanding how epistemic cognition develops across diverse demographic groups, suggesting that cultural and background factors may significantly influence reasoning approaches.

Furthermore, Kuhn and Weinstock (2002) discussed the need for a more explicit and consistent conceptual framework in studying PE. While many research programs agree on the general transition from absolutist or objectivist views to relativistic perspectives, there remained significant inconsistencies across various stage models. This lack of coherence has hindered progress, leading to confusion about the defining characteristics of each developmental stage. Kuhn and Weinstock proposed a more unified approach emphasizing the interaction between subjective and objective dimensions of knowledge. They argued that personal epistemology evolves through a progression from objectivism to subjectivism, eventually reaching a balanced integration of these perspectives. This adaptive nature calls for a more holistic understanding of how individuals' views on knowledge are shaped.

Early models, such as Perry's schema, provided the basis for understanding how individuals move from dualistic to more relativistic and nuanced perspectives. Subsequent research, including the models proposed by Kuhn (1991) and King and Kitchener (1994), has further illuminated the complex relationship between epistemological beliefs and cognitive development, particularly in problem-solving and reflective reasoning. However, as Ryan (1984) emphasized, the mixed results in studies on context-specific epistemology underline the need for a more refined and coherent framework. The contributions of Kuhn and Weinstock (2002) suggested a shift towards integrating the subjective and objective facets of knowledge, proposing a more unified model that accommodates the variability between contexts and individual experiences.

2.4.2 Epistemological Beliefs and Dimensionality

Schommer (1990) proposed a multifaceted approach emphasizing epistemological beliefs' complexity and variability in response to the evolving understanding of personal epistemology and challenged the assumptions of developmental models (Hofer, 2016). Schommer’s model consisted of five independent dimensions that she argued through different models. The structure of the model included the following dimensions: (i) ‘certain knowledge’ (temporal nature of knowledge vs its certainty), (ii) ‘simple knowledge’ (isolated concepts vs interconnected ones), (iii) ‘quick learning’ (learning occurs quickly vs incrementally), (iv) ‘innate ability’ (beliefs regarding the malleability of intelligence), and (v) ‘omniscient authority’ (perceptions about the definitive source of knowledge).

Consequently, researchers have developed instruments to measure these dimensions of students’ epistemological beliefs (Hofer, 2001). These tools have enabled a deeper exploration of how students perceive knowledge and learning, providing insights into educational strategies supporting more effective learning outcomes. In particular, the dimensions of ‘quick learning’ and ‘fixed ability’ have led to debates in general epistemology. Researchers have sought reliable ways to measure these constructs, considering the ongoing debates surrounding the dimensions of epistemological beliefs and their implications for education. Lee et al., 2021 contributed by providing an overview of various questionnaires and assessment tools designed explicitly for quantitatively evaluating epistemology in science education. The measurement tools most commonly used in research studies are recapitulated below.

(a) ***Scientific Epistemic Beliefs Questionnaire (Conley et al., 2004):*** It is the most widely used questionnaire. It comprises four sub-dimensions: ‘certainty of knowledge’, ‘source of knowledge’, ‘justification of knowledge’, and ‘development of knowledge’. It was developed for primary school students and applied to secondary and higher education students and prospective teachers.

(b) ***Colorado Learning Attitudes about Science Survey (Adams et al., 2006):*** This survey includes sub-dimensions such as ‘personal interest, real-world connection, problem-solving general, problem-solving confidence, problem-solving sophistication, sense-making/effort, conceptual understanding, and applied conceptual understanding’. It was generally used on higher education students.

(c) ***Scientific Epistemological Views Questionnaire (Tsai & Liu, 2005):*** This questionnaire examines five aspects of science: social interaction in science, the creative nature of science, theory-based research, cultural influences, and the variability of science. The questionnaire has often been used to assess higher education students' views on scientific knowledge.

(d) ***'Epistemological Beliefs Assessment for Physical Science Questionnaire' (Elby et al., 1997):*** It covers five sub-dimensions, such as 'structure of science knowledge, nature of knowing and learning, real-life applicability, evolving knowledge, and source of ability to learn.' It was applied to secondary school students and pre-service teachers.

(e) ***The Epistemological Beliefs Questionnaire (Schommer, 1990)*** comprises four sub-dimensions: 'simple knowledge, certain knowledge, fixed ability, and quick learning.' It was first developed for secondary school students and later used for primary school students.

(f) ***'Epistemic Belief Questionnaire (Kuhn et al., 2000)*** has three sub-dimensions: absolutists, pluralists, and evaluators. It targets many participants and is generally administered to higher education students and trainee teachers.

(g) ***Justification for Knowing Questionnaire (Bråten et al., 2013):*** This questionnaire includes three subscales: 'personal justification, justification by authority, and justification by multiple sources'. It was generally used on secondary school students.

Building on the framework established by Schommer's multidimensional model, subsequent research has explored how epistemological beliefs influence specific cognitive processes in learning contexts. The related studies are summarized in Table 2.3.

Table 2.3 Epistemological Beliefs and Dimensionality

Study	Sample	Instrument	Key Findings
Kardash and Howell (2000)	40 undergraduate students in an educational psychology course	Modified version of Schommer's Epistemological Beliefs Questionnaire	Epistemological beliefs about quick learning influenced cognitive processing; sophisticated beliefs led to better understanding and strategy use.
Qian and Alvermann (1995)	212 middle school students in grades 9 to 12 from a rural public high school	Adapted 53-item Epistemological Beliefs Questionnaire	Beliefs about simple-certain knowledge were significant predictors of conceptual learning; no relationship found with learned helplessness.
Schraw et al. (2002)	16 female graduate students in a reflective teaching practices course	Pre- and post-test questionnaires, essays, and interviews	Reflective practices increased awareness of personal beliefs; most participants retained stable beliefs, with minor shifts observed.
Conley et al. (2004)	187 fifth-grade students from 12 classrooms in the southwestern U.S.	26-item questionnaire on epistemological beliefs focusing on source, certainty, development, and justification of knowledge	Students developed more sophisticated beliefs about source and certainty of knowledge; SES and academic performance significantly influenced belief development.
Baytelman et al. (2020)	Theoretical study on dimensions of personal epistemology	Literature review and theoretical discussion	Dimensions of epistemological beliefs remain contentious but are essential for understanding knowledge acquisition and cognitive engagement.

For instance, Kardash and Howell (2000) examined how undergraduate students' epistemological and subject-specific beliefs influence how they make sense of and process (cognitively and strategically) a text about the relationship between HIV and AIDS. The study involved 40 undergraduate students (F: 27, M: 13) taking an educational psychology course. Most participants were Caucasian (83%), and their ages ranged from 19 to 59 years. Participants completed a modified version of Schommer's (1990) 'Epistemological Beliefs Questionnaire', focusing on beliefs about the 'certainty and structure of knowledge' and the acquisition rate. The results showed that 'epistemological beliefs', particularly about 'quick learning', significantly influenced cognitive processing. Students who recognized that learning was not quick or effortless demonstrated more use of cognitive processes and strategies, including building awareness and making semantic connections within the text. Participants who scored high on the ‘quick learning’ factor tended to use strategies to resolve ambiguous situations and make connections between different topics. However, the relationship between these strategies was not very strong; there was only a slight connection. Also, unexpectedly, having more advanced beliefs about the ‘certainty of knowledge’ was positively associated with misunderstanding or incorrectly processing text. This study suggested that undergraduate students with more sophisticated epistemological beliefs tend to engage in more reflection and in-depth study of the text, using various mental strategies to understand better and recall the text.

Similarly, extending this line of inquiry to younger students, Qian and Alvermann (1995) examined how middle school students' ‘epistemological beliefs’ influence their understanding of scientific concepts, particularly in the context of Newton's theory of motion. The study involved 212 students in grades 9 to 12 from a rural public high school in Georgia. The demographic makeup was predominantly European American (87%). The researchers adapted the 53-item ‘Epistemological Beliefs Questionnaire’ based on Schommer's study and focused on three factors identified through EFA: ‘simple-certain knowledge’, ‘quick learning’, and ‘innate ability’. They also assessed learned helplessness and administered an achievement test consisting of two subtests: ‘conceptual understanding’ and ‘application reasoning’. Canonical correlation analyses revealed that students' beliefs about ‘simple-certain knowledge’ were the most significant predictors of conceptual change learning, while their beliefs about ‘innate ability’ were the least influential. In the study, there was no significant relationship between ‘epistemological beliefs’ and learned helplessness, and these beliefs did not predict the type of prior knowledge that students had. Moreover, no notable interaction was found between prior knowledge type and epistemological beliefs concerning conceptual change learning. The findings underlined the importance of epistemological beliefs in students' ‘academic performance’, especially when faced with challenging tasks.

Epistemological beliefs about ‘simple-certain knowledge’ and ‘quick learning’ play a role in students' understanding and applying new scientific concepts.

Expanding the investigation of epistemological beliefs across diverse educational contexts, Schraw et al. (2002) examined how these beliefs and ontological perspectives influenced graduate students engaged in reflective teaching practices. A mixed-methods study conducted at a large university in Southern California focused on the beliefs of 16 female graduate students enrolled in a course titled 'The Study of Teaching.' The participants, who ranged in age from 20 to 41 years and had between 1 and 9 years of teaching experience, were studying for a master's degree and attended the course for two and a half hours per week for 15 weeks. The research examined two hypotheses: the first predicted that most students would retain stable beliefs over the semester; the second anticipated that engaging in action research would encourage reflection and enhance critical awareness of their personal beliefs regarding teaching practices. Data were collected through pre-and post-test questionnaires, essays, and end-of-semester interviews. The results showed that about 63% of the participants held consistent beliefs throughout the semester. Around 30 percent experienced minor changes in their beliefs, while only one participant experienced a significant change. Participation in action research and reflective activities positively affected all students by increasing their awareness and improving their ‘personal beliefs’. The researchers outlined four ways in which participatory action fostered deeper understanding: offering chances to experiment with new activities in real-world settings, creating a space for scrutinizing beliefs, bridging theory with practice, and promoting reflection on individual beliefs. In summary, while substantial shifts in worldviews were uncommon throughout the 15-week course, the training experiences still allowed teachers to understand their epistemological beliefs better. This awareness empowered them to make more informed decisions regarding curriculum and teaching methods in their classrooms.

Shifting the focus to younger learners, Conley et al. (2004) explored the development of ‘epistemological beliefs’ among elementary science students, examining how these beliefs evolve and the role of demographic factors such as gender, ethnicity, and socioeconomic status. 187 fifth-grade students (57% girls) from 12 different classrooms in the southwestern region of the United States took part in a nine-week interactive science curriculum. ‘Epistemological beliefs’ were assessed using a 26-item questionnaire adapted from Elder (2002) that focused on four dimensions: ‘source of knowledge’, ‘the certainty of knowledge’, ‘development of knowledge’, and ‘justification of knowledge’. Students rated the items on a 5-point Likert scale at two-time points during the science unit. The results showed that students developed more sophisticated beliefs about ‘the source and certainty of knowledge’ over time, trusted external authorities less, and accepted the provisional nature of knowledge more. However, no significant changes were observed in beliefs about the ‘development of knowledge’ and ‘justification of knowledge’. Gender and ethnicity were not significant predictors or moderators in developing epistemological beliefs. Conversely, socioeconomic status (SES) and ‘academic performance’ had pronounced effects, with students from lower SES backgrounds and those with lower ‘academic performance’ showing less developed epistemological beliefs. This indicates that while gender and ethnicity have minimal impact, SES and ‘academic success’ are key factors in shaping the epistemological beliefs of primary science students.

Despite the insights gained from previous studies, the dimensions of ‘epistemological beliefs’ remain a subject of debate. Baytelman et al. (2020), underscore the contentious nature of these dimensions, which are still vigorously discussed in personal epistemology. However, there is a compelling case for their relevance to personal epistemology. This argument is reinforced by their association with fundamental beliefs about ‘quick learning’ and cognitive abilities, which play a vital role in shaping how an individual approaches and engages in acquiring knowledge.

2.4.3 Alternative Approaches to Personal Epistemology

Alternative approaches to understanding personal epistemology have emerged as scholars seek to challenge traditional frameworks and offer new perspectives. In her study of epistemological development, Hofer (2001) criticized conventional perspectives on how individuals develop beliefs about knowledge and the process of knowing. Traditionally, stage models have dominated this field, proposing that beliefs about knowledge progress through distinct phases. However, Hofer (2001) introduced an alternative approach, suggesting that these beliefs may instead function as personal theories, which offer a more integrated and nuanced understanding of how individuals' perspectives on knowledge are organized. This shift from rigid stages to personal theories aims to provide deeper insight into how people develop their epistemological views. Hofer (2001) suggested that conceptualizing epistemological thinking as personal theories enhances our understanding of how individuals acquire and adjust their beliefs over time. Furthermore, she emphasizes the importance of considering disciplinary differences in these beliefs, as individuals tend to have specific epistemological assumptions depending on the academic field.

The model proposed by Hofer and Pintrich (1997) highlights two key dimensions: the nature of knowledge (including 'certainty' and 'simplicity') and the process of knowing (involving the 'source' and 'justification of knowledge'). While necessary for education, beliefs about learning and intelligence are not central to the epistemological domain. Hofer (2001) concluded that clarifying these dimensions helps refine the field of 'personal epistemology'.

Hammer and Elby (2002) criticized traditional models of personal epistemology, particularly questioning the consistency of beliefs across different contexts. They argue that while individuals may hold consistent beliefs within a specific context, such as a physics course, these beliefs may vary significantly in other settings, such as a psychology class or personal relationships. This suggests that epistemological beliefs are not fixed traits but somewhat more fluid and situational. Their model, which aligns with growing research in science education, proposes a more dynamic view of personal epistemology, where beliefs about knowledge and knowing are shaped by the specific context, including factors like the teacher's beliefs and instructional methods.

This situated approach highlighted the complexity of personal epistemology and called for further research to explore how beliefs change between disciplines and within different instances of the same subject, such as between two physics classes with differing pedagogical approaches. Hammer and Elby's (2002) perspective advanced the understanding of personal epistemology by integrating it with the concept of situated cognition, where the environment and social interactions influence knowledge and thinking.

2.4.4 Personal Epistemology and Achievement

Empirical research has significantly increased following developing instruments to measure personal epistemology (Hofer, 2016; Lee et al., 2021a). Early research predominantly used correlational methods to examine the links between 'epistemological beliefs' and a variety of other factors, such as a particular field of study (Hofer, 2000), 'educational achievement' (Schommer et al., 1997) and 'perceptions of teaching and learning' (Chan & Elliot, 2004). The meta-analytic review conducted by Greene et al. (2018) highlights the significance of examining how individual's perceptions of knowledge and learning impact their educational achievements across different subjects and contexts. This influence of epistemic cognition pertains to overall 'academic performance' and applies to specific disciplines and topics. The related studies are presented in Table 2.4.

Table 2.4 The Studies Related to Personal Epistemology and Achievement

Study	Sample	Instrument	Key Findings
Cano (2005)	Spanish secondary school students (middle, junior high, senior high)	Schommer's questionnaire (1990)	Epistemological beliefs influenced academic achievement directly.

Table 2.4 (Cont'd)

Study	Sample	Instrument	Key Findings
Greene et al. (2018)	Meta-analytic review across different subjects and contexts	Meta-analysis of studies on epistemic cognition and academic performance	Epistemic cognition was positively correlated with academic achievement; instruments focusing on development and justification of knowledge had higher correlations.
Kizilgunes et al. (2009)	507 female and 534 male sixth-grade students in Ankara	Epistemological Beliefs Questionnaire (modified by Conley et al. (2004))	Epistemological beliefs directly affect learning strategies and indirectly impact motivation and academic success; students believing knowledge is evolving show higher learning orientation.
Yerdelen-Damar and Eryılmaz (2021)	107 tenth-grade students from two public high schools	Maryland Physics Expectations Survey II and Force and Motion Conceptual Tests I & II	Metacognitive instruction enhances conceptual understanding in physics; higher initial epistemic cognition leads to greater gains.
Özmen and Özdemir (2019)	186 ninth-grade students (Female: 109, Male: 77) from an Anatolian Teacher High School in Ankara	Heat and Temperature Achievement Test, Personal Epistemology Questionnaire on Physics	Explicit epistemologically reinforced instruction significantly improved physics achievement and personal epistemologies compared to implicit and traditional methods.

Building on these findings, further research has explored the intricate relationships between 'epistemological beliefs' and other educational factors, such as 'achievement motivation' and learning strategies. In research conducted by Kizilgunes et al. (2009), a model was suggested to elucidate the connection between students' 'epistemological beliefs, achievement motivation, learning strategies, and academic success'. The study sampled 507 female and 534 male sixth-grade students from various public elementary schools in an Ankara district, with a mean age of 11.5 years. 'The Epistemological Beliefs Questionnaire,' modified by Conley et al. (2004), assessed students' beliefs about science in four dimensions: 'source, certainty, development, and justification'.

The results indicated a model in which epistemological beliefs directly affect learning strategies and indirectly impact both learning approaches and 'academic success' by influencing achievement motivation. More specifically, students who believed that knowledge is evolving '(i.e., development)' and transmitted by authority '(i.e., source)' were more 'self-efficacious', with a stronger orientation towards both learning and performance goals. This suggests that these students felt capable of learning and excelling in school and tended to study not only to demonstrate their abilities and achieve high grades but also to deepen their understanding.

Alternatively, the study indicated that students who prioritize the role of evidence and view knowledge as a result of reasoning, reflection, and experimentation '(justification)' generally reported lower 'self-efficacy' and a reduced focus on 'performance goals', often dedicating their studies to content mastery rather than external achievements. Furthermore, students who perceived knowledge as 'fixed and absolute (i.e., certainty)' showed lower levels of both learning and performance goal orientations. These results underscore that a learning-goal orientation was positively correlated with all dimensions of 'epistemological beliefs', except for the belief in 'certainty'.

Extending the exploration of epistemic cognition's impact on learning, another study investigated how metacognitive instruction, designed to enhance students' epistemic beliefs, influenced their understanding of complex scientific concepts such as force and motion (Yerdelen-Damar & Eryılmaz, 2021). The participants were 107 tenth-grade students (Female: 49, Male: 58) from two public high schools. The students, aged 15-17, had previously completed a ninth-grade physics course. A quasi-experimental design was used, with intact classes randomly assigned to an experimental or control group. The experimental group received inquiry-based teaching with metacognitive activities, while the control group received traditional instruction. 'The Force and Motion Conceptual Tests I and II' measured conceptual understanding, and the 'Maryland Physics Expectations Survey II' assessed epistemic cognition. Based on Hammer's epistemic dimensions, 'pieces vs. coherence, formulas vs. concepts, and authority vs. independence,' the survey included Likert and multiple-choice items. Results showed that metacognitive instruction significantly improved students' conceptual understanding compared to traditional teaching. A key finding was that students with higher initial epistemic cognition in the experimental group showed more significant gains. In contrast, in the control group, students' conceptual progress was unrelated to their initial epistemic cognition. In summary, metacognitive instruction considering students' epistemic beliefs can enhance students' understanding of complex physics concepts. The study highlights the importance of addressing epistemic cognition in instructional design for deeper learning.

Building on the evidence that epistemic cognition can shape students' learning outcomes, Özmen and Özdemir (2019) study further investigated how epistemologically reinforced instruction—whether explicit or implicit—can influence ninth-grade students' 'personal epistemology' and 'physics achievement'. The primary aim was to determine whether explicitly or implicitly integrating epistemological dimensions into teaching can enhance students' 'physics-related personal epistemologies' and performance in physics. The study involved 186 ninth-grade students (Female: 109, Male: 77) from an Anatolian Teacher High School in Ankara. A quasi-experimental design with matched pretest-posttest control groups was employed. The six available classes were randomly assigned to one of three teaching methods: explicit epistemologically reinforced instruction, implicit epistemologically reinforced instruction, or traditional instruction. Each method was applied to two classes, and the same teacher taught all classes to control for teacher-related variables. To evaluate the outcomes, 'the Heat and Temperature Achievement Test' was administered to measure students' 'physics achievement', and the 'Personal Epistemology Questionnaire on Physics' was used to assess changes in their epistemological understanding. MANCOVA was used to analyze data, controlling age, gender, previous physics grades, pre-existing 'personal epistemology', and pre-test 'physics achievement'. The findings indicate that explicit epistemologically reinforced instruction significantly improved students' 'physics achievement' and personal epistemologies compared to implicit instruction and traditional methods. This highlights the importance of making epistemological dimensions explicit in teaching to foster deeper understanding and engagement.

2.4.5 Personal Epistemology across Grade Levels

Research on personal epistemology has shown that these beliefs evolve as students move through different educational levels (e.g., Cano, 2005). Several studies, summarized in Table 2.5, have indicated that students' epistemological development influences their ‘academic performance’, learning strategies, and approaches to new information. Understanding how these beliefs shift across grade levels provides critical insights into learners' cognitive and educational development.

Table 2.5 The Comparative Studies on Personal Epistemology across Grade Levels

Study	Sample	Instrument	Key Findings
Cano (2005)	1600 Spanish students aged 12-20 across junior, senior, and senior high school levels	Epistemological Beliefs Questionnaire (Schommer, 1993), Learning Process Questionnaire (Barca, 1999)	Epistemological beliefs become more sophisticated with age, but deep learning approaches decrease; beliefs influence academic performance through learning approaches.
Fatma (2009)	1557 Turkish students in 6th, 8th, and 10th grades	26-item Epistemological Beliefs Questionnaire (Conley et al., 2004)	Grade level significantly impacts beliefs; 10th graders show more advanced beliefs about the non-absoluteness and evolution of knowledge.
Yenice (2015)	336 pre-service science teachers in western Turkey	Epistemological Beliefs Questionnaire (Schommer, 1990)	No significant variation in epistemological beliefs based on academic standing among pre-service science teachers.
Aydemir et al. (2013)	356 high school students (54% female) in 9th and 11th grades from Ankara	Epistemological Beliefs Questionnaire (Conley et al., 2004), adapted to Turkish by Ozkan (2008)	9th and 11th graders show varying levels of development across belief dimensions, with less developed beliefs about justification and development of knowledge.

To explore this developmental progression in more detail, Cano (2005) conducted a study that examined how ‘epistemological beliefs’ and learning approaches evolve among Spanish students across different educational levels. With a sample of approximately 1600 students (junior, senior, and senior high school students) aged between 12 and 20 years, the study used instruments like the ‘Epistemological Beliefs Questionnaire’ (Schommer, 1993) and the ‘Learning Process Questionnaire’ (Barca, 1999) to measure beliefs and approaches. The research reveals that as students progress through their studies, their epistemological beliefs become more sophisticated, but their tendency to adopt deep learning approaches decreases. The results showed that epistemological beliefs not only directly influence ‘academic performance’ but also indirectly through influencing learning approaches. It revealed a significant transformation in students’ epistemological views throughout their secondary education. Initially more naïve and simplistic, these beliefs became increasingly realistic and complex as students progressed through their schooling, reflecting a deeper and more nuanced understanding of knowledge.

Similarly, Fatma (2009) investigated how Turkish students' epistemological beliefs varied across grade levels, along with factors such as gender and field of study. This research involved 1,557 students from 6th, 8th, and 10th grades. The 26-item ‘Epistemological Beliefs Questionnaire’ developed by Conley et al. (2004) assessed the students' epistemological beliefs. The MANOVA analyses showed that grade level had a statistically significant effect on these beliefs. Eighth-grade students exhibited more advanced beliefs compared to sixth-grade students, recognizing that teachers and other experts do not solely construct knowledge and that multiple correct answers can exist. However, there were no significant differences between eighth and sixth graders regarding the necessity of experiments and data usage or the belief that scientific knowledge can evolve. Compared to sixth- and eighth-graders, tenth-grade students showed a higher level of advanced beliefs. Their perspective was that knowledge is not dictated by authority, that scientific knowledge is open to change, and that knowledge lacks absoluteness.

While previous studies have demonstrated significant differences in students' ‘epistemological beliefs’ across various grade levels, Yenice (2015) found that pre-service science teachers did not exhibit such variations based on their academic standing. The research involved 336 students from the education faculty of a public university located in western Turkey. Data were collected using the 'Epistemological Beliefs Questionnaire', developed by Schommer (1990). The findings revealed no significant differences in the participants' 'epistemological beliefs' based on their grade level.

Shifting the focus to younger students, Aydemir et al. (2013) conducted a study with high school students to examine how epistemological beliefs evolve during earlier stages of education, specifically in the 9th and 11th grades. The study included 356 students (54% female, 46% male) from three high schools in Çankaya, Ankara. Data were collected using the 'Epistemological Beliefs Questionnaire' developed by Conley et al. (2004) and adapted to Turkish by Ozkan (2008). A two-way MANOVA was conducted to assess the effects of grade level and gender on high school students' epistemological beliefs. The analyses revealed that both 9th and 11th-grade students held more sophisticated 'epistemological beliefs' regarding the development of knowledge, indicating that they believe knowledge can change over time. However, beliefs related to the source and certainty of knowledge were observed to be the least developed. Additionally, the study revealed that high school students exhibit varying levels of development across different dimensions of epistemological beliefs. While 11th-grade students showed more sophisticated beliefs regarding the 'source and certainty of knowledge', their beliefs about the 'justification' and 'development of knowledge' were less developed. These findings underscore the multidimensional nature of epistemological beliefs and suggest that their development may not follow a uniform pattern across all dimensions. This highlights the importance of considering the complexity and gradual progression of epistemological understanding throughout students' educational journeys. Overall, these findings showed that students' epistemological beliefs would change across various grade levels.

2.4.6 Personal Epistemology and Gender

Gender plays a significant role in shaping personal epistemology, as evidenced by various studies examining differences in how male and female learners perceive and justify knowledge (Topçu & Yılmaz-Tüzün, 2009; Kurt, 2009; Fatma, 2009; Chen & Pajares, 2010; Aydemir et al., 2013; Yenice, 2015). Understanding these differences not only aids in identifying diverse learning needs but also informs strategies to create more equitable educational environments. Previous studies have examined whether male and female students differ in their epistemic cognition, with varying findings across different contexts and educational levels. Table 2.6 provides a summary of comparative studies investigating gender-related differences in personal epistemology.

Table 2.6 Studies on Personal Epistemology and Gender

Study	Sample	Instrument	Key Findings
Topçu and Yılmaz-Tüzün (2009)	941 Turkish students in grades 4–8 from Ankara	Epistemological Beliefs Questionnaire (adapted by Topçu and Yılmaz-Tüzün (2007))	Female students in 4th and 5th grades had more sophisticated beliefs in innate ability and quick learning than males. From 6th to 8th grade, females showed more sophisticated beliefs in innate ability, quick learning.
Kurt (2009)	1557 Turkish students in 6th, 8th, and 10th grades from Çankaya, Ankara	Epistemological Beliefs Questionnaire (Conley et al., 2004, translated by Özkan, 2008)	Gender significantly influences epistemological beliefs; female students show more advanced beliefs about knowledge acquisition.
Fatma (2009)	1557 Turkish students in 6th, 8th, and 10th grades from Ankara	Epistemological Beliefs Questionnaire (Conley et al., 2004)	Girls exhibited more sophisticated beliefs and valued empirical evidence and scientific processes more than boys.

Table 2.6 (Cont'd)

Study	Sample	Instrument	Key Findings
Chen & Pajares (2010)	508 6th-grade science students from a public middle school in the southeastern U.S.	26-item scale developed by Elder (2002)	Epistemological beliefs significantly influence academic motivation and achievement, with no significant gender differences in beliefs.
Aydemir et al. (2013)	356 high school students (54% female, 46% male) in 9th and 11th grades from Ankara	Epistemological Beliefs Questionnaire (Conley et al., 2004), adapted to Turkish by Ozkan (2008)	Female students had more advanced beliefs about development and justification of knowledge, while males were more advanced in source and certainty.
Yenice (2015)	336 pre-service science teachers (248 female, 88 male) in western Turkey	Epistemological Beliefs Questionnaire, Metacognitive Views Questionnaire on the Nature of Science	Epistemological beliefs significantly predicted metacognitive views on the nature of science; no gender differences were found in beliefs, but females had more sophisticated views on accessing knowledge.

In 2007, a study was conducted to explore the relationships among epistemological beliefs, metacognitive abilities, and science achievement among Turkish students in grades 4–8, with gender and socioeconomic status (SES) considered as variables (Topçu & Yılmaz-Tüzün, 2009). The 'Epistemological Beliefs Questionnaire (EBQ),' originally developed by Schommer (1990) to assess beliefs in four sub-dimensions—'simple knowledge, certain knowledge, fixed ability, and quick learning'—was adapted into Turkish by Topçu and Yılmaz-Tüzün (2007) and administered to a sample of 941 students: 315 in the 4th and 5th grades and 626 in the 6th, 7th, and 8th grades in Ankara.

The study had two main focuses: (1) investigating how science achievement, metacognition, and epistemological beliefs are interrelated among 4th–5th graders and 6th–8th graders, and (2) exploring how gender and SES intersect with metacognition and epistemological beliefs. Results indicated that for younger students (grades 4–5), science achievement was primarily influenced by their metacognitive knowledge and regulatory skills, as well as beliefs in 'quick learning.'

In contrast, for older students (grades 6–8), science achievement was linked to metacognitive skills and beliefs in ‘innate ability’ alongside ‘quick learning.’

While metacognition was related to both gender and SES across groups, ‘epistemological beliefs’ were predominantly related to gender. For female students in particular, there was a notable correlation between their awareness of knowledge and their ability to manage their thinking across both grade groups. Female students also demonstrated more advanced beliefs in ‘quick learning’ and ‘innate ability.’ However, among 6th–8th graders, there was a decline in the tendency to rely on an all-knowing authority for knowledge, suggesting a developmental progression in their epistemological beliefs.

Kurt (2009) examined Turkish students' epistemological beliefs regarding gender, grade level, and fields of study. The study involved 1557 sixth, eighth, and 10th grade students in Çankaya, Ankara. To collect data, participants completed a demographic questionnaire about their gender, grade level, ‘academic performance’, and socioeconomic status. Additionally, they filled out the Epistemological Beliefs Questionnaire, which was originally created by Conley et al. (2004) and later translated into Turkish by Özkan (2008). This survey evaluates beliefs across four domains: origin, certainty, evolution, and justification. The dataset underwent a two-way multivariate analysis of variance (MANOVA) to evaluate the influence of gender and grade level on ‘epistemological beliefs’. The findings revealed that gender significantly influenced the students’ epistemological beliefs. It was discovered that female students possessed more advanced beliefs regarding the acquisition of knowledge compared to their male counterparts.

According to Fatma (2009), gender plays a crucial role in shaping the epistemological beliefs of Turkish students. The study surveyed 1,557 students from the 6th, 8th, and 10th grades in Ankara and used the 26-item ‘Epistemological Beliefs Questionnaire’ by Conley et al. (2004) to evaluate these beliefs. The results of the MANOVA indicated that girls exhibited more sophisticated beliefs than boys and were more inclined to think that experiments and data usage are essential for constructing knowledge. This difference suggests that female students value empirical evidence and scientific processes more than their male counterparts.

Chen and Pajares (2010) investigated the epistemological beliefs of 6th-grade science students and their effects on academic motivation and achievement. The study included 508 sixth-grade students (Female: 211 Male: 297) attending a public middle school in a large suburban area in the southeastern United States. Data were collected using a 73-item self-report questionnaire, and students' end-of-term grades in science courses were obtained from school records. Epistemological beliefs were assessed using a 26-item scale developed by Elder (2002), which encompasses four key dimensions: 'source', 'certainty', 'justification', and 'development'. The data were analyzed using path analysis. Descriptive statistics indicated no significant gender differences in students' epistemological beliefs. However, male students believe slightly more than female students that they can improve their abilities. Epistemological beliefs significantly influenced students' academic motivation and achievement.

Aydemir et al.'s (2013) study revealed that female students exhibited more sophisticated beliefs regarding the development and justification of knowledge. In contrast, male students displayed more advanced beliefs concerning the source and certainty of knowledge. Additionally, male students emphasized personal reasoning as a source of knowledge and believed that knowledge might not always be accurate.

Yenice (2015) investigated the connection between pre-service science teachers' 'epistemological beliefs' and their metacognitive views on the nature of science. The study involved 336 pre-service teachers enrolled in the primary science education program at a faculty of education in a state university in western Turkey. Among the participants, 248 were female (73.8%), and 88 were male (26.2%), ranging from first- to fourth-year students. The findings revealed that participants held positive 'epistemological beliefs' and metacognitive views about the nature of science. Additionally, it was found that 'epistemological beliefs' significantly predicted metacognitive perceptions concerning the nature of science. The study found no significant differences in 'epistemological beliefs' and metacognitive perceptions based on gender. The results indicated that participants had advanced 'epistemological beliefs' about the importance of effort in learning. However, their beliefs were less sophisticated regarding the idea that learning is based on 'innate ability' and the notion of a single, unchanging truth. It was also found that female students held more sophisticated beliefs about accessing knowledge than male students.

2.5 Personal Epistemology and Other Variables

No direct study has found a link between PPE and a SOB. For this reason, this section reviews some studies examining the relationship between 'personal epistemology' and some affective and cognitive variables. Related studies are recapitulated in Table 2.7.

Table 2.7 Studies Related to Association between Personal Epistemology and Other Variables

Study	Sample	Instrument	Key Findings
Burns et al. (2018) & Khine et al. (2020)	Meta-analysis across various domains	Various questionnaires and meta-analytic methods	Epistemological beliefs shape self-efficacy and self-concept across domains.
Hofer (1994)	438 college students majoring in mathematics	Epistemological Beliefs Survey	Advanced epistemological beliefs correlate with higher self-efficacy in mathematics.
Chen & Pajares (2010)	508 6th-grade science students in the southeastern U.S.	26-item scale developed by Elder (2002)	Advanced epistemological beliefs in science related to higher self-concept
Urhahne (2006)	High school students in science classes	Epistemological Beliefs and self-concept measurement tools	Epistemological beliefs and reflective thinking influence science identity through interest and competence/performance beliefs

Table 2.7 (Cont'd)

Study	Sample	Instrument	Key Findings
Guo et al. (2022)	High school students with translated Epistemological Beliefs Questionnaire (Conley et al., 2004)	Epistemological Beliefs Questionnaire (Conley et al., 2004), structural equation modeling	Reflective thinking bridges beliefs about knowledge and scientific self-identity; epistemological beliefs collectively influence science identity.
Ulu (2023)	1197 high school students using Physics-Related Personal Epistemology Questionnaire (PPEQ)	Physics-Related Personal Epistemology Questionnaire (PPEQ)	No gender difference in epistemic cognition; epistemic cognition, metacognition, and interest predict physics identity.

Numerous studies have repeatedly confirmed that one's beliefs about the nature of knowledge are significantly associated with 'self-efficacy' and 'self-concept'. For example, Burns et al. (2018) and Khine et al. (2020) emphasized how these epistemological beliefs shape individuals' perceptions of their abilities. Specifically, Hofer (1994) surveyed 438 college students majoring in mathematics. The findings revealed that students with more advanced epistemological beliefs demonstrated higher levels of 'self-efficacy'. These students exhibited greater confidence in their mathematical skills and believed in their ability to excel in mathematics.

Chen and Pajares (2010) observed that people with more nuanced beliefs about knowledge had greater confidence in their learning abilities. These individuals felt more assured in their capacity to complete learning tasks, indicating a strong connection between complex epistemologicies and heightened 'self-efficacy' in scientific settings.

Additionally, practical research indicates a positive link between ones' personal epistemology about scientific knowledge and their self-perception. Urhahne (2006) proved that students with more advanced epistemological views in science also possessed a higher self-concept. This suggests that their understanding of knowledge and learning methods positively influenced how they saw themselves in their science classes.

Moreover, Guo et al. (2022) explored the relationship between ‘epistemologies, reflective thinking, and science-identity’. The ‘Epistemological Beliefs Questionnaire’, developed by Conley et al. (2004), was translated and revised for this research. The study used ‘structural equation modeling’ to investigate the relationships between three constructs shaping science identity ‘(interest, competence/performance beliefs, and external recognition)’ and the overall impression of science identity. The results indicated that epistemological beliefs and reflective thinking has a significant effect on the interest and competence/performance beliefs that shape science identity.

The results also show that engaging in reflective thinking acts as a bridge between one's beliefs about knowledge and their scientific self-identity. Specifically, high school students' understanding of the nature of knowledge enhances their confidence in their abilities and interests through reflective thought processes. Additionally, epistemological beliefs, reflective thinking, competence/performance beliefs, interest, and external recognition collectively influence the overall impression of students’ science identity. The implications of these findings are profound. They suggest that fostering advanced epistemological beliefs can significantly enhance students’ ‘self-efficacy’ and self-concept across various academic domains.

Ulu (2023) examined the relationships among epistemic cognition, metacognition, recognition, physics ‘self-efficacy’, interest, and gender in high school students. Additionally, the study observed how these variables predict physics identity. The study included 1197 high school students, and data were collected using Likert-type scales. The Physics-Related Personal Epistemology Questionnaire (PPEQ) developed by Özmen and Özdemir (2019), which consists of 27 items, was used to measure epistemic cognition. Data were collected using a convenience sampling method and analyzed using descriptive statistics, correlation, and multiple regression analyses. The results reveal that no gender difference was observed in epistemic cognition.

CHAPTER 3

METHODOLOGY

3.1 Research Design

According to Fraenkel et al. (2012), correlational research is often considered a type of associational research that examines the relationships between two or more variables without trying to alter them. The study aimed to investigate the relationships between high school students' 'epistemic cognition about physics (PPE)', their 'sense of belonging to the physics course (SoBP)', and their success in the physics course. For this reason, the study was planned as a correlation study. It further explores the differences between school types, grade levels, and gender in terms of PPE and SoBP for which a causal-comparative research design was employed.

3.2 Population and Sample of the Study

The target population for this study consisted of high school students attending Science-Oriented High Schools (SHS) and Anatolian High Schools (AHS) in Istanbul, Turkey. These school types were selected due to their distinct educational orientations—SHS with a specialized focus on science education and AHS offering a broader, general education curriculum.

The accessible population was defined as students attending SHS and AHS schools located in the Küçükçekmece district of Istanbul. This region was chosen because Istanbul is a vast city that spans two continents, hosting a diverse range of public schools across its districts. Küçükçekmece, in particular, reflects this diversity, making it a suitable representative area for studying both SHS and AHS. Moreover, the presence of both school types in this region allows for meaningful comparative analysis, providing insights into the educational experiences across different types of high schools.

Convenience sampling strategy was employed to select one SHS and one AHS from the accessible population. This non-probability sampling method was chosen because the selected schools precisely met the criteria necessary for the study's comparative analysis. The selection criteria included: (1) the availability of grades 9, 10, and 11 students to provide a comprehensive view across different grade levels, (2) a clear representation of the educational orientations of SHS and AHS, ensuring that both types were adequately covered, and (3) the willingness of the schools to participate actively in the study, facilitating smooth data collection. These specific schools were chosen because they best fulfilled these requirements, thereby ensuring that the sample accurately reflected the intended comparison between SHS and AHS.

A total of 529 students (Female: 313 Male: 216) from 9th, 10th, and 11th grades, participated in the study voluntarily. The sample included 138 9th-grade, 65 10th-grade, and 49 11th-grade students from AHS and 62 9th-grade, 88 10th-grade, and 127 11th-grade students from SHS. 12^{th} grade students were deliberately excluded from the study because filling out questionnaires instead of classes may stress them out, and their motivation to participate was already low due to their focus on preparing for the university entrance exam.

3.3 Instruments

3.3.1 Demographic Information Form

In the first part of the study, a short ‘demographic questionnaire’ was designed to collect information from the students. The questionnaire collected information about gender, grade level, school type, and the scores (out of 100) obtained from the first physics class of the first semester in their own schools, which was conducted by their own teachers in accordance with the school regulations. The demographic form collected essential information from students in the 9th, 10th, and 11th grades, including gender (coded as 1 for female and 2 for male), their most recent physics grade (scored on a scale from 0 to 100), the type of school attended (i.e., Anatolian or Science-Oriented high school), and their current academic grade.

3.3.2 The Sense of Physics Belonging Survey

Students' sense of belonging in physics (SoBP) were assessed using the four-item of the survey developed by Cwik and Singh (2022), which was translated into Turkish by the researcher. The survey utilizes a 5-point Likert scale, where a score of 1 indicates "strongly disagree," and a score of 5 represents "strongly agree." The items designed to measure students' sense of belonging to the physics course are presented in Table 3.1. The second and fourth items were negatively coded for data analysis.

Table 3.1 Physics Belonging Items (Cwik & Singh 2022)

'I feel like I belong in this class.'
'I feel like an outsider in this class.'
'I feel comfortable in this class.'
'Sometimes, I worry that I do not belong in this class.'

A lower score on the survey indicates a weaker SoBP, whereas a higher score reflects a stronger SoBP. To ensure accurate interpretation, two of the survey items were reverse-coded. The factor loadings for the items were derived from a confirmatory factor analysis conducted on the full survey by Cwik and Singh (2022). The internal consistency of these items, assessed using Cronbach's α, was reported as .85, indicating satisfactory reliability. For this study, the SoBP survey's four-item reliability coefficient was calculated as Cronbach α=.87.

3.3.3 The Physics-Related Personal Epistemology Questionnaire

The Physics-Related Personal Epistemology Questionnaire (PPEQ), developed by Özmen and Özdemir (2019), was designed to evaluate students' epistemic cognition specifically within the domain of physics education. The development of PPEQ involved a comprehensive process to ensure it accurately captures various dimensions of students' awareness and reasoning about knowledge and learning in physics. The instrument employs a 5-point Likert scale (1 = ‘strongly disagree,’ 5 = ‘strongly agree’), enabling participants to express their level of agreement with statements reflecting their epistemic cognition in the context of physics.

Factor analyses were conducted to refine the PPEQ during its development and validation process. Initially, the instrument comprised 42 items distributed across six dimensions. However, the ‘Equations in Physics’ dimension was removed due to insufficient factor loadings, and the ‘Structure of Knowledge (SK)’ dimension was subdivided into two distinct dimensions: ‘Coherent Structure of Knowledge (SKC)’ and ‘Hierarchical Structure of Knowledge (SKH).’ Following these revisions, the updated version of PPEQ included 27 items. Explanation and excerpt item for each dimension from PPEQ is presented in Table 3.2.

Table 3.2 Excerpt Items of Dimensions in PPEQ (Özmen & Özdemir, 2019)

Dimension	Explanation	Example
SK	This dimension examines how self-knowledge in physics is developed. It assesses whether connections are made between existing and new knowledge and whether the resulting structure is coherent or incoherent, hierarchical or fragmented.	"I learn new information in physics by associating it with the knowledge I already have."
JK	This dimension investigates how individuals justify their physics knowledge, focusing on the use of logical reasoning, experimental evidence, and inquiries that arise from inconsistencies between prior knowledge and new information.	"The information given in the physics course may be correct, but I question whether this information is compatible (consistent) with my knowledge."

Table 3.3 (Cont'd)

Dimension	Explanation	Example
CK	This dimension explores whether selfknowledge is adaptable and capable of evolving or if it is viewed as rigid and unchanging.	"The knowledge I learned in physics class consists of physical facts that will never change; therefore, my own knowledge will not change either."
Source	This dimension examines whether individuals actively construct their own understanding or simply accept information from authoritative sources such as educators, textbooks, and scientists. It also acknowledges that even authoritative knowledge can be re-evaluated and reconstructed through critical thinking.	"I accept what my physics teacher tells me without questioning."
QL	This dimension evaluates whether the process of learning physics is gradual and deliberate, involving active construction of understanding, or if it is acquired quickly without extensive effort.	"I can understand the logic of the information given in the physics course when I spend enough time and study."

Reliability analyses revealed that Cronbach's alpha coefficients for the individual dimensions of PPEQ ranged from .71 to .83, indicating satisfactory internal consistency for each dimension. Additionally, the overall reliability for the full set of 27 items was calculated as .92, reflecting a high degree of reliability and ensuring the robustness of the instrument. For this study, PPEQ's reliability coefficient Cronbach's alpha was found .89. The reliability coefficients of the five sub-dimensions in the PPEQ are presented in Table 3.3.

Table 3.4 Reliability Coefficients of Subdimensions in the PPEQ

Sub-dimensions of PPEQ	Number of Items	Cronbach α
Structure of Knowledge (SK)	9	.72
Justification of Knowledge (JK)	5	.73
Changeability of Knowledge (CK)	5	.70
Source of Knowledge (Source)	4	.78
Quick Learning and Effort (QL)	4	.78
Entire – PPEQ	27	.89

3.3.4 Physics Achievement

The students' physics achievement scores were derived from their existing school exams, which were designed to assess their mastery of the physics curriculum objectives. The distribution of topics, learning objectives, question numbers, total scores, and difficulty levels for 9th grade physics exam is presented in the following Table 3.4.

Table 3.5 The Distribution of Questions According to Topic, Objective and Difficulty Levels in 9th Grade Physics Exam

Unit	Objective	SHS Question Numbers	Total Score	AHS Question Numbers	Total Score	Taxonomy & Difficulty Level
Introduction to Physics	9.1.3.1. Classifies physical quantities.	1, 2, 3, 4, 6, 8, 9	40	1, 2, 3, 4	40	Understanding (Low-Medium)
	9.1.4.1. Explains the importance of research centers for physics science.	5, 7	10	5, 6	20	Analysis (Medium-High)
Matter and Properties	9.2.1.1. Explains density by relating it to mass and volume.	10, 11, 12, 13	40	7, 8, 9	30	Analysis (Medium-High)
	9.2.1.2. Provides examples of situations where density is utilized in daily life for pure substances and mixtures.	14	10	10	10	Understanding (Low-Medium)

The 9th-grade physics exams for SHS and AHS are designed to maintain a consistent focus on foundational understanding, critical analysis, and practical application. Both exams allocate equal weight (40%) to Analysis (Medium-High) tasks, such as classifying physical quantities, ensuring a uniform evaluation of students' analytical skills. Understanding (Low-Medium) tasks, on the other hand, are weighted slightly differently—20% in SHS and 30% in AHS—to reflect the differing academic priorities of these school types without disrupting the overall balance. Application (Medium) tasks, which measure students' ability to relate theoretical knowledge to real-world contexts, are also emphasized, with SHS allocating 40% and AHS 30%.

These minor variations in score distribution are tailored to the specific educational objectives of each school type while preserving the overall alignment in structure, difficulty levels, and intended outcomes. The exams provide a standardized and comprehensive framework to fairly assess students' physics achievements.

Following the analysis of the 9th-grade physics exams, the structure and distribution of topics, learning objectives, and difficulty levels for the 10th-grade physics exams are presented in Table 3.5.

Table 3.6 The Distribution of Questions According to Topic, Objective and Difficulty Levels in 10th Grade Physics Exam

Unit	Objective	SHS Question Numbers	Total Score	AHS Question Numbers	Total Score	Taxonomy & Difficulty Level
Electricity and Magnetism	10.1.1.1. Explains the concepts of electric current, resistance, and potential difference.	1, 8, 9	20	1, 6, 11, 13	25	Understanding (Low-Medium)
	10.1.1.2. Analyzes the variables affecting the resistance of a solid conductor.	2, 3, 7	15	2, 4, 5	20	Analysis (Medium-High)
	10.1.2.1. Analyzes the relationship between electric current, resistance, and potential difference.	4, 5, 6, 10, 12, 13	45	3, 7, 8, 9, 10, 17, 18	35	Analysis (Medium-High)
	10.1.2.2. Explains the reasoning for connecting batteries in series and parallel.	11	10	14, 16	10	Understanding (Low-Medium)
	10.1.2.3. Relates the concepts of electrical energy and electrical power.	14	10	12, 15	10	Application (Medium)

Both exams exhibit a balanced structure, addressing both fundamental and advanced learning objectives. This design aims to enhance students' knowledge while fostering their analytical and application skills. The exams not only evaluate academic performance but also promote the development of problem-solving and critical thinking abilities.

While slight differences in point distribution reflect the distinct educational needs of each school type, the overall structure remains similar. Additionally, the distribution of taxonomy levels ensures a balance between lower and higher cognitive skills, aligning well with the students' abilities. This comprehensive structure provides a fair and equitable assessment framework for students across both school types.

Following this, the analysis of the 11th-grade physics exams is presented in Table 3.6, highlighting the distribution of topics, learning objectives, and difficulty levels for this grade.

Table 3.7 The Distribution of Questions According to Topic, Objective and Difficulty Levels in 11th Grade Physics Exam

Unit	Objective	SHS Question Numbers	Total Score	AHS Question Numbers	Total Score	Taxonomy & Difficulty Level
Force and Motion	11.1.1.1. Explains the properties of vectors.			1	5	Understanding (Low-Medium)
	11.1.1.3. Calculates the resultant of vectors using different methods.	1, 8, 11	20	2, 3, 4	15	Analysis (Medium-High)
	11.1.1.4. Draws components of a vector in a two-dimensional Cartesian coordinate system and calculates their magnitudes.			5	5	Analysis (Medium-High)
	11.1.2.1. Interprets the motion of two objects with constant velocity relative to each other.	7, 10	15	6, 7	15	Understanding (Low-Medium)

Table 3.6 (Cont'd)

Unit	Objective	SHS Question Numbers	Total Score	AHS Question Numbers	Total Score	Taxonomy & Difficulty Level
	11.1.2.3. Performs calculations related to relative motion.	3, 9	15	8, 9	20	Application (Medium)
	11.1.3.2. Performs calculations related to the motion of an object under the influence of a net force.	2, 3, 4, 5, 6	50	10, 11, 12, 13	40	Application (Medium)

The 11th-grade physics exams for SHS and AHS demonstrate a shared focus on foundational topics such as vectors, relative motion, and Newton's Laws of Motion. Both exams include Understanding (Low-Medium) tasks that address fundamental concepts like vector properties and motion interpretation. Additionally, Analysis (Medium-High) tasks are designed to challenge students with vector calculations, fostering critical thinking and problem-solving skills. Application (Medium) tasks, particularly those involving Newton's Laws, constitute a significant portion of both exams, with SHS allocating 50 points (40%) and AHS 40 points (40%) to these tasks.

While slight differences in point distribution reflect the unique academic priorities of SHS and AHS, the overall structure, difficulty levels, and learning objectives remain consistent. This alignment ensures that both exams provide a fair and comprehensive assessment framework, equitably measuring students' physics achievement across different school types.

The 9th, 10th, and 11th-grade physics exams demonstrate strong content validity, as they are closely aligned with the national physics curriculum. The exams comprehensively cover essential learning objectives and a range of cognitive skills, from foundational understanding to higher-order analysis and application, as evidenced in the detailed distribution tables. The inclusion of taxonomy levels ensures a balanced assessment of students' cognitive abilities, reflecting both lower and higher cognitive domains.

In terms of criterion-related evidence, the exams serve as standardized tools designed by educators to assess student performance within the curriculum framework. Although direct statistical validation was not conducted, the exams’ consistent structure, alignment with national standards, and widespread use in evaluating physics achievement provide indirect evidence supporting their validity. The similarity in point distribution, question types, and difficulty levels across SHS and AHS exams ensures fair and comparable assessments, which are critical for reliably measuring students' physics achievement across different school types.

Since the exams were pre-existing and not specifically tailored for this study, direct measures of reliability (e.g., Cronbach’s alpha) could not be calculated. However, the consistency in exam structure, question difficulty, and scoring across SHS and AHS exams suggests a degree of reliability. These factors contribute to the comparability and fairness of the assessment framework.

3.4 Procedure

Ethical approval for this study was obtained from the Middle East Technical University Human Research Ethics Committee, ensuring that all procedures complied with ethical standards prior to data collection. The data were collected through an online questionnaire hosted on Google Forms (Appendices A and B), which was distributed to students from a SHS and an AHS located in Küçükçekmece, Istanbul. School administrators were fully briefed about the study's objectives and procedures, and their formal permission was secured before initiating the data collection process.

The survey instrument comprised three sections: a demographic form, the SoBP survey, and the PPE questionnaire. Participants were explicitly informed about the voluntary nature of their participation and their right to withdraw from the study at any point without any consequences. The responses were automatically recorded in an Excel format through Google Forms. These data were then transferred to SPSS 27 software for systematic analysis, ensuring accuracy and consistency.

3.4.1 Data Collection Procedure

This study received approval from the Middle East Technical University Human Research Ethics Committee (0519-ODTUIAEK-2024). To initiate the study, official petitions were submitted to the administrations of the participating schools to secure the necessary permissions. Since the participants were under the age of 18, informed consent was obtained through signed parental consent forms ('Parent Consent Letter'). These forms provided detailed information about the study's aims, procedures, data usage, and participants' rights, including the right to withdraw from the study at any time without any negative consequences.

Following the approval process, announcements about the study were made in each class, and an online link to the questionnaire was shared with the students. The data collection period lasted for two weeks, during which periodic reminders were sent to encourage participation, ultimately resulting in a sample of 555 students out of 1365 invited students, yielding a response rate of approximately 40.7%. The online format of the questionnaire allowed participants to complete it at their convenience within the data collection period, as no specific time constraints were imposed.

Participation in the study was entirely voluntary. Students were clearly informed about the voluntary nature of their participation, the research objectives, the procedures involved, and their right to withdraw at any time without any adverse consequences.

3.5 Threats to Internal Validity

The internal validity of the correlational study is critically examined with insights from Fraenkel et al. (2012). This section addresses potential threats to validity and the measures taken to minimize them across various aspects such as instrumentation, location, subject characteristics, testing, and mortality.

3.5.1 Subject Characteristics

Fraenkel et al. (2012) highlight that when specific characteristics of individuals are correlated, additional factors such as age, gender, socioeconomic status, and students' beliefs may also account for the observed correlations. In this study, variables such as age (grade level) and gender were explicitly incorporated into the analysis, thereby mitigating the potential threat posed by these confounding factors to the validity of the findings. However, variables such as socioeconomic status and parental education level were not included in the analysis, which may still represent a potential threat to the validity of the results.

3.5.2 Location

Fraenkel et al. (2012) suggest that variations in data collection locations can lead to different interpretations of results. In this study, the survey was administered online, and efforts were made to mitigate this threat by instructing students to complete the survey in a comfortable and quiet environment, such as one resembling a library setting, to ensure optimal focus and comprehension of the questions.

The risk of location-based discrepancies was further minimized by employing an online data collection method over a two-week period. This extended timeframe provided participants with the flexibility to complete the questionnaire at a time and place most convenient for them, reducing pressure and encouraging higher participation rates. During the first week, students were allowed to respond independently, without time constraints, fostering a more relaxed and voluntary approach. In the second week, frequent announcements were made to remind students to complete the survey, further increasing the response rate.

3.5.3 Instrumentation

Data Collector Characteristics: Fraenkel et al. (2012) emphasize that the characteristics of data collectors, such as their gender, age, or ethnicity, can influence participants' responses, particularly in studies involving attitudinal or opinion-based instruments. In this study, the survey was administered online, eliminating the direct involvement of individual data collectors during the data collection process. This approach minimized the potential impact of data collector characteristics on the responses. Additionally, the survey link was shared with all participants under the same standardized instructions, ensuring that the data collection process was consistent and free from potential biases that might arise from variations in data collector characteristics. This method helped maintain the validity of the findings by reducing extraneous influences.

Data Collector Bias: In this study, the data collection process was conducted through online surveys, with all participants following the same standardized instructions. Therefore, the threat of data collector bias was eliminated. Since the surveys were completed automatically, there was no possibility for individual data collectors to intervene or influence the results.

Additionally, while the fact that the data collector is a physics teacher might have influenced the responses in a face-to-face setting, the online format effectively mitigated this potential bias. This approach addressed both *Data Collector Bias* and *Data Collector Characteristics*, ensuring that the data collection process remained neutral and unaffected by such factors.

3.5.4 Testing

In correlational studies, completing the first instrument may influence how participants respond to subsequent instruments (Fraenkel et al., 2012). To address this potential bias, all questionnaires in this study were administered online via Google Forms and completed by participants in a standardized order. Each instrument was presented independently, and participants were explicitly informed that the tools served different purposes and were unrelated to each other.

3.5.5 Mortality

Conducting the research online enabled participants to engage from any location with internet access, eliminating physical barriers to participation. Since the data was collected online, the risk of losing participants due to physical absence (common in face-to-face studies where participants might miss sessions) was almost eliminated. Participants could participate in the survey within two weeks at the time that suits them best.

3.6 Ethical Considerations

This study was reviewed and approved by the Middle East Technical University Human Research Ethics Committee. Given that the participants were under the age of 18, informed consent forms were obtained from their parents or legal guardians prior to participation. These consent forms were duly filled out and signed by the families to ensure their agreement and understanding of the study. Participation in the study was entirely voluntary, and participants were informed that they could withdraw at any time without any negative consequences. To maintain confidentiality, all collected data were anonymized and accessible only to the research team. Additionally, all procedures adhered to the ethical guidelines and standards set forth by the committee to protect the rights and well-being of the participants.

3.7 Data Analyses

The data gathered from the participants via Google Form including demographic information, PPEQ and SoBP was converted to Microsoft Excel file. Later, the data were entered to IBM SPSS Statistics 25 program. Finally, the related variables were formed and analyses of the data were conducted.

Initially, missing data and outlier analyses was administered for data cleaning. Normality assumption was analyzed via Kolmogorov-Smirnov test and skewness and kurtosis statistics. Accordingly, the reliability of the PPEQ and SoBP scales are tested via Spearman-Rank test. Descriptive statistics were utilized to summarize the participants' scores on the Sense of Belonging to Physics survey, PPEQ, and their first physics exam scores from the fall semester. The reliability of each instrument was assessed to confirm internal consistency, and correlations among the variables were analyzed to explore potential relationships.

For hypothesis testing, Multivariate Analysis of Variances (MANOVA) and post-hoc analysis was performed.

3.8 Descriptive Analyses of Non-Participants

In addition to analyzing data from participants, descriptive statistics and comparisons were conducted for non-participants to provide a comprehensive understanding of the sample and assess potential non-response bias. Out of the 1365 students invited to participate, 810 students did not complete the survey, resulting in a non-response rate of approximately 59.3%.

To compare participants' and non-participants' physics achievement, independent-sample t-tests were performed for various subgroups.

- Anatolian High School (AHS): An independent-sample t-test revealed a statistically significant difference in physics achievement between participants (N=252, *M* = 69.46, *SD* = 15.14) and non-participants (N= 472, *M* = 65.64, *SD* = 15.96); $t(733) = -3.175$, $p = .002$ (two-tailed). The effect size measured by Cohen's d was .25 indicating a small effect (Cohen, 1988).
- Science High School (SHS): A statistically significant difference was also observed between participants (N=277, *M* = 69.35, *SD* = 17.27) and non-participants (N=315, *M* = 64.88, *SD* = 18.40); $t(605) = -3.079$, $p = .002$ (two-tailed). The effect size measured by Cohen's d was .25 indicating a small effect (Cohen, 1988).
- Male Students: A significant difference in physics scores was found between male participants (N= 214, *M* = 70.87, *SD* = 16.47) and male non-participants (N= 400, *M* = 64.51, *SD* = 17.71); $t(623) = -4.42$, $p < .001$ (two-tailed). The effect size measured by Cohen's d was .37 indicating a small effect (Cohen, 1988).
- Female Students: No statistically significant difference was found between female participants (N= 315, *M* = 68.41, *SD* = 16.10) and female non-participants (N=387, *M* = 66.18, *SD* = 16.15); $t(715) = -1.839$, $p = .066$ (two-tailed). The effect size measured by Cohen's d was .13 indicating a small effect (Cohen, 1988).

Although the analyses indicated that higher-achieving students were more likely to complete the survey, the observed differences in physics scores were statistically significant but practically small. These findings suggested that the potential impact of non-response bias on the study's conclusions is minimal.

3.9 Power Analysis

The significance level of the study (α) was set to .05 which is commonly used value in education literature. Minimum desired power value was set to .80 that was recommended by Hinkle, Wiersma and Jurs (2003). For the current study, estimated sample size for the desired power value was calculated by using G power program.

The sample size analysis was conducted using the MANOVA (Multivariate Analysis of Variance) special effects and interactions method, accompanied by a power analysis of the type "A priori: Compute required sample size – given α, power, and effect size," performed using the G*Power program. The alpha error probability (α err prob) was set at 5%, indicating that the acceptable likelihood of false positive results was limited to 5%. According to Cohen's (1988) guideline, the effect size parameters for eta-square (η^2) interpreted as "small," "medium," and "large," for .01, .06 and .14 respectively. As G*Power computes analysis on $f^2(V)$, eta-square value is converted to f^2 by following equation:

$$f^2 = \frac{\eta^2}{1 - \eta^2}$$

For this study, the effect size ($f^2(V)$) was set at .0638, representing medium effect size, which reflects the magnitude of the independent variables' influence on the dependent variables.

The analysis involved a total of 12 groups, derived from 2 (school type) × 3 (school level) × 2 (gender) factorial design, focusing on the combinations of independent variables or comparisons among different groups. Based on these calculations, the minimum required sample size to achieve the desired statistical power for the MANOVA analysis was determined to be 85 participants. In the current study, total sample size was 529, the calculated power was found .99.

3.10 Unit of Analysis

Each student served as the unit of analysis in this study, while each study class served as the comparison unit. To achieve independence of observation for data collection, students were not permitted to communicate with one another during the test.

3.11 Assumptions and Limitations

The assumption of this study is:

- Participants of the study completed all data collection instruments consciously and truthfully.

The limitation of the study is:

- The results of the study are limited to ninth, tenth and eleventh grade students at AHS and SHS.

CHAPTER 4

RESULTS

This chapter consists of six sections that are associated to the study's findings. Data cleaning and missing data analysis are summed up in the first section. Then, outlier analysis results are presented. in the second section. The examination of the descriptive statistics of the variable scores in this study is included in the third section. The fourth section then presents the findings of correlational analysis and fifth section conitnues with the results of the inferential statistics. The last section presents a summary of the results obtained.

4.1 Data Cleaning and Missing Data Analysis

In both schools, there were 1365 students in total (SHS; N = 613, AHS; N = 752). Five hundered fifty five students had completed the test. To ensure the integrity of the dataset and enhance the validity of the analysis, data cleaning procedures were conducted. Initially, the data obtained from a total of 565 participants were examined, and records from 10 participants identified as containing duplicates or missing data were removed from the dataset. As a result of this process, a total of 555 valid data sets were obtained for analysis.

4.2 Outlier Analysis

Boxplot analyses revealed 25 outliers in the dataset. These outliers were removed to improve normality and reduce the impact of extreme values. Boxplots for dependent variables are given in Figure 4.1After removing these outliers, the final sample size was reduced to 530, which supports the robustness of the data for MANOVA analysis.

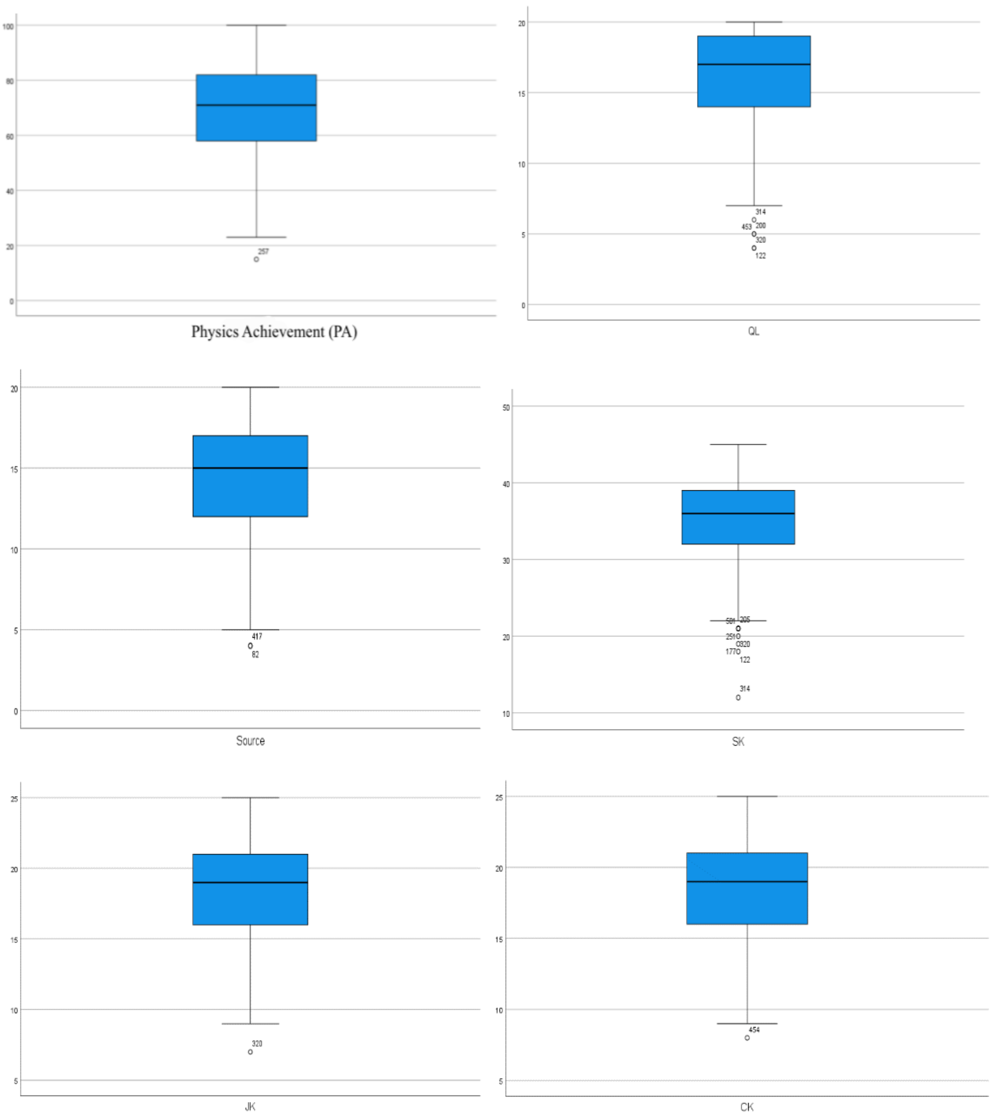


Figure 4.1 Boxplots for PA Scores, QL, Source, SK, JK, and CK variables

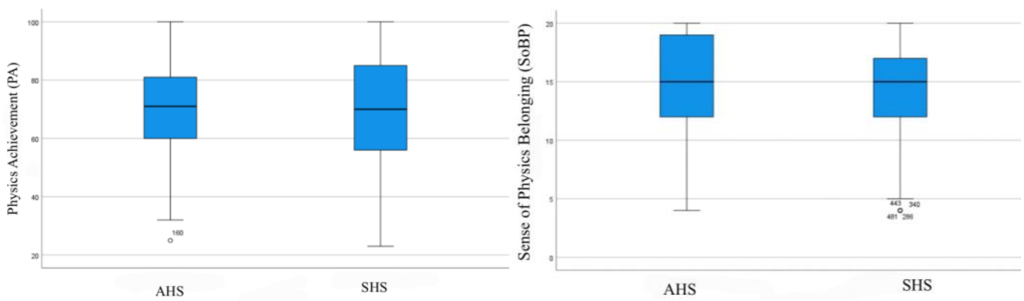


Figure 4.2 Boxplots for PA and SoBP Scores across Type of School

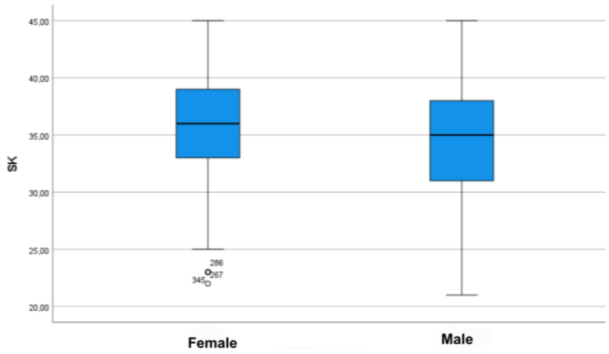


Figure 4.3 Boxplot for SK Scores Due to Gender

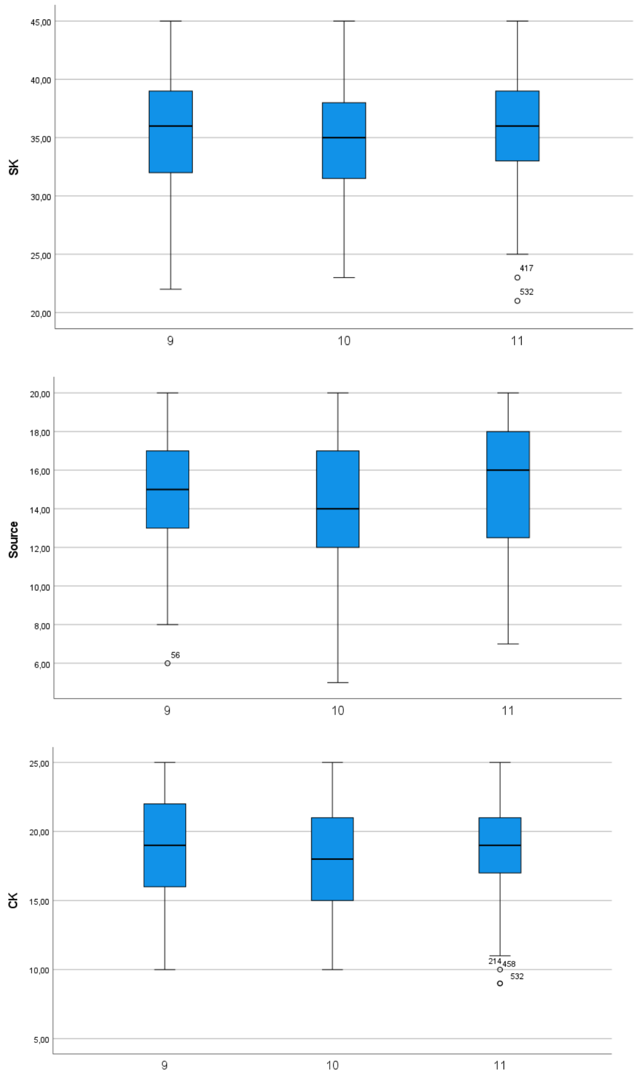


Figure 4.4 Boxplot of SK, Source, and CK Scores Across Grade Levels

The Mahalanobis distances were analyzed to identify potential multivariate outliers in the dataset. The highest Mahalanobis distance observed was 24.893, with a mean of 6.987 (SD = 4.080). Using the chi-square distribution table, the critical value for Mahalanobis distance at df = 7 (degrees of freedom corresponding to the number of independent variables) and p = 0.001 is approximately 24.32.

One observation exceeded this critical threshold (Mahalanobis distance = 24.893) and was flagged as a potential multivariate outlier. Upon review, this observation was removed from the dataset to ensure the robustness of the multivariate analysis. After removing this outlier, the dataset was re-evaluated, and the final sample size was reduced to 529. This adjustment strengthens the validity of the analysis by minimizing the potential influence of extreme multivariate outliers.

As a result, 529 students from AHS (N = 252) and SHS (N = 277) participated in the study, resulting in a response rate of approximately 38.7%. 59.17% of the participants were female (N = 313), and 40.83% were male (N = 216). The number of female students was greater than male students in general, except for 9th-grade SHS students. The gender distribution due to type of school and grade levels is given in Table 4.1.

Table 4.1 Gender Distribution by Grade Levels in AHS and SHS

Type of School	Grade Level	Gender	*N*	Percentage (%)
AHS	9	F	93	17.58
		M	45	8.51
	10	F	45	8.51
		M	20	3.78
	11	F	34	6.43
		M	15	2.84
SHS	9	F	28	5.29
		M	34	6.43
	10	F	45	8.51
		M	43	8.13
	11	F	70	13.23
		M	57	10.76
		Total	529	100

Note: F: Female, M: Male

4.3 Descriptive Analysis

The descriptive statistics for the participants from AHS are presented in Table 4.2, including details regarding independent variables such as type of school, grade level, gender and dependent variables, and measures such as the number of students (N), minimum and maximum scores, mean values, standard deviations, skewness and kurtosis values.

Table 4.2 Descriptive Statistics of AHS Students' PA, SoBP and Subdimensions of PPEQ Scores

Grade	*Gender*	*DV*	*N*	*Min*	*Max*	*Mean*	*St. Dev.*	*Skewness*		*Kurtosis*	
								Stat.	*SE*	*Stat.*	*SE*
9	F	PA	93	34	93	71.49	12.73	-.59	.25	-.02	.49
9	F	SoBP	93	4	20	13.84	4.48	-.43	.25	-.43	.49
9	F	QL	93	10	20	16.20	2.88	-.56	.25	-.77	.49
9	F	Source	93	8	20	14.87	2.98	-.12	.25	-.48	.49
9	F	SK	93	23	45	35.16	4.72	-.15	.25	-.29	.49
9	F	JK	93	11	25	18.13	3.57	.35	.25	-.65	.49
9	F	CK	93	10	25	18.33	3.31	.29	.25	-.55	.49
9	M	PA	45	44	98	75.44	14.36	-.66	.35	-.28	.69
9	M	SoBP	45	4	20	15.60	4.72	-1.15	.35	.47	.69
9	M	QL	45	11	20	17.36	2.46	-.82	.35	.08	.69
9	M	Source	45	9	20	15.60	2.89	-.08	.35	-.47	.69
9	M	SK	45	24	45	35.07	5.32	-.11	.35	-.84	.69
9	M	JK	45	11	24	18.44	3.00	-.39	.35	.19	.69
9	M	CK	45	13	25	2.022	3.04	-.39	.35	-.61	.69
10	F	PA	45	37	100	65.64	16.06	.12	.35	-.72	.69
10	F	SoBP	45	4	20	13.98	3.95	-.29	.35	-.14	.69
10	F	QL	45	8	20	15.84	3.12	-.41	.35	-.57	.69
10	F	Source	45	8	20	13.89	2.94	.32	.35	-.55	.69
10	F	SK	45	23	45	34.89	4.89	-.27	.35	-.34	.69
10	F	JK	45	11	25	17.18	3.60	.29	.35	-.66	.69
10	F	CK	45	12	25	17.16	3.23	.41	.35	-.65	.69
10	M	PA	20	40	88	7.80	12.05	-.85	.51	.79	.99
10	M	SoBP	20	7	20	16.20	3.49	-.98	.51	.85	.99
10	M	QL	20	7	20	15.75	3.74	-.78	.51	-.26	.99
10	M	Source	20	5	20	14.10	3.73	-1.00	.51	1.48	.99
10	M	SK	20	29	42	34.40	3.18	-.18	.51	-.43	.99
10	M	JK	20	10	25	17.20	3.68	-.24	.51	-.72	.99
10	M	CK	20	14	24	18.50	3.14	.46	.51	-.48	.99
11	F	PA	34	32	89	64.59	14.44	-.62	.40	.16	.79

Table 4.2 (Cont'd)

11	F	SoBP	34	6	20	15.74	4.24	-.80	.40	-.29	.79
11	F	QL	34	10	20	16.67	2.75	-.77	.40	-.27	.79
11	F	Source	34	8	20	14.65	3.55	-.16	.40	-.86	.79
11	F	SK	34	31	43	37.91	3.23	-.28	.40	-.72	.79
11	F	JK	34	11	25	19.12	3.24	-.09	.40	.03	.79
11	F	CK	34	13	25	18.47	3.04	.25	.40	-.34	.79
11	M	PA	15	35	95	68.13	17.29	-.43	.58	-.50	1.12
11	M	SoBP	15	4	20	14.93	4.73	-.89	.58	.49	1.12
11	M	QL	15	13	20	16.80	1.82	-.48	.58	.39	1.12
11	M	Source	15	12	20	15.87	2.48	.24	.58	-.38	1.12
11	M	SK	15	29	42	34.33	3.46	.75	.58	.28	1.12
11	M	JK	15	14	25	20.00	3.05	-.05	.58	-.01	1.12
11	M	CK	15	14	24	2.07	2.84	-.32	.58	.00	1.12

Similarly, the descriptive statistics for the participants from SHS are provided in Table 4.3, offering details to enable a comprehensive comparison between the two school types.

Table 4.3 Descriptive Statistics of SHS Students' PA, SoBP and Subdimensions of PPEQ Scores

Grade	*Gender*	*DV*	*N*	*Min*	*Max*	*Mean*	*St. Dev.*	*Skewness*		*Kurtosis*	
								Stat.	*SE*	*Stat.*	*SE*
9	F	PA	28	32	96	65.54	18.33	.29	.44	-1.00	.86
9	F	SoBP	28	5	20	12.96	4.05	-.11	.44	-.37	.86
9	F	QL	28	12	20	16.21	2.77	-.25	.44	-1.18	.86
9	F	Source	28	9	20	16	3.19	-.27	.44	-.75	.86
9	F	SK	28	27	44	36.57	4.37	-.62	.44	-.08	.86
9	F	JK	28	15	25	19.68	2.48	-.01	.44	-.27	.86
9	F	CK	28	15	25	2.14	3.12	-.28	.44	-.83	.86
9	M	PA	34	31	100	7.32	18.48	-.19	.40	-.87	.79
9	M	SoBP	34	5	20	15.12	4.33	-.78	.40	-.34	.79
9	M	QL	34	8	20	15.74	3.35	-.46	.40	-.73	.79
9	M	Source	34	9	20	15	2.94	.11	.40	-.73	.79
9	M	SK	34	22	45	34.62	5.45	-.26	.40	-.20	.79
9	M	JK	34	12	25	18.26	3.65	.23	.40	-.92	.79
9	M	CK	34	13	25	19.94	3.69	-.28	.40	-1.19	.79
10	F	PA	45	40	100	8.98	13.02	-1.49	.35	2.43	.69

Table 4.3 (Cont'd)

10	F	SoBP	45	5	20	13.8	3.22	-.18	.35	.28	.69
10	F	QL	45	12	20	16.82	2.76	-.53	.35	-.86	.69
10	F	Source	45	10	20	15.24	2.85	-.04	.35	-1.36	.69
10	F	SK	45	25	45	35.16	4.87	-.34	.35	-.19	.69
10	F	JK	45	12	25	19.20	3.55	-.11	.35	-.96	.69
10	F	CK	45	11	24	18.69	3.13	-.33	.35	-.51	.69
10	M	PA	43	44	99	78.49	13.89	-.72	.36	-.22	.71
10	M	SoBP	43	7	20	15.95	3.66	-.69	.36	-.49	.71
10	M	QL	43	9	20	16.63	2.89	-.96	.36	.19	.71
10	M	Source	43	9	20	14.88	3.03	.05	.36	-1.30	.71
10	M	SK	43	24	45	34.61	5.33	-.11	.36	-.79	.71
10	M	JK	43	10	25	18.35	4.21	-.23	.36	-.87	.71
10	M	CK	43	10	25	19.05	3.55	-.24	.36	-.50	.71
11	F	PA	70	25	94	61.67	15.80	-.08	.29	-.55	.57
11	F	SoBP	70	7	20	14.40	3.98	-.32	.29	-1.02	.57
11	F	QL	70	7	20	16.29	3.22	-.88	.29	.24	.57
11	F	Source	70	8	20	15.94	3.10	-.61	.29	-.47	.57
11	F	SK	70	27	45	36.46	4.39	-.061	.29	-.55	.57
11	F	JK	70	10	25	19.90	3.79	-.52	.29	-.39	.57
11	F	CK	70	11	25	19.50	3.19	-.46	.29	.28	.57
11	M	PA	57	23	95	63.86	15.32	-.19	.32	-.29	.62
11	M	SoBP	57	6	20	15.42	3.012	-.55	.32	.40	.62
11	M	QL	57	9	20	15.58	3.11	-.31	.32	-1.01	.62
11	M	Source	57	7	20	14.91	3.71	-.55	.32	-.39	.62
11	M	SK	57	25	45	35.07	4.77	-.16	.32	-.36	.62
11	M	JK	57	12	25	18.68	3.34	.01	.32	-.54	.62
11	M	CK	57	11	25	18.40	3.64	.13	.32	-.84	.62

4.4 The Results of Correlational Analysis

Before delving into the detailed analyses of school types and the subdimensions of PPE, a general examination of the relationships among the key variables—PA, PPE, and SoBP—across the entire sample will be presented. This initial overview aims to provide a foundational understanding of the overall patterns of association observed in the study. Following this, differences in these relationships between AHS and SHS students will be explored. Finally, the subdimensions of PPE will be analyzed in greater depth to uncover specific insights into how these epistemic beliefs interact with students' PA and SoBP.

The hypotheses tested in this section are as follows:

Null Hypotheses (H_0) for Correlation Analysis

H_{01}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology among Anatolian and Science High School students in Küçükçekmece, İstanbul.’

H_{02}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for male students in Anatolian and Science High Schools in Küçükçekmece, İstanbul.’

H_{03}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for female students in Anatolian and Science High Schools in Küçükçekmece, İstanbul.’

H_{04}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 9th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul.’

H_{05}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 10th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul.’

H_{06}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for 11th-grade students in Anatolian and Science High Schools in Küçükçekmece, İstanbul.’

H_{07}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for students in Anatolian High Schools in Küçükçekmece, İstanbul.’

H_{08}: ‘There are no significant correlations among physics achievement, sense of belonging to physics, and physics-related personal epistemology for students in Science High Schools in Küçükçekmece, İstanbul.’

4.4.1 The Relationships among High School Students’ Physics Achievement, Physics Related Personal Epistemologies, and Sense of Belonging to Physics Course

To determine the appropriate statistical procedure, the normal distribution conformity of the independent variables (SoBP, PPE, and PA) was assessed using the Kolmogorov-Smirnov test, and the results are presented in Table 4.4. The analysis indicated that the three independent variables in the study did not adhere to a normal distribution ($p<.05$).

Table 4.4 Results of The Test for Conformity to Normal Distribution

	Kolmogorov-Smirnov Test		
Variables	Test Statistics	Degrees of Freedom	*p-Value*
PA	.068	555	<.01
PPE	.056	555	<.01
SoBP	.102	555	<.01

Since the criterion of conformity to normal distribution was violated, data analysis was performed with the non-parametric Spearman rank order correlation (or Spearman’s rho) analysis. This non-parametric correlation analysis is used to assess statistical dependence between two rank-ordered (continuous or discrete) variables. The Spearman’s rho coefficient may range between -1 and +1. The values between .0-.1 refers to none/trivial association, .1-.3 to weak/small, .3-.5 moderate/medium, .5-1.0 to strong, 1.0 refers to perfect association between two variables (Coreder & Foreman, 2009). Correlations (spearman's rho coefficients) between PA, PPEQ and SoBP scores by grade level according to school type are presented in Table 4.5.

Table 4.5 Correlations (Spearman's Rho Coefficients) Between PA, PPE And SoBP Scores by Grade Level According to School Type

Type of School	Grade Level	Variables	PPE	SoBP
AHS	9	PA	.239**	-.085
		PPE		.072
	10	PA	.360**	-.113
		PPE		.099
	11	PA	.323**	.248*
		PPE		.272*
SHS	9	PA	.240*	.142
		PPE		.247*
	10	PA	.409**	.119
		PPE		.212*
	11	PA	.065	-.064
		PPE		.137

$^{*}p<0{,}05$ $^{**}p<0{,}01$

For AHS students, PA shows consistently positive correlations with PPE across all grades, with moderate strength in 10th grade (ρ = .360) and 11th grade (ρ = .323), and a small-to-moderate relationship in 9th grade (ρ = .239). Similarly, for SHS students, a weak positive association between PA and PPE was observed in 9th grade (ρ = .240), while a moderate association was found in 10th grade (ρ = .409). However, no significant correlations were identified between PA and PPE, PA and SoBP, or PPE and SoBP for 11th grade SHS students.

4.4.2 The Relationships between High School Students' Physics Achievement, Sense of Belonging to Physics Course and PPE Sub-Dimensions

In general, the analyses conducted on the basis of students' schools and grades revealed different degrees of relationships between students' PPE and their PA, SoBP (see Table 4.6). For this reason, the relationships between the sub-dimensions of PPE and PA and SoBP scores were also analyzed. These sub-dimensions include

a) ‘Structure of Knowledge’ (SK),
b) ‘Justification of Knowledge’ (JK),
c) ‘Changeability of Knowledge’ (CK),
d) ‘Source of Knowledge (Source)’, and
e) ‘Quick Learning and Effort’ (QL).

When the relationships between the variables were analyzed, significant positive relationships were found between PA and each sub-dimension of the PPE. A higher significant positive relationship was found between students' PA and the sub-dimension of QL (ρ=.334, p<.01). In other words, it can be said that students who are successful in physics courses have high beliefs that they need to make an effort to understand the physics course. Similarly, it can be said that students who have a high SoBP have sophisticated PPE that they need to make an effort to understand the course (ρ=.213, p<.01).

Table 4.6 Correlations (Spearman's Rho Coefficients) Between PA, SoBP And Subdimensions of PPE

	SK	JK	CK	Source	QL
PA	.152**	.109**	.170**	.143**	.334**
SoBP	.177**	.049	.122**	.071*	.213**

*p<.05 **p<.01

4.4.3 The Relationships between High School Students' Physics Achievement, Physics-Related Personal Epistemologies, and Sense of Belonging to Physics Course by Gender

The results of the grade level-based analysis show that there were significant differences between the variables in terms of binary relationships (see Table 4.7). There was no significant relationship between PA, PPE and SoBP for 9th and 11th grade female students in AHS and 9th, 10th and 11th grade female students in SHS. While there was no significant correlation between PA and SoBP for male students in AHS, positive moderate correlations were found for 9th (ρ=.436) and 11th grade (ρ=.310) male students in SHS. In addition, a positive strong correlation was found between PA and PPE for 10th grade male students in SHS (ρ=.569) and moderate correlations for 9th and 11th grade male students (ρ=.452 and ρ=.483, respectively), and 10th grade female students (ρ=.462) in AHS.

Table 4.7 Correlations Between Students' PA, PPE and SoBP Scores (Spearman's Rho Coefficients) By Gender and Grade Level Due to Type of School

Type of School	Grade Level	Gender	Variables	PPE	SoBP
AHS	9	Female	PA	.137	-.110
			PPE		.017
		Male	PA	**.452****	-.183
			PPE		.012
	10	Female	PA	**.462****	-.192
			PPE		-.026
		Male	PA	-.012	.132
			PPE		.407
	11	Female	PA	.182	.193
			PPE		.194
		Male	PA	**.483***	.312
			PPE		.423
SHS	9	Female	PA	.352	-.013
			PPE		.142
		Male	PA	.159	.116
			PPE		**.436****
	10	Female	PA	.223	.113
			PPE		.214
		Male	PA	**.569****	.215
			PPE		.275
	11	Female	PA	.142	.034
			PPE		.055
		Male	PA	-.033	-.226
			PPE		**.310***

*p<.05 **p<.01

4.5 Assumptions of Multivariate Analysis of Variance (MANOVA)

The following assumptions were examined to perform the MANOVA in this study: sample size, normality, outliers, linearity, multicollinearity and homogeneity of variance-covariance matrices.

1. Sample size: According to Pallant (2016, p. 219), the recommended sample size for MANOVA requires having more cases in each group than the number of dependent variables to ensure adequate statistical power. In this study, seven dependent variables were identified: sense of belonging in physics (SoBP), the five subdimensions of PPE (Source, SK, JK, CK, QL), and physics achievement (PA). For each independent variable combination (e.g., grade level x gender x school type), the descriptive statistics indicate that the number of participants exceeds the required minimum threshold of six cases per group.

The smallest group size across all independent variable combinations is 15 participants (e.g., 11th-grade male students in AHS), which is greater than the number of dependent variables. Other group sizes range from 20 to over 100 participants, ensuring sufficient representation. Thus, the sample size in this study meets the criteria for MANOVA and provides adequate statistical power for the analysis.

2. Normality: The normality of the dependent variables was assessed using skewness and kurtosis values as well as histograms and Q-Q plots. All variables demonstrated acceptable levels of normality, with skewness and kurtosis values within the range of ±2, as recommended by Kline (2016).

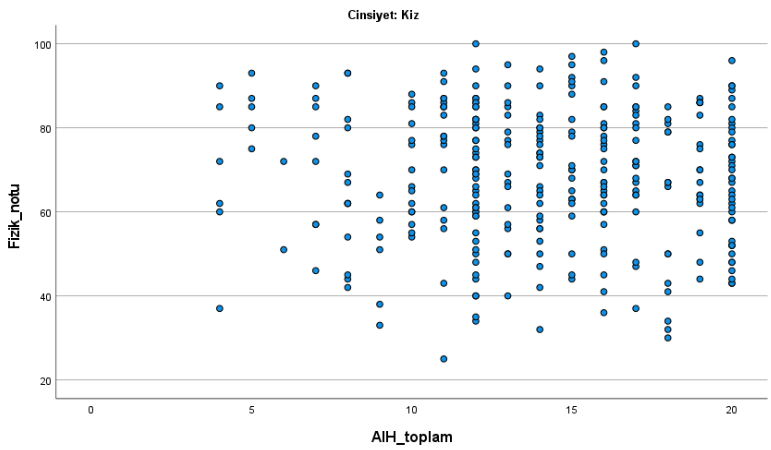
The normality assumption was examined to validate the dataset for MANOVA analysis. The Kolmogorov-Smirnov and Shapiro-Wilk tests indicated non-normal distributions for the variables ($p < .001$), which is expected due to the sensitivity of these tests to large sample sizes. To further investigate normality, skewness, and kurtosis values were evaluated as alternative indicators. According to George and Mallery (2010), skewness and kurtosis values ranging between -2 and +2 indicate an acceptable range for normality. In this study, all variables fell within this range, suggesting that data was approximately normally distributed.

3. Outlier: This part is detailed in section 4.2.

4. Linearity Assumption: The linearity assumption was tested to determine whether there was a straight-line relationship between the dependent variables. Scatterplot graphs were generated separately for males and females to visually assess the relationships between the variables. The scatterplots indicated weak or no visible linear patterns between the variables.

To quantitatively confirm this, Pearson correlation coefficients were calculated for each pair of variables. The correlation between PA and total SoBP was non-significant for both females (r = -.035, p = .531) and males (r = .073, p = .286). These results indicate a lack of significant linear relationships between these variables.

Given these findings, the linearity assumption is not sufficiently met in this dataset.



5. Homogeneity of Regression: This assumption is particularly relevant for stepdown analyses, which require a theoretical or conceptual rationale for ordering dependent variables. As this study does not involve stepdown analysis, this assumption is not applicable here. Therefore, no further tests or considerations were required for this assumption.

6. Multicollinearity and Singularity: MANOVA assumes that the dependent variables are moderately correlated. Excessively high correlations between dependent variables may indicate multicollinearity, while singularity arises when one variable is a linear combination of others (e.g., total scores derived from subscales).

Table 4.8 Correlation Matrix Among Dependent Variables

		PA	*SoBP*	*QL*	*Source*	*SK*	*JK*	*CK*
PA	Pearson Correlation	1	.009	.336**	.160**	.118**	.096*	.157**
	Sig. (2-tailed)		.828	<.001	<.001	.006	.028	<.001
SoBP	Pearson Correlation	.009	1	.174**	.042	.132**	.014	.086*
	Sig. (2-tailed)	.828		<.001	.334	.002	.757	.048
QL	Pearson Correlation	.336**	.174**	1	.433**	.424**	.359**	.457**
	Sig. (2-tailed)	<.001	<.001		<.001	<.001	<.001	<.001
Source	Pearson Correlation	.160**	.042	.433**	1	.333**	.515**	.576**
	Sig. (2-tailed)	<.001	.334	<.001		<.001	<.001	<.001
	N	529	529	529	529	529	529	529
SK	Pearson Correlation	.118**	.132**	.424**	.333**	1	.459**	.338**
	Sig. (2-tailed)	.006	.002	<.001	<.001		<.001	<.001
JK	Pearson Correlation	.096*	.014	.359**	.515**	.459**	1	.428**
	Sig. (2-tailed)	.028	.757	<.001	<.001	<.001		<.001
CK	Pearson Correlation	.157**	.086*	.457**	.576**	.338**	.428**	1
	Sig. (2-tailed)	<.001	.048	<.001	<.001	<.001	<.001	

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Multicollinearity Check: Pearson correlation coefficients were calculated among the seven dependent variables, ranging between .009 and .576. All values remained below the threshold of .80, as recommended by Tabachnick and Fidell (1996). Thus, no evidence of multicollinearity was observed.

Singularity Check: Singularity was avoided by ensuring that composite variables (e.g., PPE total scores) were not simultaneously included with their subcomponents as dependent variables. The results indicate that the assumptions of multicollinearity and singularity were met, validating the appropriateness of the dependent variables for MANOVA.

7. Homogenity of Variance- Covariance Matrices: Box's M test was performed to assess whether the observed covariance matrices of the dependent variables are equal across groups. The results, as shown in Table 4.6, indicate that the assumption of homogeneity of variance-covariance matrices was violated (Box's M = 425.789, F (308, 61628.369) = 1.266, p = .001). This violation suggests significant differences in covariance matrices across groups, necessitating caution in interpreting the MANOVA results.

Table 4.9 Box's Test of Equality of Covariance Matrices

Statistic	***Value***
Box's M	425.79
F	1.27
df1	308
df2	61628.37
Sig.	.001

For the multivariate approach, it is assumed that the vector of dependent variables follows a multivariate normal distribution, and the variance-covariance matrices are equal across cells defined by the between-subjects effects. Box's M test evaluates the null hypothesis that these covariance matrices are equal across groups. The test statistic is converted into an F value with corresponding degrees of freedom (df1 and df2). In this case, the significance level was less than 0.05, indicating that the assumptions were not met, which may compromise the reliability of the MANOVA results.

To address this violation, the more robust Pillai's Trace statistic was used for the analysis, as it is less sensitive to violations of the homogeneity assumption. Additionally, the balanced group sizes in this study help to mitigate the impact of this assumption violation.

It is important to note that Box's M test is highly sensitive to large sample sizes, detecting even minor deviations from homogeneity. Furthermore, it can be influenced by departures from normality assumptions. As an additional measure, Levene’s test can be used to check the homogeneity of variances within the diagonals of the covariance matrices.

Levene’s Test was conducted to assess the assumption of homogeneity of variances for the dependent variables across groups. The test evaluates whether the variances of the dependent variables are equal across levels of the independent variables. The detailed results of Levene's Test are shown in Table 4.10.

Table 4.10 Levenes Test Equality Error Variances

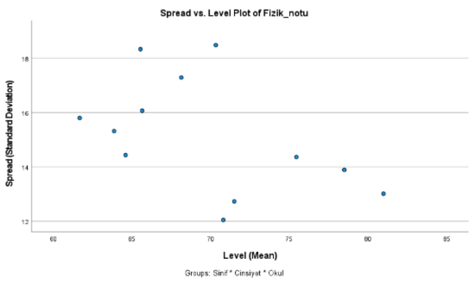
Variable	*Based On*	*Levene Statistic*	*df1*	*df2*	*Sig.*
SoBP	Mean	1.77	11	517	.06
Source	Mean	.92	11	517	.52
SK	Mean	1.71	11	517	.07
JK	Mean	1.92	11	517	.03
CK	Mean	.81	11	517	.63
QL	Mean	1.97	11	517	.03
PA	Mean	2.19	11	517	.01

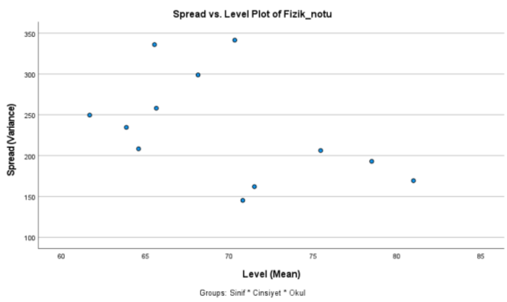
The results indicate that the assumption of homogeneity of variances is largely met for most dependent variables, with the exception of JK, QL, and PA which show p-values below the .05 threshold. These findings suggest caution when interpreting results related to these variables, as potential heterogeneity of variances could impact the robustness of the analysis.

This table examines the equality of error variances across the cells formed by the combination of factor levels. Each dependent variable is tested individually. A significance value below 0.05 indicates a violation of the ‘equal variances’ assumption. Similar to Box's M test, Levene's test can be sensitive to large datasets; therefore, it is recommended to review the spread versus level plot for the dependent variables as a visual check.

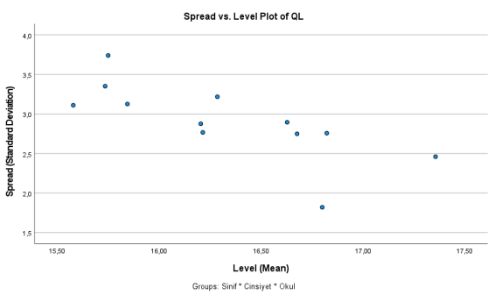
The spread-versus-level plot is a scatterplot that visually displays the relationship between cell means and standard deviations. This plot serves as a tool to evaluate the equal variances assumption while also helping to determine if any violations of this assumption are linked to a correlation between the cell means and standard deviations.

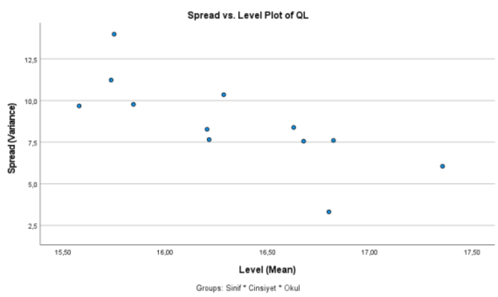
- The spread versus level plots for PA indicate that the relationship between cell means and standard deviations is non-linear. The variability in standard deviations and variances does not exhibit a clear pattern across different mean levels, suggesting potential violations of the 'equal variances' assumption. This lack of linearity highlights the need for caution in interpreting results for PA, as deviations from the assumption could affect the robustness of the analysis.





- Quick Learning (QL): The spread versus level plots for QL reveal an inverse linear relationship between the means and the variances. As the mean values increase, both the standard deviations and variances decrease, indicating a consistent pattern. This inverse correlation suggests that while variances may not be equal across groups, the relationship is systematic. The observed trend





could impact the interpretation of results, necessitating adjustments or robust statistical methods to account for this relationship.

Log-transformation was applied to QL and PA to address the violation of homogeneity assumptions. Despite the transformation, the results of Levene's Test remained significant, indicating that the variance differences persist across groups.

Table 4.11 Levene's Test Equality Error Variances

Variable	*Based On*	*Levene Statistic*	*df1*	*df2*	*Sig.*
SoBP	Mean	1.77	11	517	.06
Source	Mean	.92	11	517	.52
SK	Mean	1.71	11	517	.07
JK	Mean	1.92	11	517	.03
CK	Mean	.81	11	517	.63
LOG_PA	Mean	2.89	11	517	.00
LOG_QL	Mean	2.41	11	517	.01

According to Richardson (2011), partial eta-squared values of approximately .01, .06, and .14 correspond to small, medium, and large effect sizes, respectively. These benchmarks will be used to interpret the magnitude of observed effects in subsequent analyses.

Pillai's Trace is a robust test statistic that is particularly suitable for situations where assumptions of normality are violated or when the experimental design is unbalanced. It demonstrates greater tolerance for non-normal data, making it a preferred choice under such conditions. However, it should be noted that Type II errors are more likely with Pillai's Trace, meaning that there is an increased risk of failing to detect a significant effect when one exists. When assumptions cannot be remedied, Pillai's Trace offers a reliable alternative for analyzing multivariate data. In the following sections, Manova results will be given in detail.

4.6 Results of Multivariate Analysis of Variance (MANOVA)

Although certain assumptions of MANOVA were not fully met, MANOVA was used in this study because of its distinct advantages over nonparametric alternatives. MANOVA evaluates group differences across multiple dependent variables simultaneously while accounting for their potential correlations, reducing the likelihood of Type I error compared to separate univariate tests. Additionally, MANOVA allows for the investigation of interaction effects among independent variables on the combination of dependent variables—an analysis that is not feasible with most nonparametric tests. To ensure the robustness of the findings, nonparametric tests (e.g., Kruskal-Wallis H Test) were conducted as supplementary analyses and confirmed significant group differences for the dependent variables. These consistent results support the validity of the findings and mitigate concerns about assumption violations. Thus, MANOVA remains an appropriate and powerful analytical choice, offering richer insights into the multivariate nature of the data compared to nonparametric methods.

A one-way between-groups multivariate analysis of variance (MANOVA) was conducted to examine the effects of Grade Level, Gender, and School Type on PA, SoBP, and epistemic cognition dimensions (QL, Source, SK, JK, and CK). Preliminary assumption testing revealed a violation of the homogeneity of variance-covariance matrices, as indicated by Box's M test (p = .001), which necessitated the use of Pillai's Trace for more robust results.

The hypotheses tested in this section are as follows:

Main Effect

H_{01}: There are no significant differences in the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—based on grade level, gender, and school type among Anatolian and Science High School students in Küçükçekmece, İstanbul.

Specific Effects

H_{02}: There are no significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology across different grade levels among Anatolian and Science High School students in Küçükçekmece, İstanbul.

H_{03}: There are no significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology between male and female students among Anatolian and Science High School students in Küçükçekmece, İstanbul.

H_{04}: There are no significant differences in physics achievement, sense of belonging to physics, and physics-related personal epistemology based on school type among Anatolian and Science High School students in Küçükçekmece, İstanbul.

Interaction Effects

H_{05}: Grade level and gender do not have a significant interaction effect on the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul.

H_{06}: Grade level and school type do not have a significant interaction effect on the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul.

H_{07}: Gender and school type do not have a significant interaction effect on the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul.

H_{08}: Grade level, gender, and school type do not have a significant three-way interaction effect on the combined dependent variables—physics achievement, sense of belonging to physics, and physics-related personal epistemology—among Anatolian and Science High School students in Küçükçekmece, İstanbul.

The results of the multivariate analysis, as shown in Table 4.12, were used to test the null hypotheses related to main and interaction effects. The analysis revealed statistically significant main effects for **grade level** (Pillai's Trace = .107, F (14, 1024) = 4.136, p < .001, η^2 = .054, medium effect size) and **gender** (Pillai's Trace = .073, F (7, 511) = 5.776, p < .001, η^2 = .073, medium effect size), rejecting H_{02} and H_{03}, respectively. These findings indicate that both grade level and gender significantly influence the combined dependent variables: students' PA, PPE, and SoBP.

Table 4. 12 Multivariate Test Results

Effect	*Effect*	*Value*	*F*	*Hypothesis df*	*Error df*	*Sig.*	*Partial* η²	*Noncent. Parameter*	*Observed Power*
GL	Pillai's Trace	.11	4.14	14	1024	<0.001	.05	57.91	1
G	Pillai's Trace	.07	5.78	7	511	<0.001	.07	40.42	.99
ST	Pillai's Trace	.02	1.54	7	511	0.15	.02	10.80	.65
GL * G	Pillai's Trace	.02	0.81	14	1024	0.66	.01	11.35	.53
GL * ST	Pillai's Trace	.07	2.61	14	1024	<0.001	.03	36.56	.99
G * ST	Pillai's Trace	.03	2.04	7	511	0.05	.03	14.26	.79
GL * G * ST	Pillai's Trace	.02	0.81	14	1024	0.66	.01	11.34	.53

Note: GL: Grade Level, G: Gender, ST: School Type

However, no significant main effect was found for school type (Pillai's Trace = .021, F (7, 511) = 1.543, p = .150, η^2 = .021), supporting H_{04}, suggesting that school type does not independently affect the dependent variables.

Therefore, H_{01} is partially rejected, as significant differences were observed based on grade level and gender, while school type did not independently contribute to significant differences in the dependent variables.

Significant interaction effects were observed for **grade level and school type** (Pillai's Trace = .069, F (14, 1024) = 2.611, $p < .001$, $\eta^2 = .034$, small effect size) as well as **gender and school type** (Pillai's Trace = .027, F (7, 511) = 2.037, $p = .049$, $\eta^2 = .027$, small effect size), rejecting H_{06} and H_{07}, respectively. These results suggest that contextual factors like school type interact with grade level and gender to influence students' PA, PPE, and SoBP.

However, no statistically significant three-way interaction effect was detected between grade level, school type, and gender (Pillai's Trace = .022, F (14, 1024) = .810, $p = .659$, $\eta^2 = .011$), supporting H_{08}.

In summary, **grade level** and **gender** are key predictors of PA, PPE, and SoBP, while school type plays a more contextual role through its interactions with other variables. The absence of a significant three-way interaction highlights the independent contributions of grade level and gender in shaping students' physics-related outcomes. To further explore these relationships and identify which specific dependent variables contributed to the overall effects, follow-up ANOVAs were conducted. These analyses provide a more detailed examination of the unique patterns within each dependent variable, offering additional insights into the group differences observed in the MANOVA results. Table 4.13 shows the results of analysis.

Table 4. 13 Tests of Between-Subjects Effects

Source	*DV*	*Type III Sum of Squares*	*df*	*Mean Square*	*F*	*Sig.*	*Partial Eta Squared*	*Noncent. Parameter*	*Observed Power*[h]
GL	Source	63.28	2	31.64	3.22	.041	.012	6.448	.614
GL	JK	135.99	2	67.99	5.49	.004	.021	1.987	.85
GL	CK	118.59	2	59.29	5.47	.004	.021	1.949	.849
GL	PA	5926.65	2	2963.3	13.27	.001	.049	26.547	.998

Table 4.13 (Cont'd)

G	SoBP	21.68	1	21.68	13.08	.001	.025	13.08	.951
G	SK	188.71	1	188.71	8.57	.004	.016	8.566	.832
GL * ST	QL	69.38	2	34.69	3.95	.02	.015	7.902	.709
GL * ST	PA	6132.19	2	3066.1	13.73	.001	.05	27.467	.998
G * ST	Source	6.26	1	6.26	6.14	.014	.012	6.14	.696
G * ST	JK	64.291	1	64.291	5.19	.02	.01	5.194	.624
G * ST	CK	9.264	1	9.264	8.33	.00	.016	8.333	.822
G * ST	QL	19.073	1	19.073	2.17	.14	.004	2.172	.313

Note: GL: Grade Level, G: Gender, ST: School Type

Grade level shows significant effects on PA, JK, and CK, with small-to-moderate effect sizes. Gender demonstrates significant effects on students' SoBP and SK, albeit with small effect sizes. In contrast, school type does not exhibit significant main effects; however, marginal differences are observed for JK. Notably, interactions between grade level and school type reveal significant effects on PA, with a small-to-moderate effect size, while interactions between gender and school type significantly impact CK, albeit with a small effect size.

Having completed the MANOVA and follow-up ANOVA analyses, we now examine the group differences in greater detail using Estimated Marginal Means (EMMs) for each independent variable. These means provide a clearer summary of the differences identified in the MANOVA results, highlighting the specific effects of grade level, gender, and school type. Post hoc analyses are also presented where appropriate to pinpoint significant pairwise differences between groups.

4.6.1 Grade Level

This section examines the effects of grade level on the dependent variables, providing insights into how students' perceptions and PA vary across different grades. A detailed summary of these differences is presented in Table 4.14, which displays the estimated marginal means for each grade level.

Table 4. 14 Estimated Marginal Means by Grade Level

Dependent Variable	*Grade Level*	*Mean*	*Std. Error*	*95% Confidence Interval*	
				Lower Bound	*Upper Bound*
SoBP	9	14.380	.314	13.763	14.998
	10	14.983	.344	14.307	15.659
	11	15.122	.359	14.417	15.827
Source	9	15.368	.245	14.886	15.850
	10	14.529	.269	14.001	15.057
	11	15.342	.280	14.792	15.893
SK	9	35.354	.368	34.632	36.076
	10	34.762	.403	33.971	35.553
	11	35.943	.420	35.119	36.768
JK	9	18.629	.275	18.088	19.170
	10	17.982	.302	17.389	18.574
	11	19.425	.315	18.807	20.043
CK	9	19.610	.258	19.104	20.116
	10	18.348	.282	17.793	18.902
	11	19.110	.294	18.532	19.688
QL	9	16.377	.232	15.922	16.833
	10	16.261	.254	15.762	16.760
	11	16.335	.265	15.815	16.856
PA	9	70.700	1.170	68.401	72.998
	10	73.978	1.282	71.460	76.495
	11	64.563	1.336	61.939	67.188

Table 4.14 presents the estimated marginal means of the dependent variables across grade levels. These results are detailed to highlight critical patterns and variations, providing insights into how students' SoBP, epistemological dimensions, and PA evolve as they progress through grade levels. Key findings are summarized below:

- SoBP increases slightly from 9th (M = 14.38, SE = 0.31) to 11th grade (M = 15.12, SE = 0.36). These results suggest that students develop a stronger SoBP as they progress through grade levels.
- Students’ perceptions of the source of knowledge varied by grade level. Ninth-grade students scored 15.37 (SE = 0.245) followed by a decline in tenth-grade students with a mean score of 14.53 (SE = 0.269). Eleventh-grade students' scores increased again to 15.34 (SE = 0.280). This pattern indicates a dip in the tenth grade, followed by recovery in the eleventh grade.

- The SK dimension also showed fluctuations across grade levels. Ninth-grade students scored 35.35 (*SE* = 0.368) while tenth-grade students reported a lower mean score of 34.76 (*SE* = 0.403). Eleventh-grade students scored the highest at 35.94 (*SE* = 0.420). These findings suggest a temporary decline in the tenth grade, with recovery and improvement in the eleventh grade.
- The JK scores decreased from ninth to tenth grade before increasing in the eleventh grade. Ninth-grade students reported a mean score of 18.63 (*SE* = 0.275), while tenth-grade students scored 17.98 (*SE* = 0.302). Eleventh-grade students scored significantly higher with a mean of 19.43 (*SE* = 0.315). This pattern indicates a decline in tenth grade but substantial growth in the eleventh grade.
- The CK scores mirrored the trends observed in other epistemological dimensions. Ninth-grade students reported a mean of 19.61 (*SE* = 0.258), while tenth-grade students scored lower at 18.35 (*SE* = 0.282). Eleventh-grade students showed a slight recovery with a mean score of 19.11 (*SE* = 0.294).
- The QL scores showed minimal variation across grade levels. Ninth-grade students reported a mean of 16.38 (*SE* = 0.232), while tenth-grade students scored 16.26 (*SE* = 0.254). Eleventh-grade students showed a slight increase to 16.34 (*SE* = 0.265).
- PA scores exhibited a unique trend, with the highest mean score observed in the tenth grade (*M* = 73.98, *SE* = 1.282). Ninth-grade students scored slightly lower (*M* = 70.70, *SE* = 1.170). However, eleventh-grade students showed a significant decline in physics achievement with a mean score of 64.56 (*SE* = 1.336).

The results suggest that students' epistemological cognitions and SoBP generally improve as they progress through grade levels, with some exceptions (e.g., a decline in the tenth grade for several dimensions). PA, on the other hand, peaks in the tenth grade before significantly declining in the eleventh grade. To further examine the differences observed in the Estimated Marginal Means, post hoc analyses were conducted. These analyses identified specific pairwise differences between groups, as detailed in Table 4.15.

Table 4. 15 SPSS Output for Multiple Comparisons by Grade Level (POSTHOC)

Dependent Variable	*(I) Grade Level*	*(J) Grade Level*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*[b]
JK	9	11	-.92	.364	.034
JK	10	11	-1.26	.389	.004
CK	9	10	.926	.353	.027
SK	10	11	1.28	.519	.041
PA	10	11	-10.94	1.652	.000
PA	9	11	-7.86	1.544	.000

Based on observed means.
The error term is Mean Square (Error) = 10.832
Based on observed means.

Post-hoc comparisons using Bonferroni correction revealed significant differences among grade levels for specific dependent variables as follows:

- There was no significant difference in terms of students' SoBP among different grade levels.
- For JK, 11th-grade students scored significantly higher than both 9th-grade students (*MD* = -.9236, *SE* = .36361, *p* = .034) and 10th-grade students (*MD* = -1.2591, *SE* = .38888, *p* = .004), 11th-grade students have more sophistication in JK than 9th and 10th-grade students.
- For CK, 9th-grade students scored significantly higher than 10th-grade students (*MD* = 0.9263, *SE* = 0.35349, *p* = .027), indicating a decrease in perceptions of knowledge changeability in 10th grade.
- For SK, 10th-grade students scored significantly lower than 11th-grade students (*MD* = 1.2844, *SE* = 0.51879, *p* = .041), reflecting improved epistemic structure among 11th graders.
- In PA, 11th-grade students scored significantly lower than both 10th-grade students (*MD* = -10.94, *SE* = 1.652, $p < .001$) and 9th-grade students (*MD* = -7.86, *SE* = 1.544, $p < .001$), suggesting a notable decline in physics

performance in the 11th grade. This decline may reflect the increased difficulty of physics topics in the eleventh-grade curriculum.

As presented in Table 4.15, these findings suggest that epistemic cognitions fluctuate across grades, while belonging, source, and QL remain stable (all $p >$ .05), and 11th grade poses unique academic challenges requiring targeted support.

4.6.2 Gender

This section examines the effects of gender on the dependent variables, providing insights into how students' perceptions (PPE and SoBP) and PA vary based on gender. A detailed summary of these differences is presented in Table 4.16, which displays the estimated marginal means for each gender.

Table 4. 16 Estimated Marginal Means

DV	*Gender*	*Mean*	*Std. Error*	*95% Confidence Interval*	
				Lower Bound	*Upper Bound*
SoBP	F	14.119	.245	13.637	14.601
	M	15.538	.306	14.937	16.138
Source	F	15.099	.192	14.723	15.475
	M	15.060	.239	14.591	15.530
SK	F	36.024	.287	35.461	36.588
	M	34.682	.358	33.979	35.385
JK	F	18.867	.215	18.445	19.290
	M	18.490	.268	17.964	19.017
CK	F	18.715	.201	18.320	19.111
	M	19.330	.251	18.837	19.823
QL	F	16.341	.181	15.985	16.697
	M	16.308	.226	15.864	16.752
PA	F	68.319	.914	66.524	70.114
	M	71.175	1.139	68.938	73.412

The estimated marginal means of the dependent variables by gender indicate significant variations in students' perceptions and achievements. The results highlight the following key patterns:

- Male students report higher SoBP (*M* = 15.54, *SE* = 0.31) compared to females (*M* = 14.12, *SE* = 0.25).
- In contrast, females score higher in SK (*M* = 36.02, *SE* = 0.29) than males (*M* = 34.68, SE = 0.36). JK shows a slight advantage for females (*M* = 18.87, *SE* = 0.22) over males (*M* = 18.49, *SE* = 0.27), whereas CK is higher for males (*M* = 19.33, *SE* = 0.25) than females (*M* = 18.72, *SE* = 0.20). QL remains consistent between genders, with females scoring *M* = 16.34 (*SE* = 0.18) and males *M* = 16.31 (*SE* = 0.23).
- In terms of PA, males outperform females, scoring *M* = 71.18 (*SE* = 1.14) compared to females at *M* = 68.32 (*SE* = 0.91).

The differences in these estimated marginal means were further examined using the Pairwise Comparisons table (Table 4.17) to determine which group pairs exhibited statistically significant differences. Pairwise comparisons provide insight into whether the observed differences between gender groups are statistically meaningful.

Table 4. 17 SPSS Output for Pairwise Comparisons by Gender

Dependent Variable	*(I) Gender*	*(J) Gender*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*^{b}
SoBP	F	M	-1.418*	.392	<.001
SK	M	F	-1.342*	.459	.004

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

The results of the pairwise comparisons revealed statistically significant differences in SoBP and SK between male and female students. A summary of the significant findings is presented below:

- Male students reported a significantly higher SoBP (*MD* = 1.418, *SE* = 0.392, $p <.001$).
- In contrast, female students scored significantly higher in the SK dimension (*MD* = 1.342, *SE* = 0.459, $p = .004$), suggesting that female students perceive physics knowledge as more coherent and hierarchical.
- No significant differences were found for Source, JK, CK, QL, or PA (all $p>.05$), indicating similar perceptions and performance in these dimensions across genders.

These results suggest that while male students feel a stronger sense of belonging to the physics course, female students demonstrate a more structured approach to knowledge organization. Other dimensions appear to remain stable across genders.

4.6.3 Gender and School Type

This section examines the interaction between gender and school type to determine how these factors collectively influence students' epistemic cognitions, SoBP, and PA. A detailed summary of the estimated marginal means for each group is presented in Table 4.18, providing insights into the patterns and variations observed.

Table 4. 18 Estimated Marginal Means

DV	*Gender*	*School Type*	*Mean*	*Std. Error*	*95% Confidence Interval*	
					Lower Bound	*Upper Bound*
SoBP	F	AHS	14.517	.334	13.861	15.174
		SHS	13.721	.360	13.015	14.428
	M	AHS	15.578	.499	14.598	16.557
		SHS	15.497	.354	14.801	16.194
Source	F	AHS	14.469	.261	13.957	14.981
		SHS	15.729	.281	15.178	16.280
	M	AHS	15.189	.389	14.424	15.953
		SHS	14.932	.277	14.388	15.476

Table 4.18 (Cont'd)

SK	F	AHS	35.987	.391	35.220	36.755
		SHS	36.061	.420	35.235	36.887
	M	AHS	34.600	.583	33.455	35.745
		SHS	34.764	.415	33.950	35.579
JK	F	AHS	18.141	.293	17.566	18.717
		SHS	19.593	.315	18.974	20.212
	M	AHS	18.548	.437	17.690	19.407
		SHS	18.433	.311	17.822	19.043
CK	F	AHS	17.986	.274	17.448	18.525
		SHS	19.444	.295	18.865	20.023
	M	AHS	19.530	.409	18.726	20.333
		SHS	19.130	.291	18.559	19.701
QL	F	AHS	16.242	.247	15.757	16.726
		SHS	16.441	.265	15.919	16.962
	M	AHS	16.635	.368	15.912	17.358
		SHS	15.981	.262	15.467	16.495
PA	F	AHS	67.242	1.244	64.798	69.686
		SHS	69.395	1.338	66.765	72.025
	M	AHS	71.459	1.856	67.813	75.106
		SHS	70.891	1.320	68.298	73.483

To better understand the combined effects of gender and school type on students' perceptions and PA, the following section provides a detailed summary of the key patterns observed. These analyses highlight how male and female students in different school types vary across variables: SoBP, subdimensions of PPE, and PA. Specific trends are outlined below, emphasizing the nuanced influence of these factors. The main findings are outlined as follows:

- In SoBP, male students reported higher scores across both school types, with AHS males scoring *M* = 15.58 (*SE* = 0.50) and SHS males scoring *M* = 15.50 (*SE* = 0.35). Female students scored lower, with AHS females scoring *M* = 14.52 (*SE* = 0.33) and SHS females scoring *M* = 13.72 (*SE* = 0.36).
- In Source, SHS females scored the highest (*M* = 15.73, *SE* = 0.28), followed by AHS males (*M* = 15.19, *SE* = 0.39). AHS females scored *M* = 14.47 (*SE* = 0.26), while SHS males reported a slightly lower mean of *M* = 14.93 (*SE* = 0.28).

- For SK, female students generally outperformed males. AHS females scored $M = 35.99$ ($SE = 0.39$) and SHS females scored $M = 36.06$ ($SE = 0.42$), compared to AHS males at $M = 34.60$ ($SE = 0.58$) and SHS males at $M = 34.76$ ($SE = 0.42$).
- In JK, SHS females again scored the highest with $M = 19.59$ ($SE = 0.32$), while AHS females scored $M = 18.14$ ($SE = 0.29$). Male students' scores were similar, with AHS males at $M = 18.55$ ($SE = 0.44$) and SHS males at $M = 18.43$ ($SE = 0.31$).
- For CK, male students reported higher scores overall. AHS males scored $M = 19.53$ ($SE = 0.41$), while SHS males scored $M = 19.13$ ($SE = 0.29$). Female students in SHS scored $M = 19.44$ ($SE = 0.30$), higher than their AHS counterparts at $M = 17.99$ ($SE = 0.27$).
- QL scores were similar across gender and school types, with AHS males scoring slightly higher ($M = 16.64$, $SE = 0.37$), followed by SHS females ($M = 16.44$, $SE = 0.27$), SHS males ($M = 15.98$, $SE = 0.26$), and AHS females ($M = 16.24$, $SE = 0.25$).
- In PA, male students outperformed females in both school types. AHS males scored the highest ($M = 71.46$, $SE = 1.86$), followed by SHS males ($M = 70.89$, $SE = 1.32$). Female students scored lower, with SHS females at $M = 69.40$ ($SE = 1.34$) and AHS females at $M = 67.24$ ($SE = 1.24$).

These findings indicate that gender and school type influence students’ perceptions and PA in different ways. Male students consistently reported higher SoBP and PA scores, while females excelled in epistemic dimensions such as SK, JK, and CK, particularly in SHS. Table 4.19 presents the SPSS output for pairwise comparisons of the dependent variables (DVs), offering a detailed examination of the specific differences between groups.

Table 4. 19 SPSS output for pairwise comparisons on DVs

DV	School Type	(I) Gender	(J) Gender	Mean Difference (I-J)	Std. Error	Sig.[b]
Source	SHS	F	M	.797*	.394	.044
JK	SHS	F	M	1.160*	.443	.009
SK	AHS	F	M	1.387*	.702	.049
SK	SHS	F	M	1.297*	.590	.028
CK	AHS	F	M	-1.543*	.492	.002
SoBP	SHS	F	M	-1.776*	.505	<.001

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

The pairwise comparisons for gender differences within AHS and SHS revealed several significant findings across the dependent variables. The critical observations are detailed as follows:

- In SoBP, male students in SHS reported significantly higher scores than female students (*MD* = 1.776, *SE* = 0.505, *p* < .001), while no significant difference was observed in AHS (*p* = .078).
- For Source, female students in SHS scored significantly higher than male students (*MD* = 0.797, *SE* = 0.394, *p* = .044), suggesting that females in SHS perceive knowledge sources as more authoritative. No significant difference was found in AHS (*p* = .125).
- In SK, female students outperformed males in both school types. In AHS, the difference was significant (*MD* = 1.387, *SE* = 0.702, *p* = .049), as well as in SHS (*MD* = 1.297, *SE* = 0.590, *p* = .028). Female students have more sophisticated epistemic cognition about the existence of hierarchical and coherent structures of knowledge than male students.
- For JK, females in SHS scored significantly higher than males (*MD* = 1.160, *SE* = 0.443, *p* = .009), while no significant difference was observed in AHS (*p* = .440).

- In CK, males in AHS scored significantly higher than females (*MD* = 1.543, *SE* = 0.492, *p* = .002). However, no significant gender difference was found in SHS (*p* = .449).

4.6.4 Grade Level & School Type

This section examines the interaction between grade level and school type to explore how these factors jointly influence students' perceptions and PA. Pairwise comparisons were performed to identify specific differences between groups, offering a deeper understanding of the combined effects of these variables. A detailed summary of the estimated marginal means for each group is presented in Table 4.20.

Table 4. 20 Estimated Marginal Means

Dependent Variable	Grade Level	School Type	Mean	Std. Error	95% Confidence Interval Lower Bound	Upper Bound
SoBP	9	AHS	14.719	.364	14.003	15.435
		SHS	14.041	.512	13.035	15.047
	10	AHS	15.089	.539	14.029	16.148
		SHS	14.877	.428	14.036	15.717
	11	AHS	15.334	.622	14.112	16.556
		SHS	14.911	.358	14.207	15.614
Source	9	AHS	15.235	.284	14.677	15.794
		SHS	15.500	.400	14.715	16.285
	10	AHS	13.994	.421	13.167	14.821
		SHS	15.064	.334	14.408	15.720
	11	AHS	15.257	.486	14.303	16.211
		SHS	15.428	.279	14.879	15.977
SK	9	AHS	35.114	.426	34.277	35.951
		SHS	35.595	.599	34.418	36.771
	10	AHS	34.644	.631	33.405	35.883
		SHS	34.880	.500	33.897	35.863
	11	AHS	36.123	.727	34.694	37.552
		SHS	35.764	.419	34.941	36.586
JK	9	AHS	18.287	.319	17.659	18.914
		SHS	18.972	.449	18.090	19.854
	10	AHS	17.189	.473	16.260	18.118
		SHS	18.774	.375	18.037	19.511

Table 4.20 (Cont'd)

JK	11	AHS	19.559	.545	18.488	20.630
		SHS	19.292	.314	18.676	19.909
CK	9	AHS	19.178	.299	18.591	19.765
		SHS	20.042	.420	19.217	20.867
	10	AHS	17.828	.442	16.959	18.697
		SHS	18.868	.351	18.178	19.557
	11	AHS	19.269	.510	18.267	20.271
		SHS	18.952	.294	18.375	19.529
QL	9	AHS	16.780	.269	16.251	17.308
		SHS	15.975	.378	15.232	16.718
	10	AHS	15.797	.398	15.015	16.579
		SHS	16.725	.316	16.104	17.346
	11	AHS	16.738	.459	15.836	17.640
		SHS	15.932	.264	15.413	16.452
PA	9	AHS	73.470	1.357	70.804	76.135
		SHS	67.930	1.907	64.184	71.675
	10	AHS	68.222	2.008	64.278	72.167
		SHS	79.733	1.593	76.603	82.863
	11	AHS	66.361	2.316	61.811	70.910
		SHS	62.766	1.333	60.147	65.384

The estimated marginal means for grade level and school type reveal several notable patterns across dependent variables. The primary insights derived from the analyses are as follows:

- In SoBP, SHS students consistently scored lower than AHS students in 9th, 10th, and 11th grades. For example, in the 10th grade, AHS students scored $M = 15.09$ ($SE = 0.54$) compared to SHS students at $M = 14.88$ ($SE = 0.43$).
- For Source, SHS students reported higher scores than AHS students in 9th and 10th grades, with the most significant difference observed in the 10th grade, where SHS students scored $M = 15.06$ ($SE = 0.33$) compared to AHS students at $M = 13.99$ ($SE = 0.42$).
- In SK, the scores were relatively consistent across school types and grade levels, with minimal differences observed. SHS students scored slightly higher in the 9th and 11th grades, such as in the 9th grade where SHS students scored $M = 35.60$ ($SE = 0.60$) compared to AHS students at $M = 35.11$ ($SE = 0.43$).

- For JK, SHS students scored higher than AHS students in all grades, particularly in the 10th grade, where SHS students scored *M* = 18.77 (*SE* = 0.38) compared to AHS students at *M* = 17.19 (*SE* = 0.47).
- In CK, SHS students consistently scored higher in the 9th and 10th grades, but the difference diminished in the 11th grade. For example, in the 9th grade, SHS students scored *M* = 20.04 (*SE* = 0.42) compared to AHS students at *M* = 19.18 (*SE* = 0.30).
- QL scores showed mixed patterns, with SHS students scoring higher in the 10th grade (*M* = 16.73, *SE* = 0.32) compared to AHS students (*M* = 15.80, *SE* = 0.40), while AHS students scored higher in the 9th and 11th grades.
- For PA, SHS students outperformed AHS students in the 10th grade, with SHS students scoring *M* = 79.73 (*SE* = 1.59) compared to AHS students at *M* = 68.22 (*SE* = 2.01). However, in the 9th and 11th grades, AHS students reported higher PA scores than SHS students.

These findings highlight notable differences between AHS and SHS students across epistemic cognitions and PA, with SHS students generally excelling in dimensions such as Source, JK, and PA in the 10th grade, while AHS students showed higher performance in earlier grades and specific constructs like SoBP.

The estimated marginal means for students' perceptions and PA, broken down by gender and school type, reveal notable patterns across the dependent variables.

Table 4. 21 SPSS output for pairwise comparisons on DVs

Dependent Variable	School Type	(I) Grade Level	(J) Grade Level	Mean Difference (I-J)	Std. Error	Sig.^{b}
Source	AHS	9	10	1.241*	.508	.045
JK	AHS	10	11	-2.370*	.722	.003
CK	AHS	9	10	1.350*	.534	.035
PA	AHS	9	11	7.109*	2.684	.025
PA	SHS	9	10	-11.803*	2.485	<.001
PA	SHS	10	11	16.968*	2.077	<.001

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Bonferroni.

The pairwise comparisons using Bonferroni correction revealed significant differences across school type and grade levels for specific dependent variables. The findings are detailed in the following points:

- In Anadolu High Schools (AHS), 9th-grade students scored significantly higher than 10th-grade students in Source (*MD* = 1.241, *SE* = 0.508, *p* = .045).
- For JK in AHS, 11th-grade students scored significantly higher than 10th-grade students (*MD* = -2.370, *SE* = 0.722, *p* = .003).
- CK scores in AHS showed a significant increase for 9th-grade students compared to 10th-grade students (*MD* = 1.350, *SE* = 0.534, *p* = .035).
- Regarding PA, 11th-grade students in AHS scored significantly lower than 9th-grade students (*MD* = -7.109, *SE* = 2.684, *p* = .025).
- In Science High Schools (SHS), 11th-grade students scored significantly lower than 10th-grade students (*MD* = -16.968, *SE* = 2.077, $p < .001$), and 10th-grade students outperformed 9th-grade students (*MD* = 11.803, *SE* = 2.485, $p < .001$).

These results suggest that epistemic cognition dimensions, such as justification and changeability, fluctuate significantly across grades in AHS, while PA shows that students' PA is at its highest point in the 10th grade in SHS.

4.6.5 Summary

The correlation analysis revealed significant associations between PA, PPE, and SoBP across grade levels, gender, and school type. For AHS students, PA demonstrated consistent positive correlations with PPE across all grades, with the strongest association in 10th grade, followed by 11th and 9th grades. Among SHS students, PA was weakly correlated with PPE in 9th grade but showed a moderate correlation in 10th grade, while no significant associations were observed in 11th grade. In terms of SoBP, no significant correlation with PA was found for AHS male students, whereas in SHS, moderate positive correlations emerged for 9th and 11th grade male students. Further analysis of PPE sub-dimensions indicated that PA was positively associated with all dimensions, with the strongest relationship observed in QL. Similarly, SoBP showed a weak but significant association with QL, suggesting that students with a higher sense of belonging recognize the role of effort in learning physics. Gender-based analysis revealed no significant correlations for female students in SHS or for 9th and 11th grade female students in AHS, while strong and moderate correlations between PA and PPE were found for male students in SHS across all grades and for 10th-grade female students in AHS.

The MANOVA analysis revealed significant effects of grade level, gender, and school type on various dependent variables. By grade level, significant differences were observed in PA, JK, and CK, with small-to-moderate effect sizes and high observed power, indicating reliable findings. Specifically, PA showed the largest effect, while JK and CK had small effect sizes. In terms of gender, significant differences were found in students' SoBP and SK, both with small effect sizes. Males demonstrated higher SoBP and SK scores compared to females, with the effect on SoBP being more pronounced. Regarding school type, no significant main effects were identified. However, marginal differences were noted for JK, suggesting potential variability that may warrant further investigation. Interaction effects were also observed. A significant interaction between grade level and school type was identified for PA, while an interaction between gender and school type significantly influenced CK. The analysis reveals the following key trends, as summarized in Table 4.22.

Table 4. 22 Summary of the MANOVA Results

Dimension	Comparison	Description
SoBP	Grade Levels	No significant difference among grades
JK	11th > 9th & 10th	11th graders have more sophistication in JK
CK	9th > 10th	Decrease in CK for 10th graders
SK	11th > 10th	Improved epistemic structure in 11th grade
PA	11th < 9th & 10th	Sharp decline in PA for 11th graders

Table 4.22 (Cont'd)

SoBP	Male > Female	Males reported higher SoBP
SK	Female > Male	Females perceive knowledge as more coherent
SoBP	Male > Female	Males have higher SoBP in SHS
Source	Female > Male	Females have higher scores on Source in SHS
SK	Female > Male	Females have more sophisticated SK in AHS & SHS
JK	Female > Male	Females scored higher in JK in SHS
CK	Male > Female	Males scored higher in CK in AHS
Source	9th > 10th	9th graders have higher scores on Source in AHS
JK	11th > 10th	11th graders scored higher in JK than 10th in AHS
CK	9th > 10th	9th graders scored higher in CK than 10th in AHS
PA	11th < 9th in AHS; 11th < 10th in SHS; 10th > 9th in SHS	

CHAPTER 5

DISCUSSION & CONCLUSION

This study tested several hypotheses to explore the relationships between high school students' PA, SoBP, and PPE in Küçükçekmece, Istanbul. By examining these variables, the study also aimed to determine whether significant differences existed across school type, gender, and grade levels. This section integrates the findings, discusses their implications for educational practices and policies, and offers recommendations for future research to further clarify the dynamics of PA, SoBP, and PPE.

First of all, this study found that male students reported significantly higher SoBP compared to their female peers, a finding that aligns with a substantial body of research highlighting persistent gender disparities in physics education (Ladewig et al., 2020; Hazari et al., 2020; Li and Singh, 2021; Cwik and Singh, 2022; Li and Singh, 2023; Santana and Singh, 2023; Bottomley et al., 2024). These studies consistently reveal that societal stereotypes and male-dominated physics cultures often diminish female students' SoBP, leading to feelings of isolation and reduced motivation (Santana and Singh, 2023). Furthermore, these gendered experiences not only affect students' academic performance but also reduce their self-efficacy and long-term engagement with the field (Hazari et al., 2020).

Research emphasizes that fostering a strong SoBP in academic environments can significantly enhance female students' motivation and persistence. Teacher encouragement and peer support play critical roles in creating inclusive learning spaces where female students feel valued and respected (Martin et al., 2024). Moreover, fostering cooperative learning activities and challenging stereotypes that portray scientists as unapproachable or 'geeky' can help build a more supportive classroom culture (Lewis et al., 2016). Without deliberate efforts to ensure inclusivity, however, male students may dominate discussions, leaving female students feeling marginalized and reporting lower SoBP and self-efficacy (Aguillon et al., 2020). By addressing these structural and pedagogical barriers, educators can empower female students to persist and thrive in physics.

Additionally, this study demonstrated that the gender gap in SoBP was particularly pronounced in science high schools (SHS), where the competitive and academically rigorous environment may exacerbate existing gender-based challenges. This finding diverges from earlier research by Goodenow and Grady (1993), which reported consistent school-wide belonging scores across diverse schools and grade levels without significant variations. While their study provided valuable insights into general SOB, it did not account for the unique dynamics of subject-specific belonging, particularly in competitive disciplines like physics. The pronounced gender gap observed in SHS highlights the influence of cultural and academic pressures on students' sense of inclusion and suggests that these pressures are not evenly distributed across different educational contexts.

Expanding on the significance of belonging, research in education has long demonstrated that a strong SOB is crucial for positive academic outcomes. Students who feel connected to their school environment tend to be more motivated, exhibit higher self-esteem, and achieve greater 'academic success' (Aker & Şahin, 2022; Anderman, 2002; Furrer & Skinner, 2003; Goodenow & Grady, 1993; OECD, 2013; Osterman, 2000; Stout et al., 2013). However, **our study revealed no significant correlation between students' SoBP and their PA,** regardless of the type of school. This finding suggests a more complex relationship between 'belonging' and achievement within the context of physics education, potentially differing from the general trend across subjects.

This lack of correlation stands in contrast to prior studies documenting a positive link between 'school belonging' and 'academic success' in broader educational settings. For instance, Aker and Şahin (2022) found that SOB correlated with improved academic outcomes and reduced burnout among medical students.

Consistent with these findings, a meta-analysis by Korpershoek et al. (2019) confirmed a modest yet positive relationship between SOB and 'academic success' across different cultural contexts. Another research also highlights the impact of subject-specific belonging: Lewis et al. (2016) observed that a strong SOB in physics courses could enhance both motivation and achievement, while Cwik and Singh (2022) identified SoBP as a key predictor of student grades in physics.

Yet, the absence of a strong relationship between PA and SoBP in this study aligns more closely with findings by Liu et al. (2011), who reported no direct effect of 'school belonging' on 'academic performance' during high school transitions in China. *Their research suggested that 'academic success' may often be more influenced by cognitive skills than by emotional connections to school.* Since Turkey has an intensive examination system like China and students may have achievement goal orientation rather than mastery, they may not feel the same degree of emotional belonging to each course.

Interestingly, this study found no significant differences in SoBP across grade levels. This contrasts with findings from Whitcomb et al. (2022), who reported a decline in SoBP during the second year of university, attributed to the increasing complexity of advanced physics courses and shifts in peer dynamics. The stability observed at the high school level may stem from the structured nature of the curriculum and consistent support systems provided by teachers and peers. These findings underscore the importance of fostering a strong sense of belonging during high school, as it serves as a foundation for navigating the challenges of higher education, where SoBP becomes a critical determinant of success and retention (Hazari et al., 2020).

The findings of this study emphasize the need for targeted interventions to address gender disparities and promote SoBP across diverse educational contexts. Schools should implement inclusive teaching strategies, such as mentorship programs, cooperative group projects, and active efforts to challenge stereotypes. Creating classroom environments that value all students' contributions equally can significantly enhance SoBP and encourage greater academic persistence, particularly for female students. Furthermore, the stability of SoBP across grade levels highlights the importance of early interventions that build a resilient SOB, preparing students for the increased challenges of advanced physics courses.

Future research should explore how specific pedagogical practices, peer interactions, and teacher attitudes influence SoBP across different educational stages. Longitudinal studies tracking students from high school through university could provide valuable insights into how belonging evolves over time and its impact on academic and career outcomes in physics.

These findings regarding SoBP become more meaningful when considered alongside results indicating that PPE. **In this regard, the present study highlights the connection between PPE and PA.** Empirical research consistently links personal epistemology with 'academic achievement' across various subjects (Greene et al., 2018; Hofer, 2000). The current study's findings aligned with Greene et al.'s (2018) meta-analysis study, which emphasized the critical role that students' perceptions of knowledge and learning play in 'academic success'. Specifically, the positive correlation found here between PA and QL sub-dimension supports the broader understanding that students who view knowledge acquisition as an evolving and effort-driven process tend to adopt more effective learning strategies and perform better academically. Students who recognize the importance of sustained effort in mastering physics consistently achieve higher scores, echoing the conclusions of Kizilgunes et al. (2009). Researchers found that students who perceive knowledge as complex and effort-intensive are more motivated, employ effective learning strategies, and, as a result, attain higher 'academic performance'. Together, these findings underscore a central theme: success in scientific disciplines like physics depends not only on intellectual aptitude but also on resilience and sustained effort.

When examining PPE across grade levels, the study revealed that 11th-grade students exhibited significantly more advanced PPE compared to their younger peers, which is consistent with existing literature on the developmental progression of epistemology. Specifically, distinct patterns emerged in the dimensions of epistemic cognition, with 11th-grade students showing notably greater sophistication in JK than their 9th and 10th-grade counterparts. These findings are in line with research by Cano (2005), which suggests that older students tend to develop more advanced epistemic beliefs as they engage with increasingly complex academic tasks that require critical thinking.

Similarly, 11th graders exhibited improved epistemic sophistication in SK, reflecting their enhanced ability to organize and integrate knowledge coherently. These findings underscore the critical developmental stage represented by 11th grade, where exposure to advanced concepts and higher-order thinking tasks likely contributes to the refinement of epistemic cognition.

In contrast, the observed decline in CK among 10th-grade students compared to their 9th-grade counterparts highlights the variability in students' perceptions of knowledge during this stage. Fatma (2009) similarly reported fluctuations in CK development among Turkish students, emphasizing that growth in this dimension does not always progress uniformly with grade level. Such findings reflect the complex interplay of cognitive, contextual, and curricular factors in shaping epistemic beliefs.

On the other hand, the pronounced advancement in JK and SK among 11th graders suggests that these dimensions are particularly responsive to the rigorous demands of high school physics curricula. As students prepare for university-level education, they are required to critically evaluate information and synthesize complex ideas, fostering growth in these dimensions.

Similarly, the findings regarding the relationships between PA and PPE for both AHS and SHS students offer valuable insights into how students' academic achievements in physics are linked to their epistemic beliefs across grade levels. For

AHS students, the consistently positive correlations between PA and PPE across all grades suggest a relatively stable connection between academic performance and epistemic cognition throughout their high school years. The moderate strength of the relationship in 10th and 11th grades suggests that as students advance in their academic careers, their epistemic beliefs become more aligned with their achievements in physics, likely due to increased exposure to more complex concepts and learning tasks. Interestingly, the small-to-moderate relationship in 9th grade indicates that younger students may be at an earlier stage in forming these connections, with less developed epistemic beliefs still being influenced by other factors beyond academic performance.

For SHS students, the weak correlation observed in 9th grade supports the notion that the relationship between PA and PPE may be more tenuous at this stage. However, the moderate correlation in 10th grade indicates that as students in science-focused high schools begin to engage with more advanced material, their academic achievement in physics begins to more strongly reflect their evolving epistemic beliefs. The absence of significant correlations for 11th grade SHS students between PA and PPE, PA and SoBP, or PPE and SoBP suggests a potential disconnect at this grade level. This could be indicative of a shift in focus as students become more absorbed in preparing for exams and university entrance, possibly leading to less emphasis on the development of epistemic beliefs in relation to physics. The lack of significant correlations for 11th-grade students in SHS highlights the complexity of the relationship between academic achievement and epistemic beliefs, suggesting that other factors—such as the specific challenges of the curriculum or individual differences in learning approaches—may play a more prominent role at this stage.

This study revealed notable gender differences across several dimensions of epistemic cognition, emphasizing the complex interplay between gender, school type, and epistemic development.

Female students demonstrated more advanced beliefs in SK dimension compared to their male peers, perceiving knowledge as more coherent and interconnected across both AHS and SHS. These findings align with prior studies, such as Topçu and Yılmaz-Tüzün (2009) and Fatma (2009), which consistently reported that female students exhibit more sophisticated beliefs about knowledge acquisition and integration. The higher SK scores among females suggest that they may approach learning with a relational perspective, emphasizing the integration of new and existing knowledge.

In addition to SK, female students scored higher in Source and JK dimensions in SHS, indicating a stronger inclination to critically evaluate authoritative knowledge and justify their understanding through evidence and logical reasoning. Similarly, Aydemir et al. (2013) reported that female high school students demonstrated greater sophistication in JK, whereas males showed more advanced beliefs in the source and certainty dimensions. These consistent findings suggest that female students may approach learning with a more nuanced and relational perspective, particularly in dimensions like SK, where the ability to integrate and organize knowledge plays a critical role.

However, not all studies report significant gender differences. For instance, Chen and Pajares (2010) found no gender-based distinctions in epistemological beliefs among sixth-grade science students, and Yenice (2015) similarly observed no significant differences among pre-service science teachers.

Male students scored higher in the CK dimension in AHS, suggesting that they perceive knowledge as more adaptable and evolving compared to their female peers. This finding diverges from prior research, such as Fatma (2009), which reported more advanced CK beliefs among female students.

In SHS, female students scored higher in the Source dimension, indicating a stronger inclination to critically evaluate authoritative knowledge and actively construct their own understanding.

This suggests that female students in SHS are more likely to engage with knowledge in a reflective and analytical manner, questioning its validity and exploring its connections to broader contexts. Such a tendency could be attributed to the specific educational and cultural dynamics of SHS, where the academically rigorous environment might encourage female students to adopt more independent and critical approaches to learning.

Interestingly, these findings differ from the results of Aydemir et al. (2013), which reported that male students demonstrated more advanced beliefs in Source. This discrepancy may reflect variations in school culture or gender-specific experiences that shape students' epistemic beliefs. In SHS, female students might encounter unique challenges, such as navigating competitive academic settings, which could drive them to engage more critically with knowledge sources.

Female students in SHS also outperformed their male peers in the JK dimension, showcasing their advanced ability to justify knowledge using evidence and logical reasoning.

These findings highlight the complexity of gender dynamics in epistemic cognition, which vary not only across dimensions but also by school type. Female students' strengths in SK, Source, and JK reflect their capacity for relational and evidence-based thinking, while male students' higher scores in CK suggest a different approach to understanding knowledge. Educational practices should aim to bridge these gaps by fostering inclusive environments that support all dimensions of epistemic development.

Distinct patterns emerged across grade levels, particularly in Source, JK, and CK.

Ninth-grade students scored higher in Source compared to 10th graders, suggesting that younger students approach authoritative knowledge with a more open and evaluative mindset.

Interestingly, CK scores also declined between 9th and 10th grades, indicating that younger students in 9th grade perceive knowledge as more adaptable and dynamic.

This pattern may be linked to the transitional phase that 9th-grade students experience when moving from middle school to high school. During this period, their understanding of knowledge may still be shaped by the less rigid and more exploratory nature of middle school education, allowing for a more flexible perception of knowledge. However, as students advance to 10th grade, they encounter a more structured and assessment-focused curriculum that emphasizes mastery of established concepts, potentially leading to a more static view of knowledge. Additionally, the increased academic demands and growing familiarity with physics content in 10th grade might contribute to the development of cognitive schemas that prioritize stability over adaptability. These shifts suggest that the observed decline in CK may reflect not only curricular influences but also the evolving cognitive frameworks that students develop as they adapt to the changing expectations of high school education.

These findings underscore the dynamic and multifaceted nature of epistemic cognition in physics education, highlighting the significant influences of gender, grade level, and school type. Female students consistently demonstrated strengths in dimensions such as SK, Source, and JK, reflecting their capacity for relational and evidence-based thinking. In contrast, male students' higher scores in CK in AHS suggest a more static perception of knowledge, emphasizing the need for targeted interventions to balance these differences. Additionally, the observed fluctuations in dimensions like CK and Source during transitional grades, particularly 10th grade, point to the critical role of curriculum design and instructional strategies in shaping students' epistemic beliefs.

Research suggests that explicitly teaching students that their scientific abilities can be developed through effort may enhance their appreciation for the processes of learning, problem-solving, and perseverance in the face of failure, rather than overemphasizing outcomes like test scores or grades (Blackwell et al., 2007; Bandura, 1997). For instance, interventions emphasizing the malleability of intelligence have demonstrated significant positive effects on students' implicit theories of ability and academic trajectories (Aronson et al., 2002). Integrating such interventions into science education could foster students' confidence in their ability to learn and succeed.

Moreover, it is essential to teach students that scientific knowledge is complex, continuously evolving, and empirically constructed. While traditional methods, such as presenting the historical development of scientific concepts, provide some insight into the progression of ideas, they often fail to explicitly address the epistemic nature of science (Lederman, 1999). Instead, collaborative debate and argumentation have been shown to be more effective in improving students' conceptions of scientific knowledge. According to Bricker and Bell (2008), argumentation is central to producing and evaluating scientific knowledge and should therefore be a core component of science education. Collaborative debate enables students to engage with the social construction of scientific ideas and connect their classroom learning to broader real-world contexts, making science more relevant and meaningful (Bell & Linn, 2002).

Lastly, previous studies have not directly examined the relationship between PPE and SoBP, though some research has explored connections between epistemology and related affective factors such as 'self-efficacy' and self-concept (Chen & Pajares, 2010; Guo et al., 2022; Hofer, 1994; Ulu, 2023; Urhahne, 2006). The findings of this study contribute to the literature by suggesting that boys with a strong SoBP show a positive association with 'personal epistemology', indicating that *affective factors might indeed shape students' epistemologies.*

Research consistently demonstrates that beliefs about knowledge significantly impact self-perception and motivation in academic contexts. For example, Burns et al. (2018) and Khine et al. (2020) found that students with advanced epistemic cognition exhibit higher levels of 'self-efficacy' and a more positive self-concept, enhancing their confidence in academic abilities. Hofer (1994) further highlighted that college students with sophisticated mathematical beliefs display greater 'self-efficacy' in math. Likewise, Chen and Pajares (2010) linked nuanced knowledge beliefs with increased confidence in completing academic tasks, particularly in science subjects. Urhahne (2006) also connected epistemological beliefs with self-concept, noting that students with well-developed science beliefs tend to possess a stronger self-concept in science, a key component of their science identity. Guo et al. (2022) extended this by using structural equation modeling (SEM) to show that epistemological beliefs affect science identity through reflective thinking, impacting interest, competence, and recognition in science. Reflective thinking mediated these effects, reinforcing students' confidence and self-concept through introspection.

To broaden the insights from this study, it is first recommended that similar research be conducted across diverse cities and districts. Expanding the geographic scope could provide a more comprehensive understanding of the factors influencing student achievement. Additionally, given that participants did not take identical written exams, there is a possibility that variations in assessment content may have impacted the results. As a result, direct comparisons between student achievements were avoided to ensure the integrity of the findings.

For future research, a more focused analysis on physics achievement is advised, potentially through standardized exams administered to both Anatolian and science high school students. Such consistency in assessment would offer a clearer picture of academic performance differences across school types. Further, including a wider range of school types, such as vocational high schools, could enrich the data and enhance the generalizability of the study's conclusions.

Given the significant impact of teachers on students, it is recommended that future studies also involve teachers. Building on the findings of Julius and Evans (2015), fostering student-teacher relationships that promote reflective and intellectual mentorship may positively influence students' belonging and epistemic cognition as well as academic success.

Conclusion

This study sheds light on the multifaceted relationships among high school students' physics-related outcomes (PA, SoBP, and PPE) and key demographic and educational factors such as school type, grade level, and gender within Anatolian and science high schools. The findings reveal the importance of fostering equitable and inclusive educational environments that address disparities in belonging and epistemic cognition.

Gender emerged as a critical determinant, with male students reporting higher SoBP, particularly in competitive environments like science high schools, while female students demonstrated greater sophistication in epistemic cognition dimensions such as SK, Source, and JK. Grade-level differences highlighted the developmental trajectories of epistemic beliefs, with significant advancements in 11th grade and transitional fluctuations in 10th grade, reflecting the dynamic interplay of cognitive, contextual, and curricular factors.

These findings call for targeted interventions to bridge gender disparities, support transitions across grade levels, and foster an inclusive learning culture that nurtures all students' epistemic and academic potential. By integrating practices such as collaborative debate, mentorship, and explicit instruction on the evolving nature of scientific knowledge, educators can help students to navigate the challenges of physics education and beyond.

REFERENCES

Ada, E. N., Karabekmez, S., Alp, H., & Pehlevan, Z. (2016). The examining the sense of belonging relating to their department of physical education teacher candidates according to different variables. *Turkiye Klinikleri Journals of Sports Scienc*e, 8(2), 57–65.

Adams, W. K., Perkins, K. K., Podolefsky, N. S., Dubson, M., Finkelstein, N. D., & Wieman, C. E. (2006). New instrument for measuring student beliefs about physics and learning physics: The Colorado Learning Attitudes about Science Survey. *Physical Review Special Topics–Physics Education Research*, 2(1), Article 010101.

Aguillon, S. M., Siegmund, G.-F., Petipas, R. H., Drake, A. G., Cotner, S., & Ballen, C. J. (2020). Gender differences in student participation in an active-learning classroom. *CBE—Life Sciences Education*, 19(1), 1.

Aker, S., & Şahin, M. K. (2022). The relationship between school burnout, sense of school belonging, and 'academic achievement' in preclinical medical students. *Advances in Health Sciences Education*, 27(4), 949–963.

Alkan, N. (2016). Psychological sense of University membership: An adaptation study of the PSSM scale for Turkish University students. *Journal of Psychology*, 150(4), 431–449.

Alpaslan, M. M., Yalvac, B., Loving, C. C., & Willson, V. L. (2016). Exploring the relationship between high school students' 'physics-related personal epistemologies' and self-regulated learning in Turkey. *International Journal of Science and Mathematics Education*, 14(2), 297–317.

Alpaslan, M. M. (2019). Examining relations between physics-related personal epistemology and motivation in terms of gender. *The Journal of Educational Research*, 112(3), 397–410.

Anderman, E. M. (2002). School effects on Psychological outcomes during adolescence. *Journal of Educational Psychology*, 94, 795−809.

Aronson, J., Fried, C. B., & Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Experimental Social Psychology*, 38, 113–125.

Aydemir, N., Aydemir, M., & Boz, Y. (2013). High school students' epistemological beliefs. *Kastamonu Educational Journal*, 21(4), 1306–1316.

The labour market for physics skills in the UK and Ireland (n.d.). *Institute of Physics*. Retrieved from https://www.iop.org/sites/default/files/2022-01/Physics-in-demand-labour-market-uk-ireland.pdf

Barca, A. (1999). *Manual del cuestionario de procesos y estrategias de aprendizaje para el alumnado de educacio´n secundaria [CEPS; Manual for the learning process and strategies for secondary-level students]*. A Corun˜a: Publicaciones de la Revista Galego-Portuguesa de Psicoloxı´a e Educacio´n.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York: W.H. Freeman.

Bao, L., & Koenig, K. (2019). Physics education research for 21st-century learning. *Disciplinary and Interdisciplinary Science Education Research*, 1(1), 1-12.

Baumeister, R. F., & Leary, M. R. (1995). The need to belong: Desire for interpersonal attachments as a fundamental human motivation. *Psychological Bulletin*, 117(3), 497–529.

Baytelman, A., Iordanou, K., & Constantinou, C. P. (2020). Epistemic beliefs and prior knowledge as predictors of the construction of different types of arguments on socioscientific issues. *Journal of Research in Science Teaching*, 57(8), 1199–1227.

Baxter Magolda, M. B. (1987, April). *Gender differences in cognitive development*. Paper presented at the Annual Meeting of the American Educational Research Association, Washington, DC.

Bell, P., & Linn, M. C. (2002). Beliefs about science. How does science instruction contribute? In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The psychology of beliefs about knowledge and knowing* (pp. 321–346). Mahwah, NJ: Erlbaum.

Belenky, M. F. (1986). *Women's ways of knowing: The development of self, voice, and mind.*

Bottomley, E., Wild, V., Miles, P. J., Mavor, K. I., & Kohnle, A. (2024). Gender and the Social Cure in Undergraduate Physics Students: Physics Identity, Self-efficacy, Belonging, and Wellbeing. *International Journal of Science and Mathematics Education*, 22(4), 721–735.

Bråten, I., Ferguson, L. E., Strømsø, H. I., & Anmarkrud, Ø. (2013). Justification beliefs and multiple-documents comprehension. *European Journal of Psychology of Education*, 28(3), 879–902.

Bricker, L. A., & Bell, P. (2008). Conceptualizations of argumentation from science studies and the learning sciences and their implications for the practices of science education. *Science Education*, 92, 473–498.

Burns, R. A., Crisp, D. A., & Burns, R. B. (2018). Competence and affect dimensions of self-concept among higher education students: A factorial validation study of an academic subject-specific self-concept. *European Journal of Psychology of Education*, 33(4), 649–663. https://doi.org/10.1007/s10212-018-0369-x

Cano, F. (2005). Epistemological beliefs and approaches to learning: Their change through secondary school and their influence on academic performance. *British Journal of Educational Psychology*, 75(2), 203–222.

Chan, K., & Elliott, R. G. (2002). Exploratory Study of Hong Kong Teacher Education Students' Epistemological Beliefs: Cultural Perspectives and Implications on Beliefs Research. *Contemporary Educational Psychology*, 27(3), 392-414.

Chen, J. A., & Pajares, F. (2010). Implicit theories of ability of Grade 6 science students: Relation to epistemological beliefs and academic motivation and achievement in science. *Contemporary Educational Psychology*, 35(1), 75-87.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences*, 2nd ed. Hillsdale, NJ: Erlbaum.

Conley, A. M., Pintrich, P. R., Vekiri, I., & Harrison, D. (2004). Changes in epistemological beliefs in elementary science students. *Contemporary Educational Psychology*, 29, 186-204.

Cwik, S., & Singh, C. (2022). Students' sense of belonging in introductory physics course for bioscience majors predicts their grade. *Physical Review Physics Education Research*, 18(1).

Dare, E. A., & Roehrig, G. H. (2016). 'If I had to do it, then I would': Understanding early middle school students' perceptions of physics and physics-related careers by gender. *Physical Review Physics Education Research*, 12(2).

DeWitt, J., & Archer, L. (2015). Who aspires to a science career? A comparison of survey responses from primary and secondary school students. *International Journal of Science Education,* 37(13), 2170-2192.

Dow-Fleisner, S., Leong, A. D., & Lee, H. (2023). The interaction between peer bullying and school connectedness on youth health and wellbeing. *Children and Youth Services Review*, 155, 107147.

Dutcher, J. M., Lederman, J., Jain, M., Price, S., Kumar, A., Villalba, D. K., Tumminia, M. J., Doryab, A., Creswell, K. G., Riskin, E., Sefdigar, Y., Seo, W., Mankoff, J., Cohen, S., Dey, A., & Creswell, J. D. (2022). Lack of belonging predicts depressive symptomatology in college students. *Psychological Science*, 33(7), 1048–1067.

Dweck, C. S. (2006). Is math a gift? Beliefs that put females at risk. In S. J. Ceci & W. M. Williams (Eds.), *Why aren't more women in science? Top researchers debate the evidence* (pp. 47–55). Washington, DC: American Psychological Association

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual review of Psychology*, 53(1), 109–132.

Elby, A., Frederiksen, J., Schwarz, C., & White, B. (1997, March). *EBAPS: Epistemological beliefs assessment for physical sciences.* Paper presented at the Annual Conference of the American Educational Research Association, Chicago, IL.

Elder, A. D. (2002). Characterizing fifth grade students' epistemological beliefs in science. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The Psychology of beliefs about knowledge and knowing* (pp. 347-363). Lawrence Erlbaum Associates Publishers.

Fatma, K. (2009). *Investigating students' epistemological beliefs through gender, grade level, and field of study* (Master's thesis). Middle East Technical University, Ankara.

Feser, M. S., Rabe, T., & Haak, I. (2024). Echoes of social experience: Tracing the link between a sense of belonging in school physics classes and physics students' persistence in higher education. *European Journal of Physics*, 45(4), 045704–045704.

Foster, C. E., Horwitz, A., Thomas, A., Opperman, K., Gipson, P., Burnside, A., Stone, D. B., King, C. A. (2017). Connectedness to family, school, peers, and community in socially vulnerable adolescents. *Children and Youth Services* Review, 81, 321–331.

Fraenkel, J.R., N.E. Wallen and H.H. Hyun, 2012, *Internal Validity. How to Design and Evaluate Research in Education*, McGraw-Hill, New York.

Furrer, C., & Skinner, E. (2003). Sense of relatedness as a factor in children’s academic engagement and performance. *Journal of Educational Psychology*, 95(1), 148–162.

Good, C., Rattan, A., & Dweck, C. S. (2012). Why do women opt out? Sense of belonging and women's representation in mathematics. *Journal of Personality and Social Psychology*, 102(4), 700–717.

Goodenow, C. (1993). The Psychological sense of school membership among adolescents: Scale development and educational correlates. *Psychology in the Schools*, 30, 79-90.

Goodenow, C., & Grady, K. (1993). The relationship of school belonging and friends’ values to academic motivation among urban adolescent students. *The Journal of Experimental Education*, 62(1), 60–71.

Greene, J. A., Cartiff, B. M., & Duke, R. F. (2018). A meta-analytic review of the relationship between epistemic cognition and ‘academic achievement’. *Journal of Educational Psychology,* 110(8), 1084–1111.

Guo, X., Hao, X., Deng, W., Ji, X., Xiang, S., & Hu, W. (2022). The relationship between epistemological beliefs, reflective thinking, and science identity: A structural equation modeling analysis. *International Journal of STEM Education*, 9(1), 1-17.

Hammer, D., & Elby, A. (2002). On the form of a personal epistemology. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The Psychology of beliefs about knowledge and knowing* (pp. 169–190). Lawrence Erlbaum Associates Publishers.

Hagerty, B.M.K., Lynch-Sauer, J., Patusky, K., Bouwsema, M., Collier, P. (1992). Sense of belonging: a vital mental health concept. *Archives of Psychiatric Nursing*, 6, 172-177.

Hazari, Z., Sonnert, G., Sadler, P. M., & Shanahan, C. (2010). Connecting high school physics experiences, outcome expectations, physics identity, and physics career choice: A gender study. *Journal of Research in Science Teaching*, 47(8), 978-1003.

Hazari, Z., Sadler, P. M., & Sonnert, G. (2013). The Science Identity of College Students: Exploring the Intersection of Gender, Race, and Ethnicity. *Journal of College Science Teaching*, 42(5), 82-91.

Hazari, Z., Chari, D., Potvin, G., & Brewe, E. (2020). The context dependence of physics identity: Examining the role of performance/competence, recognition, interest, and sense of belonging for lower and upper female physics undergraduates. *Journal of Research in Science Teaching*, 57(10), 1583-1607.

Hofer, B. K., & Pintrich, P. R. (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67(1), 88–140.

Hofer, B. K. (2000). Dimensionality and disciplinary differences in personal epistemology. *Contemporary Educational Psychology*, 25, 378-405.

Hofer, B. K. (2001). Personal epistemology research: Implications for learning and teaching. *Educational Psychology Review*, 13(4), 353–383.

Hofer, B. K. (2012). Personal epistemology as a Psychological and educational construct: An introduction. In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The Psychology of beliefs about knowledge and knowing* (pp. 3–14). Taylor & Francis.

Hofer, B. K. (2016). Epistemic cognition as a Psychological construct: Advancements and challenges. In J. A. Greene, W. A. Sandoval, & I. Bråten (Eds.), *Handbook of epistemic cognition* (pp. 20–35). Routledge.

Holgate, S. A. (2023). The demand for physics skills in the UK workplace. *Physics World,* 36(10), 44–47.

Julius, M., Evans, A.S. (2015) Study of the relationship between study habits and academic achievement of students: A case of Spicer Higher Secondary School, India. *International Journal of Educational Administration and Policy Studies*, 7(7), 134–141.

Kang, H., Barton, A. C., Tan, E., Simpkins, S. D., & Turner, C. (2019). How do middle school girls of color develop STEM identities? Middle school girls' participation in science activities and identification with STEM careers. *Science Education*, 103(2), 418-439.

Kapucu, S., & Bahçivan, E. (2015). High school students' scientific epistemological beliefs, self-efficacy in learning physics and attitudes toward physics: a structural equation model. *Research in Science & Technological Education*, 33(2), 252–267.

Kardash, C. M., & Howell, K. L. (2000). Effects of epistemological beliefs and topic-specific beliefs on undergraduates' cognitive and strategic processing of dual-positional text. *Journal of Educational Psychology*, 92(3), 524–535.

Kautz, T., Heckman J. J., Diris R., Weel B., Borghans L., (2014), 'Fostering and Measuring Skills: Improving Cognitive and Non-cognitive Skills to Promote Lifetime Success', *OECD Education Working Papers*, No. 110, OECD Publishing, Paris.

Kelly, M. (2020). Epistemology, epistemic belief, personal epistemology, and epistemics: A review of concepts as they impact information behavior research. *Journal of the Association for Information Science and Technology*, 72(4), 507–519.

Khine, M. S., Fraser, B. J., & Afari, E. (2020). Structural relationships between learning environments and students' non-cognitive outcomes: Secondary analysis of PISA data. *Learning Environments Research*, 23(3), 395–412.

Kırıktas, H., & Şahin, M. (2019). Lise öğrencilerinin STEM alanlarına yönelik kariyer ilgileri ve tutumlarının demografik değişkenler açısından incelenmesi. *Academia Eğitim Araştırmaları Dergisi*, 4(1), 55-77.

Kızılgüneş, B., Tekkaya, C., & Sungur, S. (2009). Modeling the relations among students' epistemological beliefs, motivation, learning approach, and achievement. *The Journal of Educational Research*, 102(4), 243–256.

King, P. M., & Kitchener, K. S. (2004). Reflective judgment: Theory and research on the development of epistemic assumptions through adulthood. *Educational Psychologist*, 39(1), 5–18.

Kuhn, D. (1991*). The skills of argument*. Cambridge University Press.

Kuhn, D., Cheney, R., & Weinstock, M. (2000). The development of epistemological understanding. *Cognitive Development*, 15(3), 309-328.

Kuhn, D., & Weinstock, M. (2002). What is epistemological thinking and why does it matter? In B. K. Hofer & P. R. Pintrich (Eds.), *Personal epistemology: The Psychology of beliefs about knowledge and knowing* (pp. 121–144). Lawrence Erlbaum Associates Inc.

Kurt, F. (2009). *Investigating students' epistemological beliefs through gender, grade level, and fields of study* [M.S. - Master of Science]. Middle East Technical University.

Korpershoek, H., Canrinus, E. T., Fokkens-Bruinsma, M., & de Boer, H. (2019). The relationships between school belonging and students' motivational, social-emotional, behavioural, and academic outcomes in secondary education: a meta-analytic review. *Research Papers in Education*, 35(6), 641–680.

Ladewig, A., Keller, M., Klusmann, U., 2020, Sense of Belonging as an Important Factor in the Pursuit of Physics: Does It Also Matter for Female Participants of the German Physics Olympiad?' *Frontiers in Psychology*, 11.

Lederman, N. G. (1999). Teachers' understanding of the nature of science and classroom practice. Factors that facilitate or impede the relationship. *Journal of Research in Science Teaching,* 36, 916–929.

Lee, S. W., Luan, H., Lee, M., Chang, H., Liang, J., Lee, Y., & Tsai, C. (2021). Measuring epistemologies in science learning and teaching: A systematic review of the literature. *Science Education*, 105(5), 880–907.

Lewis, K. L., & Hodges, S. D. (2014). Expanding the concept of belonging in academic domains: Development and validation of the Ability Uncertainty Scale. *Learning and Individual Differences*, 37, 197-202.

Lewis, K. L., Stout, J. G., Pollock, S. J., Finkelstein, N. D., & Ito, T. A. (2016). Fitting in or opting out: A review of key social-psychological factors influencing a sense of belonging for women in physics. *Physical Review Physics Education Research*, 12(2).

Li, Y., & Singh, C. (2021). Effect of gender, self-efficacy, and interest on perception of the learning environment and outcomes in calculus-based introductory physics courses. *Physical Review Physics Education Research*, 17(1).

Li, Y., & Singh, C. (2023). Sense of belonging is an important predictor of introductory physics students' academic performance. *Physical Review*, 19(2).

Liu, Y., & Zhang, L. (2011). Trajectories of Chinese students' sense of school belonging and 'academic achievement' over the high school transition period. *Learning and Individual Differences*, 21(2), 187–190.

Lodewyk, K. R. (2007). Relations among Epistemological Beliefs, 'academic achievement', and Task Performance in Secondary School Students. *Educational Psychology*, 27(3), 307–327.

Ma, X. (2003). Sense of Belonging to School: Can Schools Make a Difference? *The Journal of Educational Research*, 96(6), 340–349.

Marchand, G. C., & Taasoobshirazi, G. (2012). Stereotype Threat and Women's Performance in Physics. *International Journal of Science Education*, 35(18), 3050–3061.

Martin, A. J., Collie, R. J., Stephan, M., Flesken A., Halcrow, F., & McCourt, B. (2024). What is the role of teaching support in students' motivation and engagement trajectories during adolescence? A four-year latent growth modeling study. *Learning and Instruction*, 92, 101910–101910.

Maslow, A.H. (1943). A theory of human motivation. *Psychological Review*, 50, 370–396.

Ministry of National Education (MoNE) (2017)

Mulvey, K. L., Mathews, C. J., Knox, J., Joy, A., & Cerda-Smith, J. (2022). The role of inclusion, discrimination, and belonging for adolescent Science, Technology, Engineering, and Math engagement in and out of school. *Journal of Research in Science Teaching*, 59(8), 1447–1464.

OECD. (2013). *PISA 2012 results: Ready to learn (Volume III): Students' engagement, drive and self-beliefs*. OECD Publishing.

Osterman, K. F. (2000). Students' Need for Belonging in the School Community. *Review of Educational Research*, 70(3), 323.

Özkan, S. (2008). *Modelling elementary students' science achievement: The interrelationships among epistemological beliefs, learning approaches, and self-regulated learning strategies* (Doctoral thesis). Middle East Technical University, Ankara.

Özmen K., Özdemir Ö.F., 2019, 'Conceptualisation and development of the physics related personal epistemology questionnaire (PPEQ*)', International Journal of Science Education*, 41:9, 1207-1227.

Özmen, K., & Özdemir, Ö. F. (2024). Explicit versus implicit instruction: Effects of epistemological enhancement on ninth graders' physics-related personal epistemology and 'physics achievement'. *Research in Science Education*, 54(3), 439–458.

Pamuk, S., Sungur, S., & Oztekin, C. (2017). A multilevel analysis of students' science achievements in relation to their self-regulation, epistemological beliefs, learning environment perceptions, and teachers' personal characteristics. *International Journal of Science and Mathematics Education*, 15(8), 1423–1440.

Perry, W. G. (1968). *Patterns of development in thought and values of students in a liberal arts college: A validation of a scheme* (Final Report, Project No. 5-0825, Contract No. SAE-8973). Bureau of Study Counsel, Harvard University. (ED024315)

Perry, W. G., Jr. (1970). *Forms of intellectual and ethical development in the college years: A scheme.* Holt, Rinehart & Winston.

Pittman, L. D., & Richmond, A. (2007). Academic and Psychological Functioning in Late Adolescence: The Importance of School Belonging. *The Journal of Experimental Education*, 75(4), 270–290.

Qian, G., & Alvermann, D. (1995). Role of epistemological beliefs and learned helplessness in secondary school students' learning science concepts from text. *Journal of Educational Psychology*, 87(2), 282–292.

Rainey, K., Dancy, M., Mickelson, R., Stearns, E., & Moller, S. (2018). Race and gender differences in how a sense of belonging influence decisions to major in STEM. *International Journal of STEM Education*, 5(1), 1-14.

Redish, E. F. (1994). The implications of cognitive studies for teaching physics. *American Journal of Physics*, 62(6), 796–803.

Ryan, M. P. (1984). Monitoring text comprehension: Individual differences in epistemological standards. *Journal of Educational Psychology*, 76(2), 248–258.

Santana, L. M., & Singh, C. (2023). Effects of male-dominated physics culture on undergraduate women. *Physical Review Physics Education Research*, 19(2), Article 020134.

Schommer, M. (1990). Effects of beliefs about the nature of knowledge on comprehension. *Journal of Educational Psychology*, 82, 498–504.

Schommer, M., Calvert, C., Gariglietti, G., & Bajaj, A. (1997). The development of epistemological beliefs among secondary students: A longitudinal study. *Journal of Educational Psychology*, 89(1), 37–40.

Schlatter, E., Molenaar, I., & Lazonder, A. W. (2020). Individual Differences in Children's Development of Scientific Reasoning Through Inquiry-Based Instruction: Who Needs Additional Guidance? *Frontiers in Psychology*, 11, 531321.

Schraw, G., & Sinatra, G. M. (2004). Epistemological development and its impact on cognition in academic domains. *Contemporary Educational Psychology*, 29(2), 95–102.

Smith, T. J., Hong, R., Hsu, Y., & Lu, Y. (2022). The relationship of sense of school belonging to physics attitude among high school students in advanced physics courses. *Science Education*, 106(4), 830-851.

Solomon, D., Battistich, V., Kim, D.-I., & Watson, M. (1996). Teacher practices associated with students' sense of the classroom as a community. *Social Psychology of Education: An International Journal*, 1(3), 235–267.

Stathopoulou, C., & Vosniadou, S. (2007). Exploring the relationship between physics-related epistemological beliefs and physics understanding. *Contemporary Educational Psychology*, 32(3), 255-281.

Stout, J. G., Ito, T. A., Finkelstein, N. D., & Pollock, S. J. (2013). How a gender gap in belonging contributes to the gender gap in physics participation. *AIP Conference Proceedings*, 1513(1), 402–405.

Topçu, M. S., & Yılmaz Tüzün, Ö. (2007). *Relationships among elementary school students' epistemological beliefs, metacognitive skills, and constructivist learning environment perceptions.* Presented at the American Educational Research Association (AERA) Annual Meeting.

Topcu, M. S., & Yilmaz Tuzun, O. (2009). Elementary students' metacognition and epistemological beliefs considering science achievement, gender, and socioeconomic status. *Ilkogretim Online*, 8(3), 676–693.

Trujillo, G., & Tanner, K. D. (2014). Considering the role of affect in learning: Monitoring students' self-efficacy, sense of belonging, and science identity. *CBE—Life Sciences Education*, 13(1), 6–15

Tsai, C.-C., & Liu, S.-Y. (2005). Developing a multi-dimensional instrument for assessing students' epistemological views toward science. *International Journal of Science Education*, 27(13), 1621–1638.

Ulu, Y., & Yerdelen-Damar, S. (2024). Metacognition and epistemic cognition in physics are related to physics identity through the mediation of physics self-efficacy. *Physical Review Physics Education Research*, 20(1), Article 010130.

Urhahne, D. (2006). Die Bedeutung domänenspezifischer epistemologischer Überzeugungen für Motivation, Selbstkonzept und Lernstrategien von Studierenden [The importance of domain-specific epistemological beliefs for students' motivation, self-concept and learning strategies]. *Zeitschrift für Pädagogische Psychologie / German Journal of Educational Psychology*, 20(3), 189–198.

Whitcomb, K. M., Maries, A., & Singh, C. (2022). Progression in self-efficacy, interest, identity, sense of belonging, perceived recognition, and effectiveness of peer interaction of physics majors and comparison with non-majors and Ph.D. students. *Research in Science Education*, 53(3), 525–539.

Wild, S. (2023). Trajectories of subject-interests development and influence factors in higher education. *Current Psychology*, 42(15), 12879–12895.

Wilson, D., Jones, D., Fraser Bocell, Crawford, J., Mee Joo Kim, Veilleux, N., Floyd-Smith, T., Bates, R., & Plett, M. (2015). Belonging and Academic Engagement Among Undergraduate STEM Students: A Multi-institutional Study. *Research in Higher Education*, 56(7), 750–776.

Wong, E. H., Rosales, K. P., & Looney, L. (2023). Improving Cognitive Abilities in School-Age Children via Computerized Cognitive Training: Examining the Effect of Extended Training Duration. *Brain Sciences*, 13(12), 1618.

Yang, F. Y., & Tsai, C. C. (2012). Personal epistemology and science learning: A review on empirical studies. In B. Fraser, K. Tobin, & C. McRobbie (Eds.), *Second international handbook of science education* (Vol. 24, pp. 179–191). Springer.

Yenice, N. (2015). An analysis of science student teachers' epistemological beliefs and metacognitive perceptions about the nature of science. *Educational Sciences: Theory and Practice,* 15(6), 1623–1636.

Yerdelen-Damar, S., & Eryılmaz, A. (2021). Promoting conceptual understanding with explicit epistemic intervention in metacognitive instruction: Interaction between the treatment and epistemic cognition. *Research in Science Education*, 51(3), 547–575.

APPENDICES

A. The Physics-Related Personal Epistemology Questionnaire

Fizik ile ilgili Kişisel Epistemoloji Ölçeği

Okuduğunuz Eğitim Kurumu Türü: □ Anadolu Lisesi □ Fen Lisesi						
Sınıfınız/ Şube:						
Cinsiyetiniz: □ Kız □ Erkek						
Aşağıda fiziği öğrenme süreciniz ile ilgili düşüncelerinizi belirlemek için bazı ifadeler yer almaktadır. Lütfen her ifadeyi dikkatle okuyunuz ve size uygun olan tek bir yanıtı "X" ile işaretleyiniz. Araştırmanın geçerliliği açısından cevaplarınızın eksiksiz olması gereklidir. Bilimsel bir çalışmaya katkıda bulunduğunuz için teşekkür ederiz.		**Kesinlikle Katılmıyorum**	**Katılmıyorum**	**Kararsızım**	**Katılıyorum**	**Kesinlikle Katılıyorum**
1	Fizik dersindeki farklı konularda öğrendiğim bilgilerin birbirleriyle ilişkisini kurmam.					
2	Fizik dersinde yeni bilgileri sahip olduğum bilgilerle ilişkilendirerek öğrenirim.					
3	Fizik dersinde bir konuyu anlayabilmem için konuyla ilgili temel kavramları anlamam gerekir.					
4	Fizik dersinde öğrendiğim bilgiler birbiriyle tutarlı (uyumlu) olmak zorunda değil.					
5	Fizik dersinde bir konuyu önceden öğrendiğim bilgiler sayesinde anlarım.					
6	Fizik dersinde karmaşık ya da üst düzey konuları anlayabilmem için temel kavramları anlamam gerekir.					
7	Fizik dersinde bir konuyu anlayabilmem için önceden öğrendiğim bilgilere ihtiyacım yok.					
8	Fizik dersinde yeni konuyla ilgili kavramları önceden öğrendiklerimle ilişkilendirerek anlamlı hale getiririm.					

9	Fizik dersinde verilen bilgilerle önceden öğrendiğim bilgiler uyumlu olmalıdır.					
10	Fizik dersinde verilen bilgiler benim doğru bildiklerime ters düşerse bu bilgilerin mantığını sorgularım.					
11	Fizik dersinde verilen bilgiler önceki bildiklerimle çelişirse, bu bilgilerin mantığını sorgulamam.					
12	Fizik dersinde verilen bilgileri ancak üzerinde düşünürsem (sorgularsam) kendim için anlamlı hale getirebilirim.					

13	Fizik dersinde verilen bilgiler doğru olabilir ancak bu bilgilerin benim bilgilerimle uyumlu (tutarlı) olup olmadığını sorgularım.					
14	Fizikteki bilgiler bilim insanları tarafından keşfedilmiş olabilir, ama bize verilen bu bilgileri ancak üzerinde düşünürsem (sorgularsam) kendi bilgim haline getirebilirim.					
15	Fizik dersinde öğrendiğim bilgiler hiçbir zaman değişmeyecek fiziksel gerçeklerdir; bu yüzden kendi bilgilerim de değişmeyecektir.					
16	Fizik ile ilgili şu an doğru olarak öğrendiklerim (yakın ya da uzak) gelecekte çürütülebilir; bu yüzden gerekirse kendi fizik bilgilerimi değiştiririm.					
17	Mantıklı açıklamalarla desteklenen yeni bilgiler sunulursa önceki fizik bilgilerimi değiştiririm.					
18	Fizik dersinde doğru olarak öğrendiğim ve mantığını kavradığım bilgilerin sonradan değişeceğine inanmıyorum.					
19	Öğrendiğim yeni bilgiler sayesinde sahip olduğum fizik bilgisi değişir ve gelişir.					
20	Fizik öğretmenimin anlattıklarını sorgulamadan kabul ederim.					
21	Fizik dersinde öğrendiğim bilgiler bilim insanları tarafından kabul edilmiş gerçeklerdir, bu bilgileri sorgulamam gerekmez.					
22	Fizik dersinde bir konuyla ilgili öğretmenimin verdiği bilgileri sorgulamama gerek yok.					
23	Fizik dersinde öğretmenimin verdiği bilgilerin mantığı üzerinde düşünürüm ve tartışırım.					
24	Yeterince zaman ayırıp çalıştığımda fizik dersinde verilen bilgilerin mantığını anlayabilirim.					
25	Fizikte anlayamadığım bir konu üzerinde tekrar tekrar düşünsem de konunun mantığını anlayamam.					
26	Fizik dersinde ilk seferde anlayamadığım bir konunun mantığını anlamak için çaba sarf ederim.					
27	Fizik dersinde verilen bilgileri ilk seferde anlamayabilirim, bu fiziği anlamayacağım anlamına gelmez.					

B. The Sense of Belonging in Physics Survey

Öğrencilerin Fizik Dersine Ait Olma Hissi Anketi

<table>
<tr><td colspan="2">Sınıf:</td><td colspan="5">Şube:</td></tr>
<tr><td colspan="7">Yaşınız:</td></tr>
<tr><td colspan="7">Cinsiyetiniz: □ Kız □ Erkek</td></tr>
<tr><td colspan="2">Aşağıdaki maddeleri genel olarak fizik derslerindeki durumunuzu düşünerek cevaplayınız. Lütfen her ifadeyi dikkatle okuyunuz ve size uygun olan tek bir yanıtı “X” ile işaretleyiniz. Araştırmanın geçerliliği açısından cevaplarınızın eksiksiz olması gereklidir. Bilimsel bir çalışmaya katkıda bulunduğunuz için teşekkür ederiz.</td><td>Kesinlikle Katılmıyorum</td><td>Katılmıyorum</td><td>Kararsızım</td><td>Katılıyorum</td><td>Kesinlikle Katılıyorum</td></tr>
<tr><td>1</td><td>Kendimi bu sınıfa ait hissediyorum.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Kendimi bu sınıfa yabancı hissediyorum</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Kendimi bu sınıfta rahat hissediyorum.</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Bazen bu sınıfa ait olup olmadığımı sorguluyorum.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

C. Ethical approval by the Middle East Technical University Human Research Ethics Committee

UYGULAMALI ETİK ARAŞTIRMA MERKEZİ
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ORTA DOĞU TEKNİK ÜNİVERSİTESİ
MIDDLE EAST TECHNICAL UNIVERSITY

Konu: Değerlendirme Sonucu 13 EYLÜL 2024

Gönderen: ODTÜ İnsan Araştırmaları Etik Kurulu (İAEK)

İlgi: İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Ömer Faruk ÖZDEMİR

Danışmanlığını yürüttüğünüz Merve Düriye BİÇMEN'in "***LİSE ÖĞRENCİLERİNİN FİZİK DERSİNE AİT OLMA DUYGULARI, FİZİKLE İLGİLİ KİŞİSEL EPİSTEMOLOJİLERİ VE FİZİK BAŞARILARI ARASINDAKİ ETKİLEŞİMİN OKUL TÜRÜ, SINIF DÜZEYİ VE CİNSİYETE GÖRE İNCELENMESİ***" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülerek **0519-ODTUİAEK-2024** protokol numarası ile onaylanmıştır.

Bilgilerinize saygılarımla sunarım.

Prof. Dr. Ş. Halil TURAN
Başkan

Prof.Dr. İ. Semih AKÇOMAK
Üye

Doç. Dr. Ali Emre Turgut
Üye

Doç. Dr. Şerife SEVİNÇ
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