THE RELATIONSHIPS AMONG METACOGNITION, EPISTEMIC COGNITION, AND PHYSICS IDENTITY CONSTRUCTS

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ABSTRACT

THE RELATIONSHIPS AMONG METACOGNITION, EPISTEMIC COGNITION, AND PHYSICS IDENTITY CONSTRUCTS

The purpose of this study was to examine the relationships between epistemic cognition, metacognition, recognition, physics self-efficacy, interest and gender for high school students. Also, how epistemic cognition, metacognition, recognition, physics self-efficacy, interest and gender predicted physics identity was observed. The study involved a sample of 1197 high school students. Likert-type scales were used to gather the data. The Physics Personal Epistemology Questionnaire (PPEQ) was used to measure epistemic cognition. Also, to check students' metacognition, the Metacognitive Awareness Inventory (MAI) was used. The physics identity scale measured interest, self-efficacy, recognition and physics identity. The data was collected via convenience sampling. Descriptive statistics, correlation and multiple regression analyses were used to analyze the data. The study showed that there was a very high positive correlation between identity, recognition, self-efficacy and interest constructs. Identity, recognition, self-efficacy and interest were moderately positively correlated with epistemic cognition and metacognition. Also, there was a high positive correlation between metacognition and epistemic cognition. Interest, recognition and self-efficacy positively predicted physics identity, while the strongest predictor was recognition. Metacognition and epistemic cognition did not predict physics identity. Regarding gender differences, males had higher levels of physics identity, recognition, interest and self-efficacy than females. On the other hand, there was no gender difference observed in metacognition and epistemic cognition.

ÖZET

ÜSTBİŞLİŞ, EPİSTEMİK BİLİŞ VE FİZİK KİMLİK YAPILARI ARASINDAKİ İLİŞKİLER

Bu çalışma, lise öğrencilerinde epistemik biliş, üst biliş, tanıma, fizik öz yeterliliği, ilgi ve cinsiyet arasındaki karşılıklı ilişkileri araştırmayı amaçlamıştır. Ayrıca, epistemik biliş, üst biliş, tanıma, fizik öz yeterliliği, ilgi ve cinsiyetin fizik kimliğini nasıl yordadığı ölçüldü. Araştırmaya 1197 lise öğrencisinden oluşan bir örneklem katılmıştır. İlişkileri incelemek için Likert tipi ölçekler kullanılmıştır. Epistemik bilişi ölçmek için Fizik ile ilgili Kişisel Epistemoloji Anketi (PPEQ) kullanıldı. Ayrıca öğrencilerin üst bilişlerini kontrol etmek için Türkçeye uyarlanmış Bilişötesi Farkındalık Envanteri (MAI) kullanılmıştır. İlgi, öz-yeterlik, tanınma ve fizik kimliğini ölçmek için Türkçe'ye uyarlanan fizik kimliği ölçeği kullanılmıştır. Veriler kolayda örnekleme yoluyla toplanmıştır. Verilerin analizinde tanımlayıcı istatistikler ve çoklu regresyon analizi kullanılmıştır. Çalışma, kimlik, tanınma, öz yeterlik ve ilgi yapıları arasında çok yüksek bir pozitif korelasyon olduğunu gösterdi. Kimlik, tanıma, öz-yeterlik ve ilgi, epistemik biliş ve üst biliş ile orta düzeyde pozitif bir korelasyona sahipti. Ayrıca, üst biliş ile epistemik biliş arasında yüksek bir pozitif korelasyon vardı. İlgi, tanıma ve öz-yeterlik, fizik kimliğini pozitif olarak yordarken, en güçlü yordayıcı tanınma idi. Üst biliş ve epistemik biliş, fizik kimliğini öngörmedi. Cinsiyet farklılıkları açısından, erkeklerin fizik kimliği, tanınma, ilgi ve öz-yeterlik düzeyleri kadınlara göre daha yüksekti. Üst biliş ve epistemik bilişte ise cinsiyet farkı gözlenmemiştir.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS/ABBREVIATIONS

DF	Degrees of Freedom
MAI	Metacognitive Awareness Inventory
OECD	Organisation for Economic Co-operation and Development
PPEQ	Physics Personal Epistemology Questionnaire
PISA	Program for International Student Assessment
SD	Standard Deviation

1. INTRODUCTION

Physics identity refers to the degree to which a person considers himself or herself to be a "physics person" (Hazari *et al.*, 2010). Various research studies have shown that students' physics identity has an impact on their participation in physics classes and their choice of careers related to physics (Hazari *et al.*, 2010; Cheng *et al.*, 2018). The sophistication in identity enables learners to become active agents in science by combining their knowledge with scientific methods of thinking to be purposeful and strategic learners (Barton and Tan, 2010). Based on research findings demonstrating the key role of identity in students' learning, engagement and career paths, OECD (2020) added scientific identity into the PISA (2024) assessment framework as the new dimension. It is claimed that it is a tool to create a learning ecology, therefore probing students' identities should be involved in the assessment framework.

On the other hand, it is noteworthy that interest in physics-related departments has been gradually decreasing. For instance, in the class of 2018, bachelor's degrees in physics made up only around %2.3 of all STEM (science, technology, engineering and mathematics) degrees. (Mulvey and Nicholson, 2020). Furthermore, although there was a slight increase in the number of physics undergraduates in the UK, there needed to be more growth since 2010 (HESA, 2021). The inadequate increase was also the case in Turkey in the rate of STEM graduates (TUSIAD, 2017). While women receive just around one-fifth of these degrees in the US (Lock, Hazari and Potvin, 2019), the low rate of women in STEM careers persisted between 2013-2019 in Turkey (Özkurt and Yakın, 2020). Also, there was not enough growth rate observed in the number of female physics undergraduates until 2018 in the UK (NCUB, 2018). Therefore, determining the factors leading to this low choice rate and gender difference is vital for physics education. Because the students' physics identity is an effective variable in their career choices, especially during the secondary education period (Hazari *et al.*, 2010), this study addresses the physics identity of high school students taking physics courses.

The physics identity framework developed by Lock, Hazari and Potvin (2013) included one main identity construct and three identity-related constructs: recognition, performance/competence and interest. In this model, students' interest and external recognition had a significant direct relationship with physics identity and performance/competence. Students' competence/performance beliefs had a positive impact on the overall model of identity. This positive effect was through the mediating effects of interest and external recognition (Lock *et al.*, 2013). Several researchers provided supporting evidence for this model (Dou and Cian, 2022; Verdín, 2021; Godwin *et al.*, 2013; Cheng *et al.*, 2018). On the other hand, further research is needed to reveal other related constructs that can be instructionally manipulated, facilitating students' physics identity development. For example, Welsh and Schmitt-Wilson (2013) argued that since metacognition includes an executive function as working memory, planning/organization, arrangement of materials and task completion, sophistication in metacognition is a prerequisite for identity formation. A high level of metacognition is linked to the successful formation of identity. For instance, Guo *et al.* (2022a) found a positive relationship between metacognition and chemistry identity in their correlational study. Similarly, Krettenauer (2005) found that identity formation was enhanced by the development of an epistemic cognition-understanding of the nature of knowledge and knowing. Peffer, Royse and Abelein (2018) suggested that people with higher science identities may have more sophisticated epistemic beliefs. However, few studies put metacognition, epistemic cognition and identity in the same model since the concept is recent (Guo *et al.*, 2022a; Guo *et al.*, 2022b). Furthermore, to the best of researchers' knowledge, there has been no research examining the relation of physics identity to either metacognition or epistemic cognition in physics, although it is well known that both epistemic cognition and identity are domain-specific constructs (Hammer and Elby, 2002; Hofer, 2000; Chen *et al.*, 2022). In contrast, whether metacognition is domain-general or domain-specific has been a long-term discussion. Recent studies supported that metacognition is domain-general rather than domain-specific, meaning that it can be generalized across domains (Mazancieux *et al.*, 2020; Lehmann *et al.*, 2022). This was because as children get older, their domain-specific metacognition eventually generalizes to other domains (Geurten, Meulemans and Lemaire, 2018).

In the physics identity model, performance/competence refers to an individual's belief in their capacity to comprehend physics information and to carry out necessary physics activities (Hazari *et al.*, 2017). In the literature, there is a term conceptualized similarly. Self-efficacy is defined as an individual's confidence in her/his ability to carry out the behaviors required to achieve particular performance goals (Bandura, 1997). That's why the present study uses performance/competence and self-efficacy terms interchangeably and mostly prefers the term self-efficacy.

Even though self-concept and self-efficacy are two terms confused, self-concept is 'the totality of the individual's thoughts and feelings having reference to himself as an object' (Rosenberg, 1979, p.7). However, researchers who study self-efficacy claim that self-efficacy is the most effective because it outperforms other self-constructs, including self-concept, in predicting later motivation and performance (Bong and Skaalvik, 2003).

Although little is known about the relation of physics identity to epistemic cognition in physics and metacognition, studies investigate bivariate relations among epistemic cognition, metacognition and other identity constructs. Epistemic cognition and self-efficacy were found to be positively correlated (Guo *et al.*, 2022b, Kapucu and Bahçivan, 2015; Chen and Pajares, 2010). Likewise, a positive correlation was revealed between epistemic cognition and interest (Gou *et al.*, 2022b; Strømsø and Bråten, 2009; Kapucu and Bahçivan, 2015). Metacognition and self-efficacy were positively correlated (Coutinho and Neuman, 2008; Cera, *et al.*, 2013; Yerdelen-Damar and Peşman, 2013). Finally, metacognition and epistemic cognition were linked to each other as well (Topçu and Yılmaz-Tüzün, 2009; Akar *et al.*, 2011; Saban and Yüce, 2012). These relations in the literature show that there is a larger framework of physics identity to work on, leading to other connections that predict physics identity such as metacognition and epistemic cognition and give hints for identities in other domains. For example, variables predicting physics identity can also predict math or STEM identity.

Furthermore, a great deal of research studies revealed gender differences in science and physics identity and science and physics-related career choices (Williams and

George-Jackson, 2014; Vincent-Ruz and Schunn, 2018; Hazari *et al.*, 2010; Hazari *et al.*, 2013, Monsalve *et al.*, 2016; Seyranian *et al.*, 2018). Male students showed higher levels of physics identity (Hazari *et al.*, 2010; Hazari *et al.*, 2013) than female students. Similarly, it was found that males chose physics as a career more than females (Monsalve *et al.*, 2016; Seyranian *et al.*, 2018). Gender differences in favor of male students were also found in recognition (Cwik and Singh, 2022, Lock, Hazari and Potvin, 2013), interest (Yerdelen-Damar and Eryilmaz, 2010, Trumper, 2006, Lock, Hazari and Potvin, 2013) and physics self-efficacy (Lock *et al.*, 2013; Nissen, 2019; Cwik and Singh, 2021).

On the other hand, a consistent gender difference has not been observed in metacognition and epistemic cognition. For instance, Yerdelen-Damar and Peşman (2013) did not find gender differences in metacognition, while Topçu and Yılmaz-Tüzün (2009) showed that female students had higher metacognition. Similarly, while some studies showed that female students had more sophisticated beliefs than males (Topçu and Yılmaz-Tüzün, 2009; Kurt, 2009), another study revealed that male students had more tentative beliefs (Özkal *et al.*, 2010). On the contrary, girls and boys tended to hold similar beliefs regarding the Source/Certainty and Development dimensions, despite girls having more complex beliefs regarding the justification of knowledge than boys (Özkan and Tekkaya, 2011). Because of the contradictions in the results, it is also necessary to inspect further gender differences in metacognition and epistemic cognition.

1.1. Variables and Operational Definitions

The variables included in this study were gender, metacognition, epistemic cognition and physics identity. The followings are the operational definitions of these variables:

- Physics identity is the degree to which a person considers himself or herself to be a "physics person" (Hazari *et al.*, 2010). To measure it, the Turkish physics identity survey adapted and validated by Ulu and Yerdelen-Damar (2022) was used.

- Epistemic cognition refers to 'individuals' beliefs about knowledge and knowing' (Hofer and Pintrich, 1997). To measure physics students' epistemic cognition, the Physics Related Personal Epistemology Questionnaire (PPEQ) (Özmen and Özdemir, 2019) was used.
- Flavell (1979) defined metacognition as cognition about cognition as in high level of thinking which had two dimensions: knowledge about cognition and regulation of cognition. To measure metacognition, the Turkish version of Metacognitive Awareness Inventory (MAI) adapted to Turkish by Akın *et al.* (2007) was used.

2. LITERATURE REVIEW

This chapter includes a literature review of the study variables of the present study. First, identity concept and physics identity framework were discussed. Second, metacognition was discussed and its subdimensions were explained. Later, epistemic cognition and its subdimensions were discussed. Afterward, the interrelationships between variables were explained. Finally, the gender differences for each variable were extendedly discussed.

2.1. Identity

Identity is defined as "the -kind of person- one wants to be and enact in the here and now" by Gee (1999, p.13). According to Kane (2012), academic and disciplinary are two identities that develop during school. Academic identity refers to how children frequently perceive their participation in learning on a daily basis. This addresses how they see themselves as students or in connection to their academia (and how others see them). Students build a feeling of competence and perseverance with basic learning activities even if they fail or are unsatisfied, which helps to shape their academic identity. Academic identity is also about students' actions in school and behaving according to normative school routines and guidelines (Kane, 2012).

Disciplinary identity, on the other hand, is about how children perceive themselves and are perceived by others while engaging in a domain (Kane, 2012). Because science identity is about how a person perceives themselves in a scientific domain, it can be investigated under disciplinary identity. That's why, when students receive scientific knowledge and engage in scientific procedures within the classroom's scientific community, their science identities are developed. (Kane, 2012).

While identity does not only depend on the individual, it also depends on the social aspects, such that it is an outcome of an individual's actions and perceptions of significant others on that person. For example, a person reaches their scientific identity as an outcome of their competence and performance in science and their recognition as a science person in their community (Carlone and Johnson, 2007).

The starting point for disciplinary identity related to science was the study conducted by Carlone and Johnson (2007). According to Carlone and Johnson (2007), science identity is made up of three components: competence, performance and recognition. While competence is related to one's knowledge and understanding of science and does not have to be visible to the public eye, performance refers to revealing scientific practices by using tools or even talking. On the other hand, recognition is a social dimension meaning that one's recognition of herself and by others as a science person and affects identity greatly. Interestingly, it is possible that one may not have each dimension adequately. One may have exceeding skills meeting the performance criterion but may not be recognized by others that she is able to perform it. One may have the relevant knowledge but may not be able to perform it or vice versa. In addition, since experiences gained in schools affect skills and knowledge, they are related to performance and competence dimensions. Although performance, recognition and competence were the key components of science identity, interest was considered as a component too, however, because they were already working with practicing scientists, interest was already attributed to the participants and it was not included in the model (Carlone and Johnson, 2007).

Hazari *et al.* (2010) developed physics identity framework utilizing Carlone and Johnson's science identity study (2007). Physics identity refers to 'the degree to which a person considers himself or herself to be a "physics person"' (Hazari *et al.*, 2010). Hazari *et al.* (2010) proposed a framework that includes performance, competency, recognition and interest, which are the fundamental interrelated constructs affecting the formation of physics identity. For the physics identity framework, competence is believing in being able to understand physics and performance is believing in being able to carry out requisite physics assignments. In addition, recognition is being acknowledged as a physics person by others when interest is defined as the eagerness to get more knowledge about physics and do more activities related to physics (Hazari *et al.*, 2010).

While Hazari *et al.* (2010) mentioned performance and competence as separate constructs, in a later study, Lock *et al.* (2013) examined how physics and math identities affect students' career choices in physics. With factor analyses, they found that performance and competence were not independent constructs, but in fact, it makes up one construct. 'Performance/competence' is defined as students believing they can do necessary physics assignments like problems and experiments and understand physics content. This identity model with three components was supported by later studies (Dou and Cian, 2022; Verdín, 2021; Godwin *et al.*, 2013; Cheng *et al.*, 2018). For example, Dou and Cian (2022) worked on expanding the STEM identity framework by looking at the connections among STEM recognition, performance-competence, interest and identity and demographic factors, such as gender, ethnicity, home support of science, parental education and science talk. They found that students' interests and external recognition are strongly connected to their competence/performance beliefs. Through the mediating effects of interest and external recognition, competence/performance beliefs contributed to the overall model of identity (Dou and Cian, 2022). The same mediational relationship between the identity constructs was also observed in the study of Verdín (2021) in which the relationship between engineering identity, interest, recognition, performance/competence beliefs, sense of belonging and persistence in the engineering career.

2.2. Metacognition

John Flavell was the one who initially coined the term "metacognition". According to Flavell (1976, p.232), 'Metacognition refers to one's knowledge concerning one's own cognitive processes or anything related to them, e.g., the learning-relevant properties of information or data'. Flavell (1979) divided metacognition into two categories: metacognitive knowledge and metacognitive experiences. Metacognitive knowledge is knowledge or beliefs about the factors or variables that influence the process and result of cognitive activities and how they behave and interact. These elements or variables can be divided into three main groups: person, task and strategy. All of your beliefs about the nature of other people and yourself as cognitive processors are included in the person category. The examples for the person category are thinking that the majority of knowledge is best learned by listening rather than reading and forgetting something you can quickly recall. There are two subcategories within the task category. One subcategory is concerned with the nature of information that a person encounters and manages in any cognitive activity. The learner is aware that how they approach the job depends on the nature of the information. For example, a child should understand that knowledge may be insufficient to allow for firm conclusions about another person's true character. The nature of task demands is related to the second subcategory. Understanding which tactics are effective for particular goals is referred to as the "strategy" category. For instance, the essence of a narrative is simpler to remember than its precise words (Flavell, 1979).

On the other hand, metacognitive experiences are 'any conscious or affective experiences that accompany and pertained to any intellectual enterprise'. Metacognitive experiences can occur prior to, during, or following cognitive activity (Flavell, 1979, p.906). You might believe, for example, that you are likely to fail in a future performance or that a previous performance was a success. According to Flavell (1979, p.908), circumstances that stimulate a lot of arousal and attention and highly conscious thought may result in metacognitive experiences such as during a performance at work or school, in a new situation where it requires careful consideration prior and review afterward.

Later, metacognition referred to knowledge and regulation of an individual's own cognition (Brown *et al.*, 1983; Brown, 1987). Brown (1987) categorized metacognition into two components: knowledge of cognition and regulation of cognition. Knowledge of cognition refers to declarative information regarding one's own cognition, whereas regulation of cognition refers to the ability of planning, monitoring, controlling and evaluating one's own cognition (Brown, 1987). Following Brown's framework, Schraw and

Dennison (1994) proposed an eight-dimensional framework to operationalize metacognitive awareness. According to this framework, knowledge of cognition has three levels: declarative knowledge (knowledge about facts and strategies), procedural knowledge (knowledge about how to apply strategies) and conditional knowledge (knowledge about when and why to apply strategies). For the regulation of cognition, five skills are necessary: planning, information management strategies, comprehension monitoring, debugging strategies and evaluation (Schraw and Dennison, 1994). The present study employed this framework to determine students' metacognition.

The question of whether metacognition is domain-specific or domain-general has received considerable discussion. The most recent research, however, discovered that metacognition is more domain-general than domain-specific, allowing it to be generalized across domains (Mazancieux *et al.*, 2020; Lehmann *et al.*, 2022). This is because domain-specific metacognition gradually generalizes to different domains as children age (Geurten *et al.*, 2018). Due to the feature of metacognition being generalized in time, we used the metacognition instrument with the domain-general version.

2.3. Epistemic Cognition

The conceptions that people have about how knowledge and understanding work, how they are applied to challenges in science and society and how they have an impact are referred to as epistemic cognition (Sinatra *et al.*, 2014). The literature has discussed it using a variety of terminology (Hofer, 2016). For example, epistemological beliefs (Schommer *et al.*, 1992), epistemological theories (Hofer and Pintrich, 1997), epistemological thinking (Kuhn and Weinstock, 2002), or epistemological resources (Hammer and Elby, 2002) have all been used to describe it. The term "epistemic cognition" was recently developed in an effort to encompass several fields of study that have examined related phenomena (Hofer, 2016). A focus on cognitive processes and how important epistemic beliefs are in these processes was highlighted by the term epistemic cognition. That is, epistemic cognition entails thinking about scientific epistemology (Sinatra *et al.*, 2014). The most recent handbook, "Handbook of Epistemic Cognition", was published in 2016 and brought together numerous studies that examine how people perceive knowledge and knowing (Greene *et al.*, 2016). The term "epistemic cognition" was used to describe how the students perceived physics knowledge and acquisition of information.

Epistemic cognition refers to one's view of the nature of knowledge, knowing and learning (Hofer and Pintrich, 1997; Elby, 2009). To examine students' epistemic cognition in physics, various frameworks are used. (e.g. Halloun and Hestenes, 1996, Hammer, 1994, Adams *et al.* 2006). For example, Hammer (1994, p.155) conceptualizes students' epistemic cognition in physics as follows:

- Beliefs about the structure of physics knowledge which can be a group made of individual parts or a sole organized system,
- Beliefs about the content of physics knowledge that can consist of formulas or content, including the use of formulas,
- Beliefs about learning physics in such a way that by getting the information in passively or by being actively involved in managing one's learning and shaping understanding.

Similar to metacognition, epistemic cognition was a concept that has been discussed thoroughly if it is domain-general or domain-specific. Muis *et al.* (2006) reviewed the studies investigating domain-generality and domain-specificity of epistemic cognition and categorized them under two titles: between-subjects design and within-subjects design. For both titles, the results dominantly pointed the domain-specificity of epistemic cognition. That's why, to measure epistemic cognition of the students, an instrument related to physics was used in the current study. The latest framework developed by Özmen and Özdemir (2019, p. 1215) was built on the literature related to epistemic cognition in the science and physics fields. The framework included six dimensions as in Table 2.1.

Table 2.1. The dimensions of the Physics Identity Survey and one example item for each sub-dimension.

Dimensions	Explanations of dimensions
Structure of knowledge Coherence (SKC)	This dimension probes the extent to which the student sees self-knowledge as a coherent vs incoherent structure.
Structure of knowledge Hierarchical (SKH)	This dimension probes the extent to which the student sees self-knowledge is formed by establishing a link between previous and new physics knowledge that has a hierarchical vs fragmented structure.
Justification of knowledge and knowing (JK)	This dimension evaluates the extent to which the student sees his/her physics knowledge can be justified by use of mental processes (i.e. logical reasoning), use of evidence from experimentation, inquiry emanated from conflicts between previous experiences and novel situations.
Changeability of knowledge (CK)	This dimension probes the extent to which the student sees the self-knowledge is subjected to change or fixed (unchangeable).
Quick learning (QL)	This dimension probes the extent to which the student sees constructing physics knowledge takes time (a gradual process of meaning-making) or learning happens very quickly.
Source of knowledge (Source)	This dimension probes the extent to which the student sees the knowledge is constructed or knowledge is accepted directly from authority (i.e. textbooks, teachers, scientists).
Note: The table was adapted from Özmen and Özdemir (2019).	

In the present study, this framework was used to determine students' epistemic cognition in physics since it is the most recent structure of epistemic cognition in physics.

2.4. Interrelationships Between the Variables

In this section, first, the relationships among constructs were discussed. Then, gender differences for each variable were elaborated.

2.4.1. Identity and Metacognition

Metacognition can have an impact on the development of identity. Welsh and Schmitt-Wilson (2013) investigated the relationship between executive function, identity and career decision-making. The data was gathered from 82 college students. To measure students' identity statuses, the Extended Objective Measure of Ego Identity Status–Revised (EOM-EIS-R) scale was used, including four identity statuses depending on a person's level of exploration and commitment, such as diffusion, foreclosure and moratorium and identity achievement. The ones with identity achievement status can make decisions in their careers and goals and pursue their careers with their own choice. The ones with foreclosure status can make their decisions, however, pursue a career with parental choices. On the other hand, the ones with identity diffusion status have no direction in their careers. Finally, the ones with moratorium status have an identity crisis and problems in decision-making in their careers. Also, The Behaviour Rating Inventory of Executive Function scale, including the metacognitive index, was used. The correlation coefficients and regression analyses were considered during data analysis. The results showed that to achieve identity formation, executive functions like working memory, planning/organization, arrangement of materials and task completion are important.

Metacognition can be effective on domain-specific identity. In a study conducted by Guo *et al.* (2022a), the relationship between metacognition and the development of students' chemistry identity in high school and how learning flow and learning burnout affect this relationship were investigated. The data was collected from 10th-grade 594 students in China with a stratified purposive sampling method. To assess metacognition, The Junior Metacognitive Awareness Inventory (Jr. MAI) developed by Sperling, Howard, Miller and Murphy (2002) was used. Jr. MAI has two dimensions: metacognitive knowledge and metacognitive regulation. To probe students' chemistry identity, the researchers adapted Student Science Identity (SSI) questionnaire and Engineering Identity Measures (EIM). The Maslach Burnout Inventory-Student Survey (MBI-SS) was used to measure learning burnout and included three sub-dimensions: exhaustion, cynicism and low sense of achievement. Finally, the Scale for Adolescents' Flow State in Learning (SAFSL) was used to measure chemistry learning flow. The data were analysed with multiple linear regression. The study showed a positive relationship between metacognitive awareness and chemistry identity. While chemistry learning burnout mediates the association between metacognition and chemistry learning flow, chemistry learning flow mediates the relationship between learning burnout and chemistry identity.

Furthermore, there have been many studies investigating the relationship between metacognition and self-efficacy. Coutinho and Neuman (2008) investigated how achievement goal orientation, learning style, self-efficacy and metacognition predicted performance with structural equation modeling. The data was collected from 629 undergraduate students taking psychology courses with surveys. The Motivated Strategies for Learning Questionnaire (MSLQ), with nine items and the Metacognitive Awareness Inventory (MAI), with 52 items, were distributed to measure self-efficacy and metacognition, respectively. As a result, the most significant predictor of metacognition was found to be self-efficacy. However, the study could have been more extensive in terms of sample size and the generalizability of the result. Later on, this finding was supported by Yerdelen-Damar and Peşman (2013) in a study in which they investigated how physics achievement is predicted by gender and socioeconomic status (SES) with the mediation of metacognition and physics self-efficacy. The data was collected from 338 high school students. While the Turkish version of the Motivated Strategies for Learning Questionnaire (MSLQ) was used to measure self-efficacy (Sungur, 2004), The Turkish version of the Metacognitive Awareness Inventory (MAI) (Akın *et al.*, 2007) was used to measure students' metacognition. The study showed that physics self-efficacy was a mediator for the relationship between metacognition and physics achievement, meaning that physics self-efficacy is critical to the effectiveness of metacognitive physics instruction.

In addition, Cera *et al.* (2013) aimed to investigate the relationship between metacognitive attitude and self-efficacy, between metacognitive attitude and issues related to self-regulation in learning and between self-efficacy and other variables. The data was gathered from 130 high school students. To assess these variables, the Metacognitive Awareness Inventory (MAI), Adaptive Self-Efficacy Scale, Questionnaire About the Popular Conceptions of Learning (QAPCOL), Awareness of Independent Learning Inventory (AILI) and Learning and Study Strategies Inventory (LASSI) were used. MAI included 35 items with four dimensions- monitoring, planning, evaluation and strategies andthe self-efficacy scale included 10 items to measure a general sense of perceived self-efficacy. The study revealed that basic metacognitive skills were highly correlated with the perception of self-efficacy.

2.4.2. Identity and Epistemic Cognition

Krettenauer (2005) found that identity formation was enhanced by the development of epistemic cognition-understanding of the nature of knowledge and knowing. For instance, Peffer *et al.*, (2018) investigated the association between affective factors like self-efficacy, metacognition and identity, inquiry practices and epistemic cognition for 17 undergraduate students in non-science fields. First, students completed a pre-test including an item measuring science identity by Godwin *et al.* (2016) and the dimensions of intrinsic goal orientation, self-efficacy and metacognitive self-regulation in the Motivated Strategies for Learning Questionnaire by Pintrich *et al.*, (1993). Afterward, students used an SCI simulation module in which they did investigations about a biological phenomenon. The study showed that students that attempted complex investigations had higher levels of self-efficacy and metacognition and indicated that students with higher science identities may have more sophisticated epistemic cognition.

Many studies indicated a positive correlation between self-efficacy and epistemic cognition. In a study by Chen and Pajares (2010), the relationship between implicit theories and epistemic cognition and how those affect the motivation and achievement of 6th-grade science students were investigated. The data was collected from 508 middle school students taking science classes with self-report surveys. To measure students' epistemic cognition related to science, an instrument adapted from Elder (2002) was used. It includes 26 items with dimensions of source, certainty, development and justification. Students' self-efficacies were measured with an instrument developed by Bandura (1997), including four items. According to the path analysis, sophisticated epistemic cognition was positively related to higher self-efficacy (Chen and Pajares, 2010).

Later on, Kapucu and Bahçivan (2015) conducted a study to examine the relationships between epistemic cognition, physics self-efficacy and attitudes toward physics. The data was gathered from 498 high school students and analyzed via structural equation modelling. In the study, a scientific epistemic cognition survey, a scale for self-efficacy in learning and attitudes toward physics survey were used as instruments. It was found that epistemic cognition for source of knowledge and justification of them, which were revealed by the nature of knowing, were strongly connected to self-efficacy in learning physics and attitudes toward physics. The reason for the positive correlation between attitudes and source beliefs was explained by the Turkish Education System, in which students were obliged to learn skills such as researching sources of information, conducting experiments and hypothesizing to increase students' source and justification beliefs. There were not significant relationships among students' attitudes, self-efficacy and certainty and growth beliefs which are the sub-dimensions of the nature of knowledge dimension in the epistemic cognition survey. It was claimed that because centralized exams only measure achievement and seek for a certain answer, students were prevented from developing sophisticated beliefs in the nature of knowledge. Finally, it was found that the more students had self-efficacy in learning physics, the more they had positive attitudes toward physics. In the study, it was suggested that the Turkish Education system should work further on students' nature of knowledge and beliefs with well-prepared instructions aiming those.

Moreover, it was found that interest and epistemic cognition were positively correlated. Strømsø and Bråten (2009) examined the link between topic-specific beliefs and multiple-text comprehension for 282 upper secondary students. Students' topic knowledge and topic interest were measured multiple-choice test and Likert-type scale developed by Strømsø and Bråten. Epistemic cognition was assessed with Topic-Specific Epistemic Belief Questionnaire (TSEBQ; Bråten and Strømsø). Also, the participants read seven different texts about climate change and their text comprehensions were measured by a sentence verification task (SVT). T tests and hierarchical regression analyses showed that the likelihood that students would comprehend the texts was higher among those who tended to believe that knowledge claims should be supported by scientific inquiry. The students with higher comprehension were more interested in the topic. Afterward *et al.*, (2015) showed a positive correlation between source and justification dimensions of scientific epistemic cognition and interest dimension of attitudes related to physics. The degree of epistemological sophistication revealed by certainty and development may not have a substantial impact on students' exam results. High school students take a multiple-choice test at the end of high school and since there is only one correct response to any multiple-choice, it may not contribute to their nature of knowledge (Kapucu and Bahcivan, 2015).

In a recent study, Guo *et al.* (2022b) looked into the connections between epistemic cognition, reflective thinking and science identity via structural equation modelling. The data was collected from 544 students in China with a stratified sampling method. To measure epistemic cognition, the survey developed by Conley *et al.*, (2004) was used. Science identity was measured with Chen and Wei's Student Science Identity (SSI) questionnaire (2020). The study revealed that epistemic cognition were highly effective on self-efficacy and interest. Self-efficacy partially mediated the link between interest and epistemic cognition. Additionally, through self-efficacy, epistemic cognition had an indirect effect on external recognition and interest.

2.4.3. Metacognition and Epistemic Cognition

There are many studies investigating the relationship between metacognition and epistemic cognition. A study supporting the relationship between metacognition and epistemic cognition investigated the relation of metacognitive awareness to epistemic cognition for elementary-level science students (Akar *et al.*, 2011). In five randomly chosen primary public schools in Ankara, Turkey, 250 eighth-grade students were given the Discipline Focused Epistemological Beliefs Questionnaire (DFEBQ) and the Metacognitive Awareness Inventory (MAI). The Discipline Focused Epistemological Beliefs Questionnaire developed by Hofer (2000) measured certainty/ simplicity of knowledge, justification for knowing, source of the knowledge and attainability of truth. The Metacognitive Awareness Inventory had two dimensions: knowledge of cognition and regulation of cognition (Schraw and Dennison, 1994). The data was analysed via multiple regression correlation. The results showed that there was a positive correlation between metacognition and epistemic cognition.

Saban and Yüce (2012) investigated the relationships between problem-solving, metacognition and epistemic cognition of 1111 6th, 7th and 8th grade students via random sampling. To measure students' metacognition, "Metacognitive Awareness Inventory for Children" (Jr. MAI)-(B Forms)" adapted by Karekelle and Saraç (2007) was used. To measure epistemic cognition, "Epistemological Beliefs Questionnaire" adapted by Özkan (2008) was used. The t-test, correlation and stepwise regression methods were used to analyze the data. It was shown that there was a statistically significant and high-level association between epistemological views and metacognitive awareness.

Afterward, Yenice (2015) examined the relationship between epistemic cognition and metacognitive perceptions about the nature of science of 336 preservice elementary science teachers. To measure epistemic cognition, the epistemological beliefs scale developed by Schommer (1990) and adapted into Turkish by Deryakulu and Büyüköztürk (2002) was used. To measure teachers' metacognitive perceptions about the nature of science, the Likert scale developed by Peters (2007) and adapted to Turkish by Yenice was used. The data were analyzed with the Mann-Whitney U test, Kruskal-Wallis H test and multiple regression analysis. The study revealed moderate and significant relationships between epistemic cognition and metacognitive perceptions.

2.5. Gender Differences

In this section, gender differences in identity constructs, metacognition and epistemic cognition were discussed.

2.5.1. Gender and Identity

Numerous studies on gender differences in science and physics identities and physics-related career choices have been conducted. Hazari *et al.* (2010) investigated how high school physics experiences and career outcome expectations affected students' perceptions of themselves as physicists. They found male students showed higher levels of physics identity than female students. Hazari *et al.* (2013) supported this finding later on while investigating how students perceive themselves in the science disciplines of biology, chemistry and physics according to their gender and underrepresented minority groups. Also, in a study in which Monsalve *et al.* (2016) investigated the link between career outcome expectations and physics identity, male students tended to have higher physics identity levels than females.

Because physical science career choices and physics identities were strongly correlated, a similar finding was observed for physics career choices. Lock, Hazari and Potvin (2013) looked at how students' identities in physics and math affected their physics career choices. The data was provided by a previous project called The Sustainability and Gender in Engineering Project. In this project, a survey was distributed to a group of students taking beginning English classes at 50 colleges and universities. While each dimension for identity was compared for gender and physics and math with the Wilcoxon test, then the effects of identities on career choice were investigated with regression analyses. When gender, parental educational level and race are controlled the analysis showed males chose physics career more than females. Additionally, Seyranian *et al.* (2018) explored the gender differences in social belonging for physics classrooms, physics identities and physics achievements, the interaction between identity and gender on achievement and flourishing change for 160 undergraduate students in STEM majors. Flourishing is an indication of well-being that frequently concentrate on positive states like life satisfaction, happiness, or positive emotion or depressive or anxious states. Physics identity and social belonging were measured by Likert scales developed by Seyranian *et al.* (2018). Students took Force Concept Inventory (FCI) and the flourishing scale. Students' physics course grades and demographics were also collected. The variables were measured at the beginning and the end of the term. The study showed that male students had higher physics identities than females at the beginning and the end of the term and physics-related career choice was made predominantly by males.

Gender differences in favor of male students were also found in recognition, interest and physics self-efficacy. Lock *et al.* (2013) investigated the influence of physics and math identity on physics career choice and they revealed higher levels of recognition for males than females. In addition, to predict performance outcomes at the end of the first semester of an algebra-based introductory physics course sequence for 827 bioscience students, Cwik and Singh (2022) compared male and female students' perceived recognition as a physics person by instructors, teaching assistants, friends and family. The perceived recognition questions, which were adapted from Godwin *et al.* (2016), assessed how much a student thinks that other people perceive them as a physicist or as capable of excelling in the subject. The data was collected at the beginning and end of the semester and analyzed with descriptive statistics and structural equation modeling. The study showed lower levels of recognition for female students than males at the beginning and end of the semester, supporting Lock *et al.* (2013)'s finding.

Similarly, many studies revealed the gender difference in interest favoring male students. A study conducted by Trumper (2006) as part of the ROSE Project in Israel examined 635 students' interest in physics, their perceptions of their science classes, their experiences outside of school and their attitudes toward science and technology. Students' interest in physics was measured with 22 items on a 4-point Likert scale. The multiple regression analysis results revealed that males had more interest in physics than females. Furthermore, Yerdelen-Damar and Eryilmaz (2010) categorized the physics questions submitted to a "ask a scientist" website in terms of the physics area of interest, the type of information requested in the question and the reason for asking the question. They also assessed whether there are differences between questions submitted by 723 users. The findings showed that more questions were submitted by women than men in the biology group, whereas more questions were posed by men in the physics group. So, women were more interested in biology than physics and men showed more interest in physics. Later, the high levels of interest in males were supported by Lock *et al.* (2013).

Finally, there was a similar gender difference determined in self-efficacy. In addition to Lock *et al.* (2013) revealing males having higher self-efficacy levels than females, Nissen (2019) aimed to determine whether female high school students had lower physics self-efficacies than males and examine gender differences in other academic and extracurricular activities. The data was collected previously from 4816 students in a Sloan study of youth and social development and analyzed with the hierarchical linear model. Similar to Lock *et al.* (2013)'s finding, women tended to have lower self-efficacy states than males. Afterward, Cwik and Singh (2021) investigated the gender difference in self-efficacies of 474 students in introductory physics courses and the change in the gender gap at the beginning of and the end of these courses. Students' self-efficacies were measured with the questionnaires developed by Schell and

Lukoff (2010) and Godwin *et al.* (2016). The linear regression analysis resulted in consistently lower self-efficacy scores for women compared to men at the beginning and end of the courses.

2.5.2. Gender and Metacognition

A consistent gender difference has not been observed in metacognition. In a study, Yerdelen-Damar and Peşman (2013) looked at how gender and socioeconomic status (SES) influence physics achievement through the mediation of metacognition and physics self-efficacy. The Structural Equation Modeling showed the relationship between gender and metacognition was nonsignificant and negative. On the other hand, a study conducted by Topçu and Yılmaz-Tüzün (2009) aimed to examine the relationship between science achievement, metacognition and epistemic cognition for students from 4th to 8th-grade and to explore the relationships among gender, socioeconomic status (SES), metacognition and epistemic cognition. While 315 4th and 5th-grade students participated in the study, 626 6th, 7th and 8th-grade students participated. Using the survey method, data was collected with Jr. MAI that was adapted to Turkish by Topçu and Yılmaz-Tüzün (2007) to assess students' metacognition. Jr. MAI had two versions, with one of them including 12 items for the students from 3rd to 5th grade and the other one including 18 items for the students from 6th to 8th grade. It was found that there was a relationship between students' metacognition and epistemic cognition.

The multiple regression analysis showed that girls increased their metacognition more from 4th to 8th-grade science courses. Furthermore, Yenice (2015) determined how 336 pre-service teachers' metacognitive perceptions of the nature of science and their epistemic cognition relate to one another and how they change depending on their gender and grade. To measure teachers' metacognitive perceptions about the nature of science, a Likert-type scale developed by Peters (2007) and adapted to Turkish by Yenice (2015) was used. The scale included three factors: attitude towards science, cause-and-effect capability and use of metacognition. Controversially, the Mann

Whitney-U Test showed that teachers' metacognitive perceptions were not significantly impacted by gender. However, the mean scores of female students' metacognitive perceptions were higher than males.

2.5.3. Gender and Epistemic Cognition

Similar to metacognition, there were various findings regarding gender difference in epistemic cognition. When Topçu and Yılmaz-Tüzün (2009) investigated the relationship between science achievement, metacognition and epistemic cognition for students from 4th to 8th-grade. Regarding gender it was observed that female students in 4th and 5th grades had more sophisticated beliefs in the innate ability and quick learning dimensions than males. From 6th to 8th grade, female students had more sophisticated beliefs in innate ability, quick learning and omniscient authority dimensions, while girls were less sophisticated in omniscient authority. Also, Kurt (2009) examined 1557 6th, 7th,, 8th and 10th grade students' epistemic cognition in different fields regarding gender and grade. A Demographical Questionnaire in which they are asked about their gender, grade, achievement and socioeconomic status and the Epistemological Beliefs Questionnaire developed by Conley *et al.* (2004) and adapted into Turkish by Özkan (2008) including source, certainty, development and justification dimensions were employed as the data collection instruments. The Multivariate Analysis of variance showed more sophisticated epistemic cognition for girls than boys. Afterward, Yenice (2015) examined the relationship between the epistemic cognition and their metacognitive perceptions about the nature of science of 336 preservice elementary science teachers. To measure epistemic cognition, the epistemological beliefs scale that was developed by Schommer (1990) and adapted into Turkish by Deryakulu and Büyüköztürk (2002) was used. The scale of epistemological beliefs consists of three dimensions: "Belief that learning is based on attempt" (attempt), "Belief that learning is based on ability" (ability) and "Belief that there is one truth" (one truth). The Mann-Whitney U test showed that gender had no significant effect on students' epistemic cognition that learning is based on the attempt and that there is only one truth. On the other hand, gender was effective on the belief of learning is based on ability. Furthermore, it was observed that female students revealed more sophisticated beliefs than males.

Another study investigating the gender differences in epistemic cognition was conducted by Chen and Pajares (2010). The data was collected from 508 6th grade students taking science courses with the 26-item scale developed by Elder (2002) and including Source, Certainty, Justification and Development dimensions. The descriptive statistics showed no gender difference in students' epistemic cognition. Later, students' scientific epistemic cognition was investigated regarding their gender and socioeconomic status (SES) by Özkan and Tekkaya (2011). The data was collected from 1230 7th grade students with the Epistemological Belief Questionnaire developed by Conley *et al.* (2004) and adapted into Turkish by Özkan (2008). The questionnaire included 26 items on a 5-point Likert-type scale with four dimensions; Source, Certainty, Justification and Development. The data were analyzed with multivariate analysis of variance, which showed that there was no gender difference in Source/Certainty and Development dimensions. However, female students had more sophisticated beliefs in Justification than males. In brief, because of contradictions in the results, it is also necessary to inspect further whether there are gender differences in metacognition and epistemic cognition.

3. SIGNIFICANCE OF THE STUDY

As far as the researcher is concerned, there has not been much study conducted on identity, especially regarding physics in Turkey. While this study is closing the gap in the literature, it also contributes to the assessment of Turkish high school students' physics identity levels. With the assessment of students' physics identities, it is possible to detect their current identity level and implement plans to develop their identities. The assessment of physics identity can lead to a development in physics learning and help overcome the equity problems in physics education. With the assessment of students' physics identity levels, instructors can apply some intervention studies or classroom strategies, leading to an increase in all students' identities and participation in physics. Also, this study investigates the related constructs that can be missing in the recent identity model. So, it gives further implications to teachers and researchers to contribute to students' identities.

Furthermore, the study can also be helpful for researchers and educators. Researchers can extend the identity framework and find other relations to physics identity based on the results of this study. Finally, relying on the relations to be found to physics identity, educators and researchers can develop classroom strategies or workshops to increase students' identity levels and diminish gender differences.

3.1. Research Questions

In the light of the above discussion, the present study aims to answer the following research questions;

(i) How are the interrelations among gender, metacognition, epistemic cognition, interest, self-efficacy, recognition and identity? (H_0) There is no statistically significant relationship among physics identity constructs, epistemic cognition, metacognition and gender for high school students in Istanbul.

(ii) Is there a statistically significant relationship between physics identity constructs and epistemic cognition for high school students in Istanbul? (H_0) There is a statistically significant relationship between physics identity constructs and epistemic cognition for high school students in Istanbul.

(iii) Is there a statistically significant relationship between physics identity constructs and metacognition for high school students in Istanbul? (H_0) There is no statistically significant relationship between physics identity constructs and metacognition for high school students in Istanbul.

(iv) Is there a statistically significant relationship between physics identity constructs and gender for high school students in Istanbul? (H_0)]There is no statistically significant relationship between physics identity constructs and gender for high school students in Istanbul.

(v) How do gender, metacognition, epistemic cognition, interest, self-efficacy and recognition predict physics identity? (H_0) Gender, metacognition, epistemic cognition, interest, self-efficacy and recognition do not predict physics identity.

4. METHODOLOGY

The research design of the study is a correlational study which is a type of quantitative research. This study aimed to investigate the inter-relations among epistemic cognition, metacognition and gender for high school students and whether these variables predicted physics identity. The data was collected via Likert-type scales. To investigate the relationships between the variables, correlation and multiple regression analyses were conducted. Descriptive statistics were used to summarize and organize the data.

4.1. Sample

For the investigation of the relationships between the variables, the data were collected from high school students taking physics lectures in Istanbul, Turkey, via convenience sampling. The target population of this study was students in public high schools in Istanbul. There are 946 public high schools in Istanbul, according to National Education Statistics (2021). The accessible population was determined as 8,561 students in public high schools in Beşiktaş, Sarıyer, Kağıthane and Beyoğlu districts. The data were collected from 1197 high school students from six different high schools in Istanbul, Turkey. While 58.2 percent of these students were female, 41.8 percent were male. The students' ages ranged from 14 to 18 or above. %24.9 of students were in 9th grade, %40.8 were in 10th grade, %33.2 were in 11th grade and %1 were in 12th grade. The reason why 12th-grade students were only %1 of the participants was that senior students get prepared for the university entrance exam and they do not come to school as often since they have extra courses out of school.

The success level of students ranged from low to high levels on students' high school entrance exam points. All the students were taking physics lectures based on the Turkish curriculum. According to students' reports on socioeconomic status questionnaire, they generally had a suitable environment to study, the internet and a technological device like a telephone, tablet, or computer. While 99.5 percent of the students indicated they had telephone, tablet or computer and internet, 94.2 percent of them had a suitable environment to study. The education levels of their parents were ranging from elementary to graduate level. For their mothers' educational background, %17.1 graduated from elementary school, %12.7 from secondary school and %35.8 from high school. %30.5 earned their bachelor's degrees and only %3.8 earned master's or PhD degrees. For their fathers' educational background, %13 graduated from elementary school, %13 from secondary school and %36.4 from high school. While %31.2 earned their bachelor's degree, %6.3 had masters or PhD degrees.

4.2. Instruments

In this study, students' physics identity, recognition, interest, self-efficacy, metacognition and epistemic cognition were assessed using different self-report instruments. Students were also given a demographic questionnaire to fill out, on which they were asked to provide information about their gender, grade level and socioeconomic status such as mother's and father's educational backgrounds and suitable environment to study.

4.2.1. Physics Identity Survey

The physics identity survey was developed by Hazari *et al.* (2010) named as PriSE survey, including questions on students' demographics, interests, encouragement and high school physics experiences. Later, Godwin *et al.* (2016) measured engineering career choice and math and physics identity. Some items were selected from the PriSE survey, including two items measuring interest, six items measuring performance/competence beliefs, two items measuring recognition and one item directly measuring overall physics identity and added a question asking the likelihood of choosing a career listed related to science, math and engineering rating from 0 (not at all likely) to 4 (extremely likely). Students were asked further questions about engineering disciplines claiming that if a career has the strongest response, there is a tendency to that. Also, items were added related to agency beliefs to assess students' opinions of their abilities to be science critics and their beliefs about science's potential to make a good difference in the world. The physics identity survey was further developed by Cheng *et al.* (2018), including one identity item, four for recognition, six for performance/competence and four for interest.

The Turkish version of the identity scale validated by Ulu and Yerdelen-Damar (2022) was employed to determine high school students' physics identity and their conceptions of identity-formation constructs. The CFA results of the Turkish scale revealed the same factor structure as that in the original scale. The multiple fit indices used to evaluate the results were within the acceptable range (γ_2(187, N = 361) = 510.12; X_2/df = 2.72; RMSEA = 0.07 (%90 CI =0.06; 0.07), SRMR = 0.05; CFI = 0.99; NFI = 0.98). Items had significant factor loadings ($p < 0.05$). The magnitude of the factor loadings varied between 0.70 and 0.98. These values are greater than the minimum required value of 0.40. Cronbach's Alpha ranged from 0.90 to 0.97 for the dimensions. The Turkish Physics Identity Survey was given in Appendix B.

Table 4.1. The dimensions of the Physics Identity Survey and one example item for each sub-dimension.

Dimensions	**Example Item for each dimension**
Identity	I see myself as a physics person.
Recognition	My physics teacher sees me as a physics person.
Interest	Physics is fun for me.
Performance/competence	I can overcome setbacks in physics.

4.2.2. The Physics Personal Epistemology Questionnaire

The latest version of the epistemic cognition survey was developed to measure physics students' personal epistemology called the Physics Related Personal Epistemology Questionnaire (PPEQ) (Özmen and Özdemir, 2019).

The questionnaire was a 5-point scale ranging from 1 (strongly disagree) to 5 (strongly agree) and included six dimensions: structure of knowledge (SK), justification of knowledge (JK), changeability of knowledge (CK), equations in physics (EQ), quick learning (QL) and source of knowledge (SOURCE).

Structure of knowledge is related to how knowledge is constructed with prior knowledge, justification of knowledge is about the demonstration and explanation of the obtained information and changeability of knowledge is about if the knowledge is fixed. Equations in physics questions how math is involved in learning physics, quick learning is related to the time of learning physics and finally, source of knowledge is related to where the knowledge is gathered.

At first, PPEQ included 42 items. However, after factor analyses, the EQ dimension was excluded and SK dimension was divided into two dimensions as structure of knowledge coherence (SKC) and structure of knowledge hierarchical (SKH). So, the remaining number of items in the questionnaire was 27, with dimensions of structure of knowledge coherence (SKC), structure of knowledge hierarchical (SKH), justification of knowledge (JK), changeability of knowledge (CK), quick learning (QL) and source of knowledge (SOURCE). While the reliability coefficients for the factors were ranging from 0.71 to 0.83, it was 0.92 for the overall 27 items.

Table 4.2. The dimensions of PPEQ and one example item for each sub-dimensions.

Dimensions	Example item
SKC	To understand a subject in physics, I need to understand the basic concepts of the subject.
SKH	I understand a subject in the physics lesson through the knowledge I have already learned.
JK	If the information given in the physics course contradicts what I know as correct, I question the rationale of this information.
CK	The knowledge I learned in the physics course is never-changing facts; so my knowledge will not change either.
SOURCE	I accept what my physics teacher says in the class without question.
QL	If I spare enough time to study, I can understand the rationale of the knowledge given in physics class.

4.2.3. Metacognitive Awareness Inventory (MAI)

While the MAI was originally developed by Schraw and Dennison (1994), it was adapted to Turkish by Akın *et al.* (2007). It includes 52 items on a 5-point Likert scale ranging from 1 (never true) to 5 (always true). The MAI includes two dimensions: knowledge of cognition and regulation of cognition. While knowledge of cognition refers to being conscious of how an individual is learning, regulation of cognition is about being able to track how well one is learning. Knowledge of cognition includes knowledge about facts and strategies (declarative), how to apply strategies (procedural) and when and why to apply them (conditional). Regulation of cognition measures planning, information management strategies, comprehension monitoring, debugging strategies and evaluation. The Cronbach alpha for the whole scale was 0.95, while for the subscales, it was ranging from 0.93 to 0.98.

Table 4.3. MAI dimensions and related items.

Dimensions **Knowledge of cognition**	**Example item**
Declarative knowledge	I understand my intellectual strengths and weaknesses.
Procedural knowledge	I find myself using helpful learning strategies automatically.
Conditional knowledge	I can motivate myself to learn when I need to.
Planning	I read instructions carefully before I begin a task.
Information management strategies	I try to break studying down into smaller steps.
Comprehension monitoring	I ask myself periodically if I am meeting my goals.
Debugging strategies	I stop and go back over new information that is not clear.
Evaluation	I know how well I did once I finish a test.

4.3. Procedure

To collect data, first ethical permissions were taken by the Ministry of Education and Boğaziçi University's Ethics Committee. The data was collected from the high schools in Istanbul via convenience sampling. The schools in the areas of Şişli, Taksim, Beşiktaş, Kağıthane and Sarıyer were visited by the researcher and the school principals were informed about the details of the research. The data was collected from the schools that are given permission for the research by the principals. The students in 9th, 10th and 11th grades were also informed about the research and told that the participation in the research was completely voluntarily and could leave the study whenever they wish. The students completed the demographic questionnaire including questions about their grades, age and socioeconomic status, physics identity survey, metacognitive awareness inventory and the physics personal epistemology questionnaire in a class hour. Gender was coded as 1 for female and 2 as male. The data was entered by the researcher with SPSS 27.

4.4. Internal Validity

According to Fraenkel, Wallen and Hyun (2012), correlational studies may face some threats internal validity, such as instrumentation, location, subject characteristics, testing and mortality.

4.4.1. Instrumentation

- Instrumentation Decay: Fatigue may occur during the study since there are multiple questionnaires that were tested at the same time. However, this was controlled by selecting a time schedule when students felt more energised, which was the earlier hours of school. Also, the questionnaire did not take much time of students and took around 40-50 minutes.
- Data Collector Characteristics and Bias: The nature of the data collected in research may be influenced by the gender, age, ethnicity, or other characteristics of the people who collect it. It's also possible that the data collectors unintentionally influence the data (Fraenkel *et al.*, 2012). To overcome these threats, the researcher collected all the data. In addition, the data collection procedure was standardized with clear instructions for students.

4.4.2. Location

Alternative interpretations for outcomes may arise as a result of the specific places where data is gathered (Fraenkel *et al.*, 2012). This threat was prevented by controlling the classroom conditions constant such as light, noise, distractions by the researcher.

4.4.3. Subject Characteristics

When some characteristics of individuals are associated, it's possible that additional features might explain the correlations that are discovered (Fraenkel *et al.*, 2012). These features can be age, gender, socioeconomic status and students' beliefs. However, this study was already covering these variables, so the threat was prevented in that way.

4.4.4. Testing

In correlational research, the experience of responding to the first instrument may impact subject responses to the second instrument (Fraenkel *et al.*, 2012). However, since the instruments were in different contexts, this threat was overcome.

4.4.5. Mortality

Since the data collection happened at a class hour and once, there was no threat for participant loss.

4.5. Ethical Consideration

For ethical consideration, firstly the study was approved by the ethical committee of Boğaziçi University and then by the Ministry of Education. Also, since the students were under the age of 18, a consent form was delivered to their parents. Participating in the study was completely voluntary. The data collected were anonymous and shared between the researchers only and kept safe in the computers and in lockers.

4.6. Data Analysis

Descriptive statistics were used to summarize the data. The reliability of the instruments was checked and the correlations between the variables was investigated. Furthermore, to examine the unique contributions of metacognition, epistemic cognition, gender, interest, recognition and self-efficacy to the physics identity, multiple regression analysis was conducted. Multiple regression analysis is used to see which independent variables predict the dependent variable and which independent variable is the best predictor (Pallant, 2016, p.167). Before the analysis of the data, the assumptions of multiple regression analysis were tested.

5. RESULTS

In this section, first descriptive statistics and correlations among variables were discussed. Gender differences were discussed for each variable. Then, the results of multiple regression analysis were presented and discussed.

5.1. Descriptive Statistics

Table 5.1 shows descriptive statistics and reliabilities for all study variables. The possible minimum and maximum values of physics identity, recognition, physics self-efficacy and interest were 0.00 and 10.0. Recognition was measured with 4 items. By adding up the points from the 4 items and dividing the total by 4, students' recognition scores were determined. Similar to recognition, interest was measured with 4 items as well and the total score was calculated by addition of the scores of the items and dividing by 4. In addition, there were 6 items to measure self-efficacy. Students' self-efficacy scores were calculated by the addition of the scores of 6 items and dividing by 6. Higher scores in the total scores of recognition, interest and self-efficacy showed higher levels in that variable.

Table 5.1. Descriptive statistics and reliabilities.

	Min	**Max**	**Mean**	**SD**	**Reliability (Cronbach's alpha)**
1.Gender	-	-	-	-	-
2.Identity	0.00	10.0	5.56	2.73	-
3.Recognition	0.00	10.0	4.86	2.57	0.88
4.Physics Self-Efficacy	0.00	10.0	5.82	2.40	0.92
5.Interest	0.00	10.0	5.38	2.92	0.95
6.Metacognition	1.00	5.00	3.38	0.63	0.96
7.Epistemic Cognition	2.48	5.00	3.89	0.45	0.88

Similarly, the minimum and maximum values of physics identity, interest, recognition and self-efficacy were 0 and 10, respectively. The means of physics identity, recognition, self-efficacy and interest were greater than the mid-point of the ten-point scale. There are 52 items on a five-point Likert scale in the MAI ranging from 1 (never) to 5 (always). To calculate students' metacognition scores, students' points from 52 items were added up and divided by 52. The maximum possible score for MAI is 5, while the lowest possible value is 1. Higher scores indicate a higher level of metacognition. The minimum and maximum scores for metacognition were 1.00 and 5.00, respectively. The mean of metacognition was greater than the mid-point of the five-point scale. For epistemic cognition, there were 27 items on a five-point Likert scale ranging from 1 (not at all) to 5 (very much so).

Students' epistemic cognition scores were calculated by adding up the points from 27 items and dividing them by 27. Again, higher scores indicated a higher level of epistemic cognition. The possible minimum and maximum values of metacognition and epistemic cognition were 1.00 and 5.00, respectively. However, the minimum value of epistemic cognition was 2.48 considering the data. The maximum value of epistemic cognition was 5.00. The mean of epistemic cognition was above the midpoint.

As seen in Table 5.1, the reliability analysis of the scales measuring the related constructs revealed that Cronbach's alpha was 0.88 for recognition, 0.92 for self-efficacy, 0.95 for interest, 0.96 for metacognition and 0.88 for epistemic cognition. Because Cronbach's alpha was bigger than 0.70 for each scale, there was a very good internal consistency reliability for each scale (Pallant, 2011).

5.1.1. Correlations Among Study Variables

Looking at the correlations among the variables in Table 5.2, the relationship between identity and interest, self-efficacy, recognition, metacognition, epistemic cognition and gender was statistically significant ($p < 0.01$). However, the relationship between gender and metacognition was not statistically significant ($p > 0.05$). Also, there was no statistically significant relationship between gender and epistemic cognition ($p > 0.05$).

Table 5.2. Correlations among all study variables.

		Epistemic Cognition	Metacognition	Gender	Recognition	Interest	Self-Efficacy	Identity
Epistemic cognition	Pearson Correlation	1	0.535**	0.004	0.364**	0.455**	0.438**	0.381**
Meta Cognition	Pearson Correlation	0.535**	1	0.007	0.380**	0.394**	0.431**	0.369**
Gender	Pearson Correlation	0.004	0.007	1	0.172**	0.227**	0.261**	0.260**
Recognition	Pearson Correlation	0.364**	0.380**	0.172**	1	0.667**	0.780**	0.802**
Interest	Pearson Correlation	0.455**	0.394**	0.227**	0.667**	1	0.768**	0.735**
Self-efficacy	Pearson Correlation	0.438**	0.431**	0.261**	0.780**	0.768**	1	0.807**
Identity	Pearson Correlation	0.381**	0.369**	0.260**	0.802**	0.735**	0.807**	1

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

As seen in Table 5.2 based on cut-off values recommended by Cohen and Cohen (1983), there was a very high positive correlation between identity, recognition, self-efficacy and interest constructs. Moreover, identity, recognition, self-efficacy and interest were moderately positively correlated with epistemic cognition and metacognition. The relationships among identity, recognition, self-efficacy, interest, metacognition and epistemic cognition were statistically significant. Finally, there was a high positive correlation between metacognition and epistemic cognition and this relationship was statistically significant as well.

5.1.2. Gender Differences

Table 5.3 shows the gender differences for each variable with mean values and standard deviations. While the mean value of female students' identities was 4.96 (SD=2.65), the mean value for males was 6.40 (SD=2.61). The descriptive statistics showed that male students had higher physics identity levels than females. Males having higher scores than females also applied to other identity-related constructs. The mean value for male students' interest was 6.17 (SD=2.78) and the female students' mean value was 4.82 (SD=2.90). For recognition, the mean value for males was 5.39 (SD=2.50), while for females, it was 4.49 (SD=2.56). Also, the mean value of male students' physics self-efficacies was 6.56 (SD=2.22) and for females, it was 5.29 (SD=2.39).

On the other hand, there was no gender difference observed in metacognition and epistemic cognition. The mean value of male and female students' metacognition was 3.38 (SD=0.63). While the mean value of male students' epistemic cognition was 3.90 (SD=0.47), the mean value of females was 3.89 (SD=0.42).

Table 5.3. Descriptive statistics according to gender.

Gender	N	Variable	Mean	Standard Deviation
Female	697	Identity	4.96	2.65
Male	500		6.40	2.61
Female	697	Interest	4.82	2.90
Male	500		6.17	2.78
Female	697	Recognition	4.49	2.56
Male	500		5.39	2.50
Female	697	Self-efficacy	5.29	2.39
Male	500		6.56	2.22
Female	697	Metacognition	3.38	0.63
Male	500		3.38	0.63
Female	697	Epistemic cognition	3.89	0.42
Male	500		3.90	0.47

In order to evaluate if there were significant gender differences in the study variables, the correlation of gender with the study variables was examined. The significant correlation indicates a significant mean difference between male and female students. Since females were the base group coded as 1, the positive correlation depicts a significant mean difference in favor of boys or vice versa. On the other hand, the absence of a relationship indicates that there is no difference between the means. As in Table 5.2, there was a medium positive correlation between gender and identity, interest and self-efficacy, while there was a low positive correlation between gender and recognition. Although there was a statistically relationship between gender, interest, self-efficacy, recognition and identity, there was no statistically significant relationship between gender and metacognition and gender and epistemic cognition. The correlation between gender and metacognition and gender and epistemic cognition were negligible.

5.2. Multiple Regression Analysis

The unique contributions of multiple independent variables to a dependent variable were examined using multiple regression analysis. In the current study, physics identity was the dependent variable and recognition, interest, physics self-efficacy, metacognition, epistemic cognition and gender were independent variables. Before conducting the multiple regression analysis, the assumptions were checked.

5.2.1. Assumptions of Multiple Regression Analysis

The following assumptions were examined to perform multiple regression analysis in this study: sample size, multicollinearity, outliers, normality, linearity and homoscedasticity (constant variance of the error terms).

Sample size: According to Pallant (2016), the sample size is effective on the generalisability of the conclusions of a study to be applied (p.169). The necessary sample size can be calculated from the formula $N > 50+80m$ where m is the number of independent variables. In this study, the number of independent variables is $m=6$. While the recommended sample size is 530, the sample size in this study is 1197.

In addition, required sample size can be determined with the power analysis for a reliable prediction. To determine a priori how many subjects are needed per group, power was taken 0.80 at the 0.05 level (Pituch and Stevens, 2016, p.121). Because there were 6 predictors, the required sample size was calculated as 688 with G-power. Thus, the sample size of the study was adequate for carrying out a reliable regression analysis. Multicollinearity and singularity: This assumption concerns how the independent variables are related. When the independent variables are strongly linked which is the correlation coefficient is more than 0.90, multicollinearity occurs. When one independent variable is a combination of several independent variables, this is known as a singularity. According to Table 5.2, multicollinearity was not an issue in the present study.

Also, Tolerance and VIF can be checked to test multicollinearity (Pallant, 2016, p.178). Tolerance indicates the variability of an independent variable is not explained by the other independent variables. If the value is less than 0.10, it shows the possibility of multicollinearity. VIF (Variance Inflation Factor) is the inverse of the Tolerance value, so if it is higher than 10, it indicates multicollinearity (Pallant, 2016, p.178). As in the table, the tolerance values are higher than 0.10 and the VIF values are less than 10 for all the independent variables.

Table 5.4. Tolerance and VIF values for the independent variables.

	Tolerance	VIF
Recognition	0.378	2.648
Self-efficacy	0.265	3.768
Interest	0.380	2.632
Metacognition	0.660	1.516
Epistemology	0.634	1.578

Outlier: According to Pallant (2016), multiple regression is sensitive to outliers (p.170). Outliers have standardised residual values more than 3.3 or less than -3.3. It is usual to detect few outlying residuals in large samples and it might not be necessary to take any action. Cook's Distance can be checked to see if the outliers impact the results. The value shouldn't be larger than 1. In the analysis, the maximum value was 0.038. So, the outliers did not have an effect on the results.

Normality: The initial assumption to perform multiple regression analysis is to have normal distributions for all the variables. Kolmogorov-Smirnov and Shapiro-Wilk tests were run to check the assumption showing non-normal distributions ($p<.05$). However, as sample size affects the results of the Shapiro-Wilk and Kolmogorov-Smirnov tests, larger samples may give significant results that suggest non-normal distributions. Taking into account the skewness and kurtosis values is an alternate method of testing the normality (George and Mallary, 2010). Normal distributions are those with skewness and kurtosis values between -2 and +2. Because there was a large sample size investigated in this study (N=1197), skewness and kurtosis values can be considered for normality. The skewness and kurtosis values resulted in between -2 and +2 in the study, showing normal distributions.

Table 5.5. Skewness and kurtosis values for independent and dependent variables.

	Skewness	Kurtosis
Identity	-0.285	-0.650
Interest	-0.187	-0.935
Recognition	-0.053	-0.688
Self-efficacy	-0.408	-0.423
Metacognition	-0.202	0.728
Epistemology	-0.278	0.223
Gender	0.334	-1.892

Analyzing the Normal Probability-Probability of Regression Standard Residual plot visually is another technique to test the assumption of normality. The normality assumption is met when the plot is a straight diagonal line from bottom left to top right.

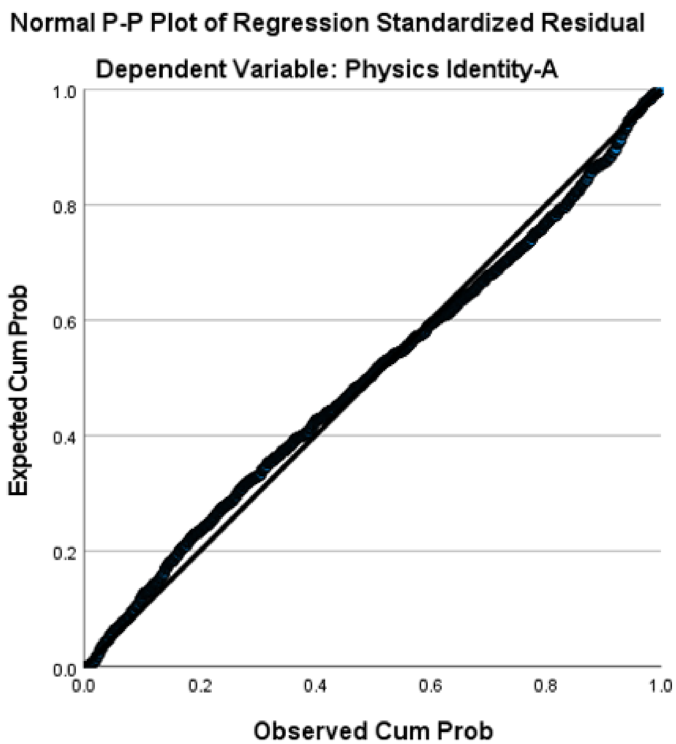

Figure 5.1. Normal plot of regression standardized residual.

Linearity: To meet this assumption, the predicted dependent variable scores and residuals should be related in a straight line (Pallant, 2016, p.171).

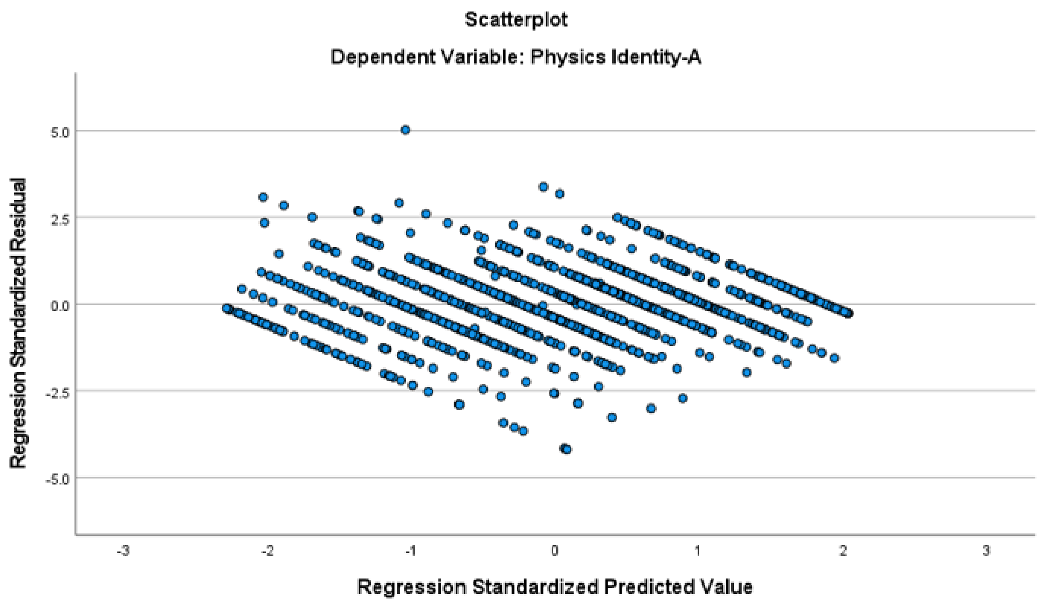

Figure 5.2. Distribution of standard residual values.

Homoscedasticity: According to the homoscedasticity assumption, the variance of the residuals about expected DV scores for each predicted score should be the same, seen from the scatterplot of standardized residuals (Pallant, 2016, p.171). In Figure 5.2, the values in the scatterplot mostly range between -2.5 and 2.5, so the assumption is met.

5.2.2. Results of Multiple Regression Analysis

After checking the data for required assumptions, standard multiple regression analysis was performed to show the contribution of each independent variable to predicting the physics identity. In standard multiple regression, all of the independent (or predictor) variables are simultaneously entered into the equation. The predictive value of each independent variable is assessed relative to what is provided by the other independent variables. This method would be used to determine the amount of variance in a dependent variable that a set of factors may explain collectively or in a block

(Pallant, 2011, p.149). The significance of the contribution of the independent factors to the dependent variable is shown in Table 5.6. The linear combination of recognition, interest, self-efficacy, gender, metacognition and epistemic cognition was found to be significantly related to physics identity (F (6, 1190)=590.4, p<.001).

Table 5.6. ANOVA results.

Model	Sum of Squares	df	Mean Square	F	p
Regression	6675.52	6	1112.59	590.43	0.000
Residual	2242.38	1190	1.88		
Total	8917.90	1196			

Table 5.7 shows how much the linear combination of independent variables explains the physics identity. According to Cohen and Cohen (1983), R-squared values of more than 0.25 show a large effect size. The current R squared value corresponds to a very large effect size (F (6, 1190)=590.4, p<.001, R^2=.749). The %74.9 variance in physics identity was explained by the linear combination of independent variables.

Table 5.7. Model Summary.

Model	R	R Square	Adjusted R2	Standard Error of the Estimate
1	0.865	0.749	0.747	1.372

Table 5.7 presents unstandardized coefficients, standardized coefficients, significance values and partial correlations for each independent variable to show how each independent variable contributes to physics identity. The beta weights show how much each independent variable contributed to the dependent variable.

Table 5.8. Summary of Coefficients.

Model	B	Standard Error	Beta	t	p	Part R
Constant	-0.118	0.393		-0.300	0.764	
Self-efficacy	0.354	0.032	0.311	11.035	0.000	0.160
Interest	0.196	0.022	0.210	8.925	0.000	0.130
Recognition	0.434	0.025	0.409	17.285	0.000	0.251
Gender	0.340	0.085	0.061	4.016	0.000	0.058
Metacognition	-0.020	0.078	-0.005	-0.261	0.794	-0.004
Epistemic Cognition	0.011	0.111	0.002	0.097	0.923	0.001

When the relative contributions of the independent variables to the physics identity are examined with the standardized beta values, recognition (β =0.409, $p< 0.05$), interest (β = 0.210, $p< 0.05$), self-efficacy (β = 0.311, $p< 0.05$) and gender (β = 0.061, $p< 0.05$) significantly contributed to the prediction of physics identity. On the other hand, metacognition (β = -0.005, $p> 0.05$) and epistemic cognition (β = 0.002 , $p> 0.05$) did not contribute significantly to physics identity above and beyond other predictors. Recognition was the variable that most significantly and positively predicted physics identity after controlling for the other predictors. Cohen (1988) states that for a coefficient, effect sizes between 0.10 and 0.29 are small, 0.30 and 0.49 are medium and 0.50 or more are large. That's why, recognition and self-efficacy have a medium to large effect size, interest has a small to medium effect size and gender has a small effect. However, metacognition and epistemic cognition have very small effect sizes.

Table 5.8 also includes Part-R values, also known as semi-partial correlation coefficients, for each independent variable. According to Pallant (2016, p. 182), the squared of this value determines the contribution of that variable to the overall R square. The highest unique contribution is by recognition variable, according to the table, showing that it can explain %6.3 of the total variance.

6. DISCUSSION AND CONCLUSION

This study aims to investigate the inter-relations among epistemic cognition, metacognition, recognition, physics self-efficacy, interest and gender for high school students. Also, how epistemic cognition, metacognition, recognition, physics self-efficacy, interest and gender predicted physics identity was observed.

First of all, the correlations between the variables were considered. There was a very high positive correlation between identity, recognition, self-efficacy and interest constructs. Identity, recognition, self-efficacy and interest were moderately positively correlated with epistemic cognition and metacognition. There was a medium positive correlation between gender and identity, interest and self-efficacy. In contrast, there was a low positive correlation between gender and recognition. Moreover, the correlations between gender and metacognition and gender and epistemic cognition were negligible. Finally, there was a high positive correlation between metacognition and epistemic cognition.

Looking at how the variables predicted the physics identity; it was observed that interest positively predicted physics identity. This was in line with the findings of Dou and Cian (2022), Verdín (2021), Godwin, Potvin and Hazari (2013) and Cheng *et al.* (2018). Also, recognition was the variable that predicted physics identity the most. Similarly, Lock, Hazari and Potvin (2013) revealed recognition to be one of the strongest predictors of physics identity. That's why to increase students' physics identity levels, working on students' recognition of physics plays one of the key roles. For example, Lock, Castillo, Hazari and Potvin (2015) addressed some strategies to be effective in increasing recognition levels, such as projects/labs addressing a community/family issue and questions requiring graphing. There were other strategies effective on students' both recognition and interest in physics. These were topics being relevant to the student's life; the student asked questions, answered questions and made comments; spoke with a male engineer/scientist visitor; the student picked the topic for labs/projects; covered engineering careers, stages and options; questions required new insight or creativity; and required conceptual understanding. Strategies like participating in outdoor activities and questions involving data presented in tables increased students' physics interests (Lock *et al.*, 2015).

While Dou and Cian (2022), Verdín (2021), Godwin, Potvin and Hazari (2013) and Cheng *et al.* (2018) showed that through interest and recognition, self-efficacy was related to identity, the results of the current study showed that self-efficacy positively predicted physics identity. This identity model aligned with the findings of Lock *et al.* (2013) that showed physics identity had three related constructs: performance/competence, interest and recognition. It was also observed that physics self-efficacy had a high impact on physics identity after recognition. There can be activities and instructions developed to increase students' self-efficacies. For example, Ballen, Wieman, Salehi, Searle and Zamudio (2017) developed STEM instruction by adding pre-lecture assignments like videos, readings, quizzes, group work during lectures, active learning modules including interpretations and discussions that resulted in an increase in students' self-efficacies. In addition, out-of-class science and engineering activities such as participating in STEM clubs, summer programs and camps lead to an increase in self-efficacy (Lock, Hazari and Potvin, 2019).

On the other hand, in the study, it was observed that metacognition could not predict physics identity directly. This result contradicted the finding of Guo *et al.* (2022a). Similarly, epistemic cognition did not predict physics identity directly, even though both Krettenauer (2005) and Peffer, Royse and Abelein (2018) indicated a relationship between identity and epistemic cognition. This contradiction may be resulting from the difference in predictors. Also, metacognition and epistemology correlated significantly with physics identity, as seen in Table 5.2. According to Tabachnick and Fidell (2013, p.160), after controlling for the mediator, the direct relationship between the independent variable and the dependent variable can be examined in multiple regression analysis. Similarly, although there was a mean difference with a small to medium effect size in physics identity scores of boys and girls, this difference had a small effect size in the regression analysis. That is, when other predictors were controlled, the gender difference decreased, which may indicate mediating effects of other predictors in the relation of epistemic cognition, metacognition and gender to physics identity. These mediating relationships can be studied further with mediation analysis studies.

Considering the gender differences in the variables, males had higher levels of physics identity, recognition, interest and self-efficacy than females. This result aligned with the previous findings of Hazari *et al.* (2010), Hazari *et al.* (2013), Cwik and Singh (2021, 2022), Lock, Hazari and Potvin (2013),

Yerdelen-Damar and Eryilmaz (2010), Trumper (2006) and Nissen (2019). Thus, we need special teaching strategies and classroom activities to decrease gender differences. For example, Sawtelle, Brewe and Kramer (2010) found that modeling instruction, including collaborative learning environments, positively influenced female students' self-efficacy. Similarly, Espinosa, Miller, Araujo and Mazur (2019) indicated that a project-based introductory physics class, including inquiry-driven projects blending with peer instruction, tutorials, estimation and experimental design activities and problem sets, reduced the gender gap in physics self-efficacy. To decrease the gender gap in physics identity and identity-related constructs, there can be instructions developed to concentrate on exploring students' values and career goals for them to see how they can achieve these by choosing a physics career (Cheng *et al.*, 2018). Furthermore, Hazari *et al.* (2010) recommended emphasizing conceptual understanding and real-world/contextual relevance in physics instruction and the discussion of women's underrepresentation in science can promote females' physics identities.

On the other hand, there was no gender difference in epistemic cognition and metacognition. While this result was supported by the findings of Yerdelen-Damar and Peşman (2013) and Chen and Pajares (2010), it contradicted the findings of Topçu and Yılmaz-Tüzün (2009), Kurt (2009), Ozkal, Tekkaya, Sungur, Cakiroglu and Cakiroglu (2010), Ozkan and Tekkaya (2011) and Yenice (2015).

In conclusion, this study investigated the relations among epistemic cognition, metacognition, recognition, physics self-efficacy, interest and gender for high school students and how gender, metacognition, epistemic cognition, interest, self-efficacy and recognition predicted physics identity. Interest, recognition and self-efficacy positively predicted physics identity, while the strongest predictor was recognition. Metacognition and epistemic cognition did not predict physics identity. In terms of gender differences, males had higher levels of physics identity, recognition, interest and self-efficacy than females. On the other hand, no gender difference was observed in metacognition and epistemic cognition. These findings suggest the importance of increasing students' physics identity levels and decreasing the gender gap by working on teaching strategies and developing instructions focusing explicitly on self-efficacy, recognition and interest constructs.

7. LIMITATIONS AND SUGGESTIONS

Since the convenience sampling method was used in this study, it may be a limitation for the generalizability of the results. Also, because students were completing the surveys themselves, they could reflect themselves in an exaggerated way or for social desirability. Finally, the study is limited to high school students taking physics courses.

Further studies can detect other variables predicting physics identity. The study can be applied to other disciplines, such as mathematics or chemistry. Other analysis methods can be conducted to investigate the relations between the variables. For instance, structural equation modeling can be conducted to make mediator analyses and investigate direct and indirect relations. Also, experimental studies can be conducted using identity formation strategies. Lastly, the study can involve a qualitative perspective to gain more insight into students' identities.

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APPENDIX A: PERMISSIONS

T.C.
İSTANBUL VALİLİĞİ
İl Milli Eğitim Müdürlüğü

Sayı : E-59090411-20-37343807 22/11/2021
Konu : Anket ve Araştırma İzni (Yaren ULU)

VALİLİK MAKAMINA

İlgi : a) Yenilik ve Eğitim Teknolojileri Genel Müdürlüğünün 21.01.2020 tarihli ve 2020/2 sayılı genelgesi.
b) Boğaziçi Üniversitesinin 05.11.2021 tarihli ve 37360 sayılı yazısı.
c) Müdürlüğümüz Araştırma ve Anket Komisyonunun 19.11.2021 tarihli tutanağı.

Araştırma Konusu	: Fizik Kişiliği İle İlgili Yapılar Arasındaki İlişki: Epistemik Biliş, Bilişüstü Farkındalık, Öğrenme Yaklaşımları, Motivasyon ve Öğrenme Ortamı İle İlgili Algılar
Araştırma Türü	: Anket
Araştırma Yeri	: Beşiktaş, Beyoğlu, Kağıthane, Sarıyer ve Şişli
Araştırma Kişiler	: Anadolu ve Fen Liselerindeki Öğrenciler
Araştırmanın Süresi	: 2021 - 2022 Eğitim ve Öğretim Yılı

Yukarıda bilgileri verilen araştırmanın; 6698 sayılı Kişisel Verilerin Korunması Kanununa aykırı olarak kişisel veri istenmemesi, öğrenci velilerinden açık rıza onayı alınması, yüz yüze eğitime geçmiş olan kurumlarımızda, Covid-19 tedbirlerinin araştırmacı ve ilgili kurum idarelerince alınması, bilimsel amaç dışında kullanılmaması, bir örneği Müdürlüğümüzde muhafaza edilen mühürlü ve imzalı veri toplama araçlarının kurumlarımıza araştırmacı tarafından ulaştırılarak uygulanması, katılımcıların gönüllülük esasına göre seçilmesi, araştırma sonuç raporunun kamuoyuyla paylaşılmaması ve araştırma bittikten sonra 2 (iki) hafta içerisinde Müdürlüğümüze gönderilmesi, okul idarelerinin denetim, gözetim ve sorumluluğunda, eğitim ve öğretimi aksatmayacak şekilde, ilgi (a) genelge esasları dâhilinde uygulanması kaydıyla Müdürlüğümüzce uygun görülmektedir.

Makamınızca da uygun görüldüğü takdirde olurlarınıza arz ederim.

Levent YAZICI
İl Milli Eğitim Müdürü

OLUR
22/11/2021
Dr. Hasan Hüseyin CAN
Vali a.
Vali Yardımcısı

Ek:
1- İlgi (b) Yazı ve Ekleri (11 Sayfa)
2- İlgi (c) Tutanak (1 Sayfa)

Bu belge güvenli elektronik imza ile imzalanmıştır.

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Belge Doğrulama : https://www.turkiye.gov.tr/meb-ebys
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9e76-a70c-3307-87f1-eaba

Figure A.1. Permission from the Ministry of Education.

Evrak Tarih ve Sayısı: 11.05.2023-126414

T.C.
BOĞAZİÇİ ÜNİVERSİTESİ REKTÖRLÜĞÜ
Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu
(FMİNAREK)

Sayı : E-84391427-050.01.04-126414 11.05.2023
Konu : 2023/17 Kayıt no'lu başvurunuz hakkında

Sayın Doç. Dr. Sevda YERDELEN DAMAR
Matematik ve Fen Bilimleri Eğitimi Bölüm Başkanlığı - Öğretim Üyesi

"The Relationships Among Metacognition, Epistemic Cognition, and Physics Identity Constructs, Üstbiliş, Epistemik Biliş ve Fizik Kimlik Yapıları Arasındaki İlişkiler" başlıklı projeniz ile Boğaziçi Üniversitesi Fen Bilimleri ve Mühendislik Alanları İnsan Araştırmaları Etik Kurulu (FMİNAREK)'e yaptığınız 2023/17 kayıt numaralı başvuru 02.05.2023 tarihli ve 2023/05 No.lu kurul toplantısında incelenerek etik onay verilmesi uygun bulunmuştur.

Bu karar tüm üyelerin toplantıya on-line olarak katılımıyla ve oybirliği ile alınmıştır. Onay mektubu tüm üyeler adına Komisyon Başkanı tarafından e-imzalanmıştır.

Saygılarımızla bilginize sunarız.

Prof. Dr. Tınaz EKİM AŞICI
Başkan

Bu belge, güvenli elektronik İmza ile imzalanmıştır.

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Internet Adresi:www.boun.edu.tr
Kep Adresi:bogaziciuniversitesi@hs01.kep.tr

Bilgi için: Nurşen MUNAR
Unvan: Mühendis

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Figure A.2. Permission from the Ethics Committee of Boğaziçi University.

APPENDIX B: PHYSICS IDENTITY SCALE

FİZİKLE İLGİLİ TUTUM VEYA DENEYİMLERİNİZ HAKKINDA:

1. Aşağıdaki ifadelere ne derecede katılıyorsunuz veya katılmıyorsunuz?
   0- Hiç katılmıyorum 10- Tamamen katılıyorum

a- Kendimi fiziğe yatkın biri olarak görürüm.	0 1 2 3 4 5 6 7 8 9 10
b- Fizik öğretmenim beni fiziğe yatkın biri olarak görür.	0 1 2 3 4 5 6 7 8 9 10
c- Ailem beni fiziğe yatkın biri olarak görür.	0 1 2 3 4 5 6 7 8 9 10
d- Arkadaşlarım veya sınıf arkadaşlarım beni fiziğe yatkın biri olarak görür.	0 1 2 3 4 5 6 7 8 9 10
e- Başkaları benim fizikle ilgili fikirlerime danışır.	0 1 2 3 4 5 6 7 8 9 10
f- Fiziği anlayabildiğime eminim.	0 1 2 3 4 5 6 7 8 9 10
g- Fizik sınavlarında başarılı olabilirim.	0 1 2 3 4 5 6 7 8 9 10
h- Fizikte çalıştığım kavramları anlıyorum.	0 1 2 3 4 5 6 7 8 9 10
i- Fizik öğrenirken kendimi rahat hissederim.	0 1 2 3 4 5 6 7 8 9 10
j- Fizik sorularını çözerken kendime güvenirim.	0 1 2 3 4 5 6 7 8 9 10
k- Fizikte başarısızlığı aşabilirim.	0 1 2 3 4 5 6 7 8 9 10
l- Fizikle ilgili daha çok şey öğrenmeye ilgiliyim.	0 1 2 3 4 5 6 7 8 9 10
m- Fizik konuları bende merak uyandırır.	0 1 2 3 4 5 6 7 8 9 10
n- Fizik öğrenmekten keyif alırım.	0 1 2 3 4 5 6 7 8 9 10
o- Fizik benim için eğlencelidir.	0 1 2 3 4 5 6 7 8 9 10

Note: This scale was used in the thesis in accordance with the 'publishing policy applicable to the reuse of the text and graphics produced by the author'.

Figure B.1. The Physics Identity Scale.