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PHYSICS TEACHERS' EPISTEMOLOGICAL BELIEFS: CORE AND PERIPHERAL DIMENSIONS

FİZİK ÖĞRETMENLERİNİN EPİSTEMOLOJİK İNANÇLARI: TEMEL VE ÇEVRESEL BOYUTLAR

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Özet: Bu çalışmanın amacı, fizik öğretmenlerinin dört inanç sistemi- bilgi, fen, öğretme ve öğrenme bilimlerine ilişkin inançları- arasındaki ilişkiyi incelemektir. Katılımcılar 59 lise fizik öğretmenidir ve yarı yapılandırılmış bir görüşme protokolü aracılığıyla öğretmenlerle bir kez görüşülmüştür. Görüşmeler, öğretmenlerin inançlarını geleneksel, geçişsel ve yapılandırmacı olmak üzere farklı düzeylerde kategorize etmek ve tanımlayıcı, korelasyonel istatistikler ve yapısal eşitlik modellemesi uygulamak için yazıya dökülmüş ve nitel yöntemle analiz edilmiş ve rubrik kullanılarak nicel veri haline dönüştürülmüştür. Sonuçlar, öğretmenlerin bilgi ve bilime ilişkin inançlarının çoğunlukla geçişsel inançlara sahip olduklarını, fen öğretimi ve öğrenimine ilişkin inançlarının ise yapılandırmacı olduğunu göstermiştir. Temel inançlar olarak bilgi ve bilime ilişkin inançlar arasında, çevresel inançlar olarak fen öğretimi ve öğrenimine ilişkin inançlar arasında anlamlı bir ilişki bulunurken, temel ve çevresel inançlar arasında pozitif korelasyon bulunmuştur. Bu bulgular, gelecekteki mesleki gelişim programlarının tasarımı yoluyla öğretmenlerin inançlarını ele almak için bir rehber olarak bir rapor sunmaktadır.

Anahtar sözcükler: inançlar, epistemoloji, fizik, öğretmen eğitimi.

Abstract: This study aims to examine physics teachers' beliefs about knowledge, science, teaching and learning science to understand the relationship among four belief systems. Participants were 59 high school physics teachers, who were interviewed once through a semi-structured interview protocol. The interviews were transcribed and analyzed through qualitative methods to categorize teachers' beliefs in different levels: traditional, transitional, and constructivist and quantify the nominal data for descriptive, correlational statistics, and structural equation modeling. The results indicated that teachers mostly held transitional beliefs about knowledge and science while their beliefs were constructivist on teaching and learning science. There was a significant relationship between beliefs about knowledge and science as core beliefs and between beliefs about teaching and learning science as peripheral beliefs, positive correlation was found between core and peripheral beliefs. These findings offer a report as a guide to address teachers' beliefs through the design of future professional development programs.

Keywords: beliefs, epistemology, physics, teacher education.

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GENİŞ ÖZET

Giriş

Fen eğitiminde reform çalışmaları, 21. yüzyıl becerilerinin bütünleştirilmesini, birçok ülkede araştırmaya dayalı ve yenilikçi stratejilerin ve müfredatların ele alınmasını amaçlamaktadır (Milli Eğitim Bakanlığı (MEB), 2011; NGSS Lead States, 2013; Singer et al., 2012). Öğretmenler bu araştırmaya dayalı yaklaşımları bütünleştirirler veya yenilikçi yöntemlerin uygulanmasını etkileyen yapısal ve kişisel faktörlere dayalı olarak değiştirmeyi tercih ederler (Enderle et al., 2022; Henderson et al., 2011). Yapısal faktörler, öğretmenlerin çalışmaları için kurumsal kararlarla ilgili olabilir, ancak öğretmen inançları gibi kişisel faktörler, öğretmenlerin müfredat, planlama, değerlendirme ve öğretim uygulamaları hakkında nasıl karar verdiklerini etkiler (Muis & Foy, 2010). Bu nedenle, öğretmen inanç sisteminin yapısını anlamak, öğretmenlerin öğretimsel kararları nasıl aldıklarını ve öğretme ve öğrenme sürecini neyin etkilediğini kavramsallaştırmak için bir araştırma kaynağıdır.

Epistemolojik inançlar, disipline özgü ve alan-genel boyutlarını incelemek için inanç sisteminin bir parçası olarak odaklanmıştır (Feucht, 2017). Alan-genel inançlar, bilginin doğası, nasıl tanımlandığı, yapılandırıldığı, kavramsallaştırdığı ve diğer inanç sistemleriyle nasıl bir bütünlük oluşturması ile ilgilenir, çünkü öğretmen epistemolojisi aynı zamanda bilim inançları ve fen öğretimi ve öğrenimi ile ilgili inançlar gibi alana özgü inançları da içerir (Sengul, 2018). Muis ve ark. (2006)'ya göre, öğretmenler veya öğrenciler matematik ve sosyoloji hakkında farklı inançlara sahip olabilirler. Yazarlar, bireylerin matematiksel bilgiye mutlak ve istikrarlı olarak yaklaşma eğiliminde olduklarını, oysa sosyal bilimlerdeki bilgiye iddiaların değerlendirilmesini gerektiren bir bilgi olarak yaklaşma eğiliminde olduklarını bulmuşlardır. Diğer araştırma sonuçları da öğretmenlerin epistemolojik inançlarının öğretme ve öğrenme bağlamına dayalı olarak etkileşim boyutlarını ve bu boyutlardaki farklılıkları içerdiğini göstermiştir.

Tsai (2002) alana özgü inançları incelemiş ve bilim, öğretme ve öğrenme arasındaki ilişkiye bakmıştır. Sonuçlar, katılımcı fen bilimleri öğretmenlerinin çoğunun, geleneksel düzeyde olmalarına rağmen, öğretme, öğrenme ve fen bilimleri hakkında uyumlu görüşlere sahip olduklarını göstermiştir. Çoğu çalışma, alana özgü inançların araştırılmasına odaklanmıştır (örneğin, Belo ve diğerleri, 2014; Tsai, 2002), ancak hiçbir çalışmada öğretmenlerin alan-genel (örneğin bilginin doğası hakkındaki inançlar) ve alana özgü (örneğin fen hakkındaki inançlar) inançları ile belirli bir disiplinin öğretimi ve öğrenimi hakkındaki inançları arasındaki kavramsal ilişki araştırılmamıştır. Bir çalışmada, Brownlee (2001) epistemik inançları çekirdek ve çevresel inançlara ayırmıştır: temel inançlar, değiştirilmesi zor olan genel ve disipliner bilgi olarak tanımlanırken, öğretme ve öğrenme ile ilgili inançlar, belirli bir bağlamda değiştirilmesi kolay çevresel bilgi olarak tanımlanır. Bu çalışmada, fizik öğretmenlerinin epistemolojik inançları, çekirdek ve çevresel inançları arasındaki ilişkinin incelenmesi amaçlanmıştır. Araştırmanın amacı, lise fizik öğretmenlerinin bilginin ve bilimsel bilginin doğası, fen öğretimi ve öğrenimi hakkındaki inançlarını inceleyerek dört inanç sistemi arasındaki ilişkiyi anlamaktır. Burada önerilen bu araştırma, alana özgü inançların çekirdek ve çevresel inançları içeren genel inançlarla ilişkisini aşağıdaki araştırma sorusu ile araştırmayı amaçlamaktadır: Fizik öğretmenlerinin epistemolojik inanç boyutları, temel ve çevresel inançları içeren genel ve disipline özel inançları birbirleri ile nasıl ilişkilidir?

Yöntem

Bu çalışma, lise fizik öğretmenlerinin inanç sistemini nicel desen ile incelemeyi amaçlamıştır (Creswell & Plano Clark, 2017). Fizik öğretmenlerinin alan-genel ve fen bilimlerine özgü inançları- bilgi, fen bilgisi, bilim öğretimi ve öğrenimi hakkındaki inançlarını nasıl kavramsallaştırdıklarını anlamayı amaçlamıştır. Katılımcıların epistemolojik inançlarını farklı boyutlarda ve alanlarda incelemek için nitel araştırma yöntemi olan mülakat yoluyla katılımcılara açık-uçlu sorular soruldu. Ardından, analiz ve sonuçların daha iyi yorumlanması ve nitel verileri ölçmek için nominal verileri rubrik yardımıyla sayısal verilere dönüştürüldü. Türkiye’de büyük bir metropolde çalışmaya katılmak için gönüllü olan 23 kadın ve 36 erkek olmak üzere fizik öğretmeni olarak 59 katılımcı vardı. Katılımcıların yaşları 30'lu yaşların başı ile 60'lı yaşlar arasında değişiyordu ve 10 yılı aşkın öğretmenlik deneyimi vardı. Deneyimli bir fizik öğretmeninin inanç sistemi istikrarlı kabul edildi, bu nedenle her öğretmenle yarı yapılandırılmış bir görüşme protokolü aracılığıyla bir kez görüşüldü. Her katılımcı, fizik öğretmenlerinin bilgi, fen ve fen öğretimi ve öğrenme boyutlarını içeren epistemolojik inançlarına odaklanan açık uçlu sorularla 40-60 dakikalık görüşmelere katılmıştır. Görüşmeler kaydedildi ve analiz için yazıya döküldü. Örnek mülakat soruları şu şekilde verilmiştir: 1) Fen öğretimi ve öğrenimi hakkındaki görüşleriniz nelerdir? 2) Bilim en iyi nasıl öğretilir ve öğrenilir? 3) Bilgi nedir? Bilgiyi nasıl tanımlarsınız? 4) Bilimin temel özellikleri nelerdir?

Verilerin analizi, katılımcıların inanç sistemlerindeki kodları ve kategorileri belirlemek için yinelemeli bir yaklaşımla gerçekleştirilmiştir. Kodlamanın ilk turunda betimsel kodlama yapılmıştır (Saldana, 2021). İlk kod turu, bilgi, bilim, bilim öğretimi ve öğrenme bilimine odaklanan hedef temel ve çevresel inançlara dayalı olarak geliştirildi. Öğretmen inanç düzeyleri geleneksel (1), geçişli (2) ve yapılandırmacı (3) olmak üzere nicel verilere dönüştürülmüştür. Kodlama işlemi iki araştırmacı tarafından yürütülmüştür: Yazar ilk başta tüm görüşmeleri kodlamış; görüşmelerin %25'i bir araştırma görevlisi tarafından kodlanmıştır. Nicel kodlama için orta düzeyde bir değerlendirme güvenirliği iki değerlendirici tarafından oluşturulmuştur; anlaşmazlıklar son tahlil için tartışılmıştır. Her bir öğretmenin inanç düzeyi tanımlandıktan sonra, sonuçların tanımlayıcı istatistikleri ve öğretmenlerin bilgi, bilim, öğretme ve öğrenme bilimleri hakkındaki inançları arasındaki olası kombinasyonlar veya ilişkiler sonuçlar bölümünde verilmiştir. Korelasyon matrisi, inanç sistemleri arasındaki ilişkiyi tanımlamak için sağlanmıştır. İnançla ilişkili yapılar arasındaki ilişkiyi araştırmak için Yapısal Eşitlik Modellemesi (YEM) yapılmıştır.

Bulgular

Sonuçlar, katılımcı fizik öğretmenlerinin çoğunlukla bilgi, öğrenme ve öğretme konusunda geçişsel inançlara sahip olduklarını göstermektedir. Öğretmenlerin bilgiye ilişkin temel inançları ile fen öğretimi ve öğrenimine ilişkin çevresel inançları birbirleri ile uyumluyken, öğretmenlerin fen bilgisi hakkındaki inançları diğer inanç türlerine göre biraz daha düşüktür. Bu fizik öğretmenlerinin bilimsel süreç becerilerini geliştirmeleri gerektiğini göstermektedir; bu bilimsel uygulamalar ve bilimsel bilginin nasıl inşa edildiği bilgisini içerir.

Pearson korelasyon matrisi, yalnızca birkaç boyutun birbiriyle anlamlı olarak ilişkili olduğunu gösterdi ve bu korelasyonların bazıları diğerlerinden daha güçlüydü. Fen öğretimi ve öğrenimine ilişkin inançlar, çevresel inançlar, arasında orta düzeyde pozitif yönde ($r=0.59$, $p < .01$); bilgi ve bilime ilişkin temel inançlar arasında orta düzeyde pozitif yönde ($r=0.52$, $p <.05$) korelasyon bulunmuştur. Bilgi ve öğretme arasında, bilgi ve öğrenme arasında, bilim ve öğretim arasında ve bilim ve öğrenme arasında istatistiksel olarak zayıf bir ilişki bulunmuştur. Sonuçlar, fizik öğretmenlerinin bilimin doğası ve bilginin doğası hakkındaki temel inançlarının önemli bir ilişkiye sahip olduğunu göstermiştir: bilgi hakkında yapılandırmacı inançlara sahip öğretmenler, bilimsel bilginin sorgulama, araştırma ve kanıta dayalı açıklamalar yoluyla geliştiğine inanmaktadır. Bu öğretmenlerin fen öğretimi ve öğrenimine ilişkin çevresel inançları da birbirleriyle pozitif yönde ilişkilidir.

Yapısal eşitlik modellemesine göre, temel inançlar ile $\beta= .72$, $p<0.05$ değerleri ile bilgiye ilişkin inançlar ve $\beta= .89$, $p<0.05$ değerleri ile fen bilimlerine ilişkin inançlar arasında pozitif ilişki bulunmuştur. Ayrıca periferik veya çevresel inançların $\beta= .85$, $p<0.05$ değerleri ile fen öğretimine ilişkin inançlar ve $\beta= .82$, $p<0.05$ değerleri ile fen öğretimine ilişkin inançlar arasında pozitif ilişki olduğu bulunmuştur. Bu sonuçlarla, temel inançların bilgi ve bilim hakkındaki inançlarla daha fazla ilişkili olduğunu, çevresel inançların ise bilim öğretme ve öğrenme hakkındaki inançlarla daha fazla ilişkili olduğunu anlamak kolay olmuştur.

Tartışma

Birçok öğretmen bilgi, bilim, öğretme ve öğrenme bilimi hakkında geçiş inançlarına sahipti ve ortalama olarak, katılımcı öğretmenler diğer inançlara kıyasla çoğunlukla fen bilimi hakkında geleneksel inançlara sahipti. Bu sonuç, kültürel bilim öğretme ve öğrenme deneyimleriyle ilgili olabilir. Bu çalışmadaki deneyimli fizik öğretmenleri, üniversitede fizik laboratuvarı dersleri almalarına rağmen, yönetimden destek alamamaları, ekipman yetersizliği veya laboratuvar koşullarının yetersizliği nedeniyle hiç laboratuvarda fizik dersi vermediklerini belirtmişlerdir. Bu nedenle, laboratuvar faaliyetlerini tanımlama formüllerin doğrulanması ve prosedürlerin takip edilmesi ile sınırlıydı. Tsai (2002) çalışmasında ezberlemeyi vurgulayan geleneksel görüşlerin aksine, çalışmadaki fizik öğretmenleri öğrencilere birçok fizik problemini çözmede rehberlik etmek için doğrulama yöntemlerine ve problem çözme stratejilerine odaklanmaktadır. Bahçıvan (2014) fen bilgisi öğretmen adaylarının fen öğretimi ve öğrenimi konusunda yapılandırmacı anlayışlara sahip olduklarını belirtmesine rağmen, deneyimli fizik öğretmenlerinin çoğu bilgi, öğretme, öğrenme ve fen bilimleri hakkında yapılandırmacı inançlar geliştirmemiştir. Ayrıca, bilgi ve bilime ilişkin inançlar temel inançlar olarak güçlü bir korelasyona işaret ederken, fen öğretimi ve öğrenimine ilişkin inançlar çevresel inançlar olarak güçlü bir korelasyona işaret etmiştir. Tsai (2002), öğretmenlerin fen öğretme ve öğrenme inançlarını değiştirmenin, bilimsel inançları gözden geçirmenin bir ön koşulu olabileceğini öne sürmüştür. Bu çalışma, bilgi bileşeni hakkındaki inançları eklemiştir, ve bilgi ve bilim hakkındaki inançlar arasındaki güçlü ilişkinin, bilim öğretme ve öğrenme hakkındaki inançları yeniden gözden geçirmek için bir ön koşul olabileceğini öne sürmüştür.

Bu çalışma, fizik öğretmenlerinin fen öğretimi ve öğrenimi ile ilgili pozitif görüşlere sahip olduklarını ve çoğu öğretmenin fen bilimleri hakkında geleneksel görüşlere sahip olduğunu göstermiştir. Bu sonuçlar, öğretmenlerin bilgi veya bilime ilişkin geçiş veya yapılandırmacı görüşlere sahip olduklarını, ancak öğretim uygulamalarının inançlarıyla uyumlu olmayabileceğini göstermiştir (Fives ve Buehl, 2012). Cross'un (2009) önerdiği gibi, matematik bilgisi hakkındaki kavramlar gibi alana özgü inançlar, matematik öğretme ve öğrenme konusundaki inançlarının ana kriteri olarak hizmet etmiştir ve öğretmenlerin öğretme ve öğrenme hakkındaki inançları pedagojik uygulamalarını etkileyebilir. Ancak, bu çalışma sınıf-içi uygulamalara odaklanmamıştır. Daha fazla araştırma, öğretmenlerin inançlarının sınıf uygulamalarıyla nasıl ilişkili olduğunu ve bu uygulamaları kolaylaştıran veya sınırlayan faktörleri araştırmalıdır.

INTRODUCTION

Reform studies in science education aim to integrate 21st century skills and address research-based and innovative strategies and curricula in many countries (Ministry of National Education (MONE), 2011; NGSS Lead States, 2013; Singer, et al., 2012). Teachers integrate these research-based strategies verbatim or they prefer to modify them based on structural and personal factors that influence the implementation of innovative methods (Enderle et al., 2022; Henderson et al., 2011). Structural factors may be related to institutional decisions for teachers' work, but personal factors such as teacher beliefs influence how teachers make decisions about curriculum, planning, assessment, and instructional practices (Muis & Foy, 2010). Therefore, understanding the structure of the teacher belief system is a concern to conceptualize how teachers make instructional decisions and what affects the teaching and learning processes.

Epistemological beliefs have been focused as part of a belief system to study discipline-specific and non-disciplinary or domain-general dimensions (Feucht, 2017). Domain-general beliefs deal with the nature of knowledge, how it is defined, structured, conceptualized, and how it forms an integrity with other belief systems since teacher epistemology also included domain-specific beliefs such as beliefs of science and beliefs about science teaching and learning (Sengul, 2018). According to Muis et al. (2006), teachers or students may hold different beliefs about mathematics and sociology. The authors found that individuals tended to approach mathematical knowledge as absolute and stable, whereas they tended to approach knowledge in social sciences as requiring evaluation of claims. The other research results also indicated that teachers' epistemological beliefs included interacting dimensions and had differences in these dimensions based on the teaching and learning context.

Tsai (2002) examined domain-specific beliefs and looked at the relationship among science, teaching, and learning. The results showed that most participating teachers of science possessed congruent views of teaching, learning and science even though they were at traditional level. Most studies focused on the investigation of domain specific beliefs (e.g. Belo et al., 2014; Tsai, 2002), but no study investigated the conceptual relationship among teachers' domain-general (e.g. beliefs about nature of knowledge) and domain-specific beliefs such as beliefs about science and beliefs about teaching and learning of a specific discipline. In one study, Brownlee (2001) divided epistemic beliefs into core and peripheral beliefs: core beliefs are defined as general and disciplinary knowledge that is difficult to change, while beliefs about teaching and learning are defined as peripheral beliefs that are easy to change in a specific context. In this study, it was aimed to investigate the relationship between epistemological beliefs, core and peripheral beliefs of physics teachers. The aim of the study is to understand the relationship between the four belief systems by examining the beliefs of high school physics teachers about the nature of knowledge and scientific knowledge, science teaching and learning.

Research Focus and Problem

Beliefs are considered as one of the factors to influence individuals' self-efficacy in completing a work (Bandura,1997). Pajares (1992) defined beliefs as a system of independent mental representations to make affective and evaluative judgements about a phenomenon, an event or situation and to function separate from the cognitive component associated with knowledge. Gess-Newsome (1999) also addressed the definition of knowledge as developed through a systematic and structured process in a dynamic and evidential way, whereas she approached beliefs as affective filters or factors to influence the usage of knowledge in different ways. Southerland and colleagues (2001) defined knowledge as constructed based on evidence, but beliefs as a subjective and static construct depending on personal experience.

Individuals hold beliefs about the nature of knowledge referring to their epistemological beliefs. Epistemology is interested in human knowledge and knowing to be constructed through verification, justification, and argumentation by the diverse influences of nature, sources, guides, and filters (Author, 2018, Hofer & Pintrich, 1997). Brownlee (2001) proposed a core-periphery beliefs framework to explain core beliefs as the central component of an epistemological belief system as difficult to change, and peripheral beliefs as changing depending on a specific task or context. A person's beliefs about the criteria for defining what knowledge is and the process of acquiring and structuring knowledge are defined as core beliefs (Author, 2018; Hofer & Pintrich,1997; Grieshaber & McArdle, 2014). Core beliefs have been studied in different frameworks: one-dimensional, but evolving in steps (Kuhn, 1991; Perry, 1970) and involving multiple dimensions (Schommer, 1990). Research on unidimensional paradigms was first studied by Perry (1970) and continued with Kuhn (1991) to understand beliefs as stage-like dimensions from an absolutist view to multiplist and evaluativist views. According to these studies, at the least mature level, individuals approach knowledge as involving absolute truths to be transferred from an authority, and there is little engagement for critical reflection. In the moderate mature level, individuals view knowledge as integration of multiple opinions with little critical reflection. In the most mature level, individuals define knowledge as evolving and coordinated with justification in a flexible manner.

Schommer (1990) defined multidimensional paradigms of a belief system as including source, certainty, structure, stability of knowledge. Hofer (2001) developed an epistemological belief questionnaire (EBQ) on four core belief systems including certainty, simplicity, justification, and source dimensions. Later, Wood and Kardash (2002) designed another questionnaire to address independent belief dimensions about speed, structure, construction and modification, student characteristics, and certainty. These studies believed that these dimensions might differ depending on context and might not necessarily develop in synchrony. A study by Braten and Stromso (2006) examined the students' beliefs about knowledge and learning. Students defined knowledge as certain and unchanged as they focused on memorization and repetition to reproduce what was given to them, and they were less able to engage in critical reflection. In Brownlee et al. (2016)'s study, students with evaluativist epistemology tended to act as an active participant to take responsibility for their learning and engage in critical reasoning. In another study, Braten and Ferguson (2015) defined sources as accumulated resources such as books, encyclopedias, and articles, practical resources such as experimental or observational experiences, and popular resources such as social and popular media. Teachers in their study focused more on practical resources to have experiential experiences in knowledge construction.

In addition, some researchers believed that individuals' epistemological beliefs might differ in disciplinary domains, such as science, mathematics, or social sciences (Buehl et al., 2002; Muis et al., 2006; Schommer-Aikins et al., 2003). For example, Buehl, Alexander, and Murphy (2002) focused on mathematics and history majors' definition of knowledge through a questionnaire. The results showed that students in mathematics defined knowledge as integrated and less-related daily-life, whereas history majors approached knowledge as social process and ill-structured. In another study, Hofer (2000) explored the epistemological beliefs of science and psychology majors. The participants from a psychology class responded to a questionnaire by considering each item for science and psychology. The results showed that students defined scientific knowledge as certain, objective, and unchanging, but students defined psychology as personal knowledge and subjective. In an educational review, Muis and colleagues (2006) argued that Hofer (2000) and Buehl et al. (2002) presented the evidence of domain-specificity of epistemological beliefs to make connections to the structure of the domain and nature of concepts. These arguments highlighted the significance of examining the relationship between domain-general and domain-specific beliefs with beliefs about teaching and learning at specific disciplines.

According to Brownlee (2001), epistemological beliefs involve core beliefs as beliefs about knowledge in general and beliefs about a specific discipline such as science. Epistemological beliefs also include peripheral beliefs such as beliefs about teaching and learning science that are easy to change according to the context in which they are used. Learning was defined in two categories: surface and deep approaches to learning, in which the former one focused on memorizing, repetition, and unreflecting thinking and the latter one focused on meaning making processes through active participation and knowledge construction in diverse ways. Surface approaches viewed knowledge as discrete facts to absorb, and deep approaches viewed knowledge as complex and interconnected personal constructions. Teachers' approaches to teaching and learning may influence their classroom preparation and instruction. Although some teachers thought that active learning strategies or constructivist pedagogies were time consuming and not easy to handle (Fives & Buehl, 2012), teacher education programs or diverse professional development designs could guide teachers to develop strategies to enact inquiry-based lessons (Enderle et al., 2022; Sengul et al., 2020).

Tsai (2002) examined the relationship among domain-specific beliefs including beliefs about science and teaching and learning science among 37 Taiwanese science teachers. The participants had consistent beliefs about teaching and learning science. For example, teachers mostly supported traditional beliefs about teaching and learning science that science was best taught when the teacher was the sole source of the information to recite, and learning science occurred through memorization and repetition. Some studies showed that teachers possessed constructivist beliefs to teach science through enhancing student participation to establish personal meaning making. Van Driel, Bulte and Verloop (2007), and Belo et al. (2014) examined science teachers' domain specific beliefs such as teaching specific topics or curricular goals. In Van Driel et al. (2007), the authors investigated the relationships between teachers' general educational beliefs and domain-specific beliefs about chemistry curriculum. The study was conducted with 348 chemistry teachers in the Netherlands to explore the belief structures. The results showed that chemistry teachers mostly emphasized chemistry-specific beliefs about curriculum and students' learning with technology and society focus to address the general educational beliefs. They concluded that teachers' learner-centered beliefs expressed their emphasis on using a curriculum addressing society and technology issues. Belo et al. (2014) explored the beliefs about teaching and learning in general and beliefs about physics. The participants were 126 secondary school physics teachers in the Netherlands and responded to a questionnaire. The results showed that teachers' general beliefs were related to goals of education with content-oriented physics instruction and curriculum. This relationship indicated the interrelationship between teacher goals and teacher regulated curriculum emphasis rather than emphasizing student-regulated learning.

These studies showed that previous research investigated teachers' epistemology at different dimensions and domains separately. Domain-general beliefs deal with the nature of knowledge, how it is defined, structured, conceptualized, and how it forms an integrity with other belief systems since teacher epistemology also included domain-specific beliefs such as beliefs of science and beliefs about science teaching and learning. Domain-general beliefs and disciplinary knowledge are defined as core beliefs that are difficult to change, while beliefs about teaching and learning are defined as peripheral knowledge that is easy to change in a specific context. Research on investigation of how domain-general epistemological beliefs relate to domain-specific epistemological beliefs or how beliefs about knowledge relate to beliefs about science and beliefs about teaching and learning science may provide evidence to understand how core and peripheral beliefs monitor and are effective in the process of teaching and learning science. However, research studies focusing on beliefs about knowledge in relation to domain-specific beliefs are missing in the same study in the literature. This proposed research here aims to explore the relation of domain specific beliefs with general beliefs including core and peripheral beliefs with the following research question: How do domain-general and domain-specific epistemological beliefs including core and peripheral dimensions relate to each other?

METHODS

General Background

This study aimed to explore high school physics teachers' belief system through a quantitative research design based on post-positivist paradigm (Creswell & Plano Clark, 2017). Quantitative research design aims to collect and analyze numerical data to test hypotheses of specific variables and answer research questions. Research process in quantitative research starts with a problem through an extensive literature review to set the hypothesis, determine the research design for data collection and analysis and report the results. The design of this study utilized an open-ended questionnaire (Luft & Roehrig, 2007) to investigate epistemological beliefs of participants at different domains and dimensions. The questions aimed to understand how physics teachers conceptualized the domain-general and domain-specific beliefs-their beliefs about knowledge, science knowledge, teaching and learning science. Their responses converted to numerical data through a rubric for statistical analysis and better interpretation of results.

Context and Participants

The study focused on high school physics teachers in a large city in the northwest region of Turkey. The instructional context was high schools including students with a high mathematics and science background (Vocational schools were eliminated; Anatolian High Schools and Science High Schools were included). The author visited the schools to invite experienced physics teachers to the study. Physics teachers in a large metropolitan city were asked for their voluntary participation. There were 59 physics teachers, 23 women and 36 men, who agreed to participate after they were informed about the purpose of the study. These participants were purposefully selected as experienced teachers with more than 10 years of teaching experience. The participants' ages ranged from the early 30's to 60's. Some teachers (29 teachers) completed a four-year physics program in the department of physics and took a teaching certificate to become a physics teacher. Some teachers (30 teachers) attended a five-year teaching physics program in a department of education in a university in different regions of Turkey.

Instrument and Procedures

Table 1
*Sample coding guide**
**modified from Tsai (2002) and Muis (2007)*

	Beliefs about
Traditional	Knowledge: Knowledge is stable and certain Science: Scientific knowledge is based on accurate answers Teaching: Knowledge acquisition between teacher and students Learning: Reproducing knowledge through memorization
Transitional	Knowledge: Knowledge depends on alternative sets of ideas Science: Scientific knowledge requires following instructions Teaching: Focusing on problem-solving procedures Learning: Process of verification
Constructivist	Knowledge: Construction of evidence-based explanations Science: Scientific knowledge requires collaboration and subjectivity in constructing knowledge Teaching: Focusing on students' prior conceptions and active participation Learning: Relating to prior knowledge to construct personal meaning

Sinatra (2016) argued that epistemological beliefs were stable or shifted only through targeted professional development designs. In this study, an experienced physics teacher's belief system was considered stable, so each teacher responded to open-ended interview questions focusing on physics teachers' epistemological beliefs including knowledge, science, and science teaching and learning dimensions. Interviews were recorded and transcribed for analysis. Sample questions were taken from Luft and Roehrig (2007) and provided as follows: 1) What are your views about teaching and learning science? 2) How is science best taught and learned? 3) What is knowledge? How do you define knowledge? 4) What are the main characteristics of science?

Data Analysis

The data analysis was conducted through an iterative approach to identify the codes and categories in participants' belief systems. During the first round of coding, descriptive coding was conducted (Saldana, 2021). The first round of codes was developed based on target core and peripheral beliefs focusing on knowledge, science, teaching science, and learning science. Teacher beliefs were coded based on these categories within a framework to identify the levels as traditional, transitional, and constructivist. Sample coding guide was shown on Table 1. These nominal levels were modified for the knowledge category where traditional beliefs focused on the stability of knowledge, transitional beliefs valued alternative sets of ideas without searching for evidence, and constructivist beliefs acknowledged the collaboration and construction of evidence-based explanations through exploration, data collection and analysis (Muis, 2007; Tsai 2002). The level of teacher beliefs was converted to ratio data as follows: traditional (1), transitional (2), and constructivist (3). The coding process was conducted by two researchers: The author coded all responses at first; a research assistant coded 25% of the answers. A moderate interrater reliability (70%) for coding was established by two raters; disagreements were discussed for final analysis. After defining the level of each teacher's beliefs, descriptive statistics of the results and possible combinations of or relationships among teachers' belief about knowledge, science, teaching and learning science were provided in the results section. The correlational matrix was provided to define the relevance among belief systems.

Additionally, Structural Equation Modeling (SEM) was conducted to investigate the relationship among belief-related constructs. The LISREL program was used for the analysis of the SEM. A ratio of x^2/df between zero to two is explained as a good fit, and between two and three is explained as an acceptable fit. A root-mean-square error of approximation (RMSEA) value between 0.08 and 0.05 is considered acceptable, a value below 0.05 is considered a good fit. The following fit indices were also reported with recommended threshold levels: NNFI (>0.90), comparative fit index CFI (>0.90), RMSEA (<0.08), standardized root-mean-square residual SRMR (<0.05).

Ethical Considerations

This study was conducted through taking ethical approval from the researchers' university to collect data and keep the participants' confidentiality. Ethical form is available upon request.

RESULTS

Descriptive results

Results indicate that participating physics teachers held mostly transitional beliefs in knowledge, learning, and teaching with means approximately equal to two. Their core beliefs about knowledge and their peripheral beliefs about teaching and learning science were aligned with each other, whereas teachers' beliefs about science knowledge were slightly lower than other belief types. Only six physics teachers held constructivist beliefs about the nature of science since most teachers held traditional (24) or transitional (29) beliefs of science. This finding indicated that these physics teachers needed to develop science process skills- knowledge of scientific practices and how scientific knowledge was constructed. Descriptive statistics for each belief dimension was shown on Table 2.

Table 2
Participants' epistemological beliefs

Beliefs about	Knowledge	Learning	Teaching	Science
Traditional	13	11	14	24
Transitional	33	30	27	29
Constructivist	13	18	18	6
Mean	2	2.12	2.09	1.69
Std. Dev.	0.68	0.70	0.73	0.65
N	59	59	59	59

According to Table 2, fourteen physics teachers (23.73%) defined teaching physics with traditional views as a top-down processing mechanism. Examples from participants' responses were provided below. Participant-1(P1) stated,

> *"Teaching science involves lecturing, transferring accepted knowledge. Teachers need to have subject competency."*

Twenty-seven physics teachers (45.76%) focused on teaching physics as a process of making connections to real life in solving multiple problems from a transitional perspective. Participant-2 stated:

> *"Physics can be taught at different places based on the topic such as a garden, seaside to outdoor pressure to make measurements. Teaching physics involves developing problem-solving strategies through thought experiments and communication."*

Teachers' constructivist beliefs about teaching science referred to student-centered instruction through exploration (18 teachers- 30.51%). Participant-3 stated:

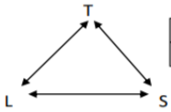
> *"Teaching science involves experiments to help students actively learn by doing and observing tangible experiences. We need to show applications through using the laboratory to develop students' analytical and critical thinking skills, to make students active and responsible to learn on their own with responsibility."*

Moreover, Table 3 shows the relationships among beliefs about knowledge, teaching, learning, and science. Only two participants held consistent "traditional" beliefs, five participants possessed transitional beliefs, and two participants indicated “constructivist” beliefs across four belief systems. Besides this consistency, some teachers’ domain-specific beliefs showed consistency while their beliefs about knowledge were different. For instance, two teachers with transitional beliefs about knowledge expressed constructivist views about teaching, learning, and science.

Besides consistency between four belief systems, participating physics teachers had related beliefs about at least two belief systems. For example, as shown on Table 3, nine physics teachers held traditional beliefs about knowledge, but they had related beliefs about teaching and learning science or about teaching science and scientific knowledge. These teachers had related constructivist beliefs (two teachers), transitional beliefs (four teachers) or traditional views (one teacher) on teaching and learning science. There were also teachers with traditional conceptions about teaching science and scientific knowledge (two teachers). Two participants indicated divergent beliefs among teaching, learning, and science knowledge. Although these teachers held constructivist views about instruction, they expressed transitional views of student learning, and traditional views of the nature of science. These teachers’ beliefs about knowledge and science were consistent with each other.

Table 3

Relationships in physics teachers’ beliefs system

<table>
<tr><th>Knowledge</th><th>Consistent</th><th>Related</th><th>Divergent</th></tr>
<tr>
<td>Traditional (1)</td>
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>1</td><td>1</td><td>1</td><td>2</td></tr></table></td>
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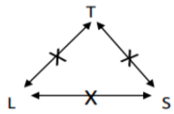
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>3</td><td>2</td><td>1</td><td>2</td></tr></table></td>
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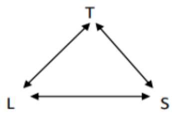
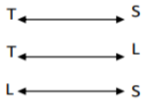
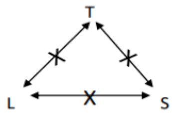
<td>Transitional (2)</td>
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>3</td><td>3</td><td>3</td><td>2</td></tr><tr><td>2</td><td>2</td><td>2</td><td>5</td></tr><tr><td>1</td><td>1</td><td>1</td><td>1</td></tr></table></td>
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>3</td><td>3</td><td>2</td><td>2</td></tr><tr><td>2</td><td>2</td><td>1</td><td>7</td></tr><tr><td>3</td><td>2</td><td>2</td><td>2</td></tr><tr><td>2</td><td>1</td><td>2</td><td>1</td></tr><tr><td>2</td><td>3</td><td>2</td><td>3</td></tr><tr><td>2</td><td>1</td><td>1</td><td>1</td></tr><tr><td>1</td><td>2</td><td>2</td><td>3</td></tr><tr><td>1</td><td>2</td><td>1</td><td>1</td></tr><tr><td>3</td><td>3</td><td>1</td><td>1</td></tr><tr><td>1</td><td>1</td><td>2</td><td>2</td></tr></table></td>
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>1</td><td>2</td><td>3</td><td>1</td></tr><tr><td>2</td><td>3</td><td>1</td><td>1</td></tr></table></td>
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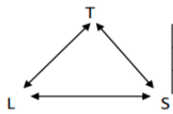
<tr>
<td>Constructivist (3)</td>
<td><table><tr><td>T</td><td>L</td><td>S</td><td>#</td></tr><tr><td>3</td><td>3</td><td>3</td><td>2</td></tr><tr><td>2</td><td>2</td><td>2</td><td>2</td></tr></table></td>
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<td>No divergent beliefs!</td>
</tr>
</table>

Physics teachers with transitional beliefs about knowledge (33 teachers) also held related (23 teachers) and divergent (two teachers) views. There was related constructivist, transitional, or traditional views between teaching and learning science (12 teachers), teaching science and science knowledge (five teachers), and conceptions about learning science and science knowledge (six teachers). Two participants had divergent views: a teacher held traditional views about teaching science, transitional conceptions about learning science, and constructivist beliefs about science; another teacher held constructivist views of instruction, transitional beliefs about science learning, and traditional conceptions about science.

Among physics teachers with constructivist beliefs about knowledge (13 teachers), nine teachers possessed related views: beliefs about teaching and learning science (one teacher with traditional views, three teachers with constructivist beliefs), beliefs about learning science and science knowledge (one teacher with traditional and one teacher with transitional beliefs), beliefs about teaching science and science knowledge (one teacher with constructivist beliefs, two teachers with transitional beliefs). There were no physics teachers indicating divergent beliefs about teaching, learning, and science while they held constructivist beliefs about knowledge.

Correlation Matrix

To explore the relationships between two belief systems, correlational analysis was conducted (Table 4). Pearson correlation matrix indicated that only a few dimensions were significantly correlated with one another; and some of these correlations were stronger than others. There was a moderate positive correlation between beliefs about teaching and learning science ($r = 0.59$, $p < .01$) as peripheral beliefs and moderate positive correlation between beliefs about knowledge and science (r = 0.52, $p < .05$). A statistically weak correlation was found between knowledge and teaching, between knowledge and learning, between science and teaching, and between science and learning as shown on Table 4. The results showed that physics teachers' core beliefs about nature of science and nature of knowledge have significant relevance: teachers with constructivist beliefs about knowledge believed that scientific knowledge was developed through questioning, exploration, and evidence-based explanations. These teachers' peripheral beliefs about teaching and learning science were also positively related to each other.

Table 4
Correlations between belief dimensions

	Knowledge	Teaching	Learning	Science
Knowledge	1			
Teaching	0.24	1		
Learning	0.18	0.59*	1	
Science	0.52**	0.26	0.27	1
	*p < 0.01	**p<0.05	Not Significant	

Structural Model

The results showed that the core beliefs and peripheral belief dimensions had positive and meaningful relationships with each other. The findings were presented in Figure 1. These results also showed that peripheral beliefs had positive influences on core beliefs (β= .45, p<0.05). A ratio of x^2/df between zero to two was explained as a good fit as the study value was found to be 1.11. An RMSEA value below 0.05 was considered a good fit, and this study's value was found to be 0.044. The following fit indices, NNFI (>0.95) = 0.99, CFI (>0.95) = 0.999, RMSEA (<0.05) = 0.044, SRMR (<0.05) = 0.0151 were found as good fit values. SEM only expresses whether the proposed model is compatible or not, and the results obtained in LISREL showed excellent fit for the proposed model, as shown in Table 5. According to structural equation modeling, the core beliefs had a positive relationship to beliefs about knowledge with β= .72, p<0.05 values and beliefs about science with β= .89, p<0.05 values. It was also found that peripheral beliefs had a positive relationship to beliefs about teaching science with β= .85, p<0.05 values and learning science with β= .82, p<0.05 values. With these results, it was easy to understand that core beliefs were more associated with beliefs about knowledge and science, whereas peripheral beliefs were more associated with beliefs about teaching and learning science. To support this conclusion, as seen on Figure 2, we looked at the standardized solution and t values, and no inconsistencies were found in the model. In this figure, the t values are shown as 5.33, 5.45, 2.93 and 2.35. There is a significant relationship between the two variables.

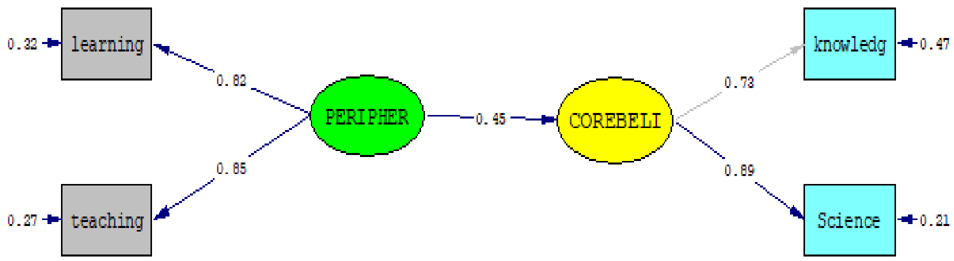

Figure 1. Standardized Solution

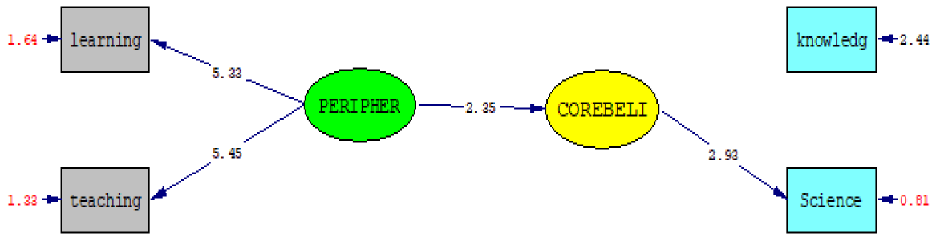

Figure 2. t values

Table 5.
Fit values for the model

Index	Perfect Fit Criteria*	Acceptable Fit Criteria*	Research Evidence	Result
x^2/df	0-2	2-3	1.11/1=1.11	Perfect Fit
RMSEA	≤ .05	≤ .08	0.0441	Perfect Fit
RMR	≤ .05	≤ .08	0.00742	Perfect Fit
SRMR	≤ .05	≤ .08	0.0151	Perfect Fit
CFI	≥ .95	≥ .90	0.999	Perfect Fit
NNFI	≥ .95	≥ .90	0.991	Perfect Fit
NFI	≥ .95	≥ .90	0.987	Perfect Fit
IFI	≥ .95	≥ .90	0.999	Perfect Fit
RFI	≥ .95	≥ .90	0.919	Perfect Fit
GFI	0.95 ≤ GFI ≤ 1.00	0.90 ≤ GFI ≤ 0.95	0.991	Perfect Fit
AGFI	0.90 ≤ AGFI ≤ 1.00	0.85 ≤ AGFI ≤ .90	0.907	Perfect Fit
Critical N (CN) (Is sample size enough?)			346.270	YES if the number is larger than 200.

DISCUSSION

Recent national and international standards support science teachers, in particular physics teachers, to develop knowledge of innovative curriculum, research-based pedagogy, and knowledge of students' learning (MONE, 2011; National Research Council (NRC), 2012). This study aimed to examine physics teachers' belief system to explore the association between core beliefs and peripheral beliefs. This study found that most teachers held transitional views for core and peripheral beliefs including knowledge, science, teaching and learning dimensions. These results were inconsistent with the findings of previous research. Tsai (2002) conducted research on science teachers' beliefs about science, teaching and learning science and found that most teachers expressed traditional views of science in parallel to conceptions of teaching and learning science. Tsai (2002)'s study was conducted in a different context with Taiwanese science teachers, and these teachers were traditionally oriented to transfer information to passive listeners. Van Driel at el. (2007) and Belo et al. (2014) investigated the relationship between domain general and domain-specific beliefs among science teachers in the Netherlands. These studies found that teachers' science specific beliefs were more dominant in their decision-making than general beliefs. However, in our study, most teachers possessed transitional views about teaching and learning science as well as transitional beliefs about knowledge and science. These teachers thought that knowledge included multiple sets of ideas and problem-solving procedures required instructions to reach a solution. These experienced physics teachers indicated that physics required solving multiple different types of problems to understand the concepts.

These results suggested that conceptions of teachers might differentiate across different cultures and societies (Brownlee et al., 2016). Bahcivan (2014) also showed that in Turkey, pre-service teachers' constructivist conceptions of teaching and learning promoted constructivist beliefs about science knowledge. In the current study, many teachers held transitional beliefs about knowledge, science, teaching and learning science, and on average, participating teachers mostly possessed traditional beliefs about science in comparison to other beliefs. This result might be related to the cultural science teaching and learning experiences. These experienced physics teachers indicated that although they took physics laboratory classes at college, they had never taught physics in a laboratory due to lack of support from the administration, lack of equipment, or insufficient laboratory conditions. Therefore, their laboratory activities were limited to verification of formulas or following the procedures. Unlike traditional views in Tsai (2002) study to emphasize memorization, these physics teachers focused on verification methods and problem-solving strategies to guide students in solving a lot of physics problems. Although Bahcivan (2014) stated that pre-service science teachers held constructivist conceptions about teaching and learning science, most experienced physics teachers failed to possess constructivist beliefs about knowledge, teaching, learning, and science. This result showed that although pre-service science teachers developed sophisticated beliefs about teaching and learning science when they were in a teacher education program, their core beliefs or transitional beliefs about knowledge and science might be more effective to change their peripheral beliefs or beliefs about teaching and learning science easily. Beliefs about knowledge and science indicated strong correlation as core beliefs, and beliefs about teaching and learning science indicated the strong correlation as peripheral beliefs. Tsai (2002) suggested that changing teacher beliefs of teaching and learning science might be a precondition of revising scientific beliefs. Our study added the dimension of beliefs about knowledge and suggested that the strong association between beliefs about knowledge and science could be a precondition for reconsidering and revising beliefs about teaching and learning science.

This study showed that physics teachers most held related views about teaching and learning science, and most teachers held traditional views about science. These results indicated that teachers had transitional or constructivist views of knowledge or science, but their instructional practices might not align with their beliefs (Fives & Buehl, 2012). As suggested by Cross (2009), domain-specific beliefs such as conceptions about mathematics knowledge served as the main criteria of their beliefs about teaching and learning mathematics, and teachers' beliefs about teaching and learning might influence their pedagogical practices. However, the current study did not focus on the practices. Further research should explore how teachers' beliefs relate to their classroom practices and the factors facilitating or limiting these practices.

CONCLUSION AND IMPLICATIONS

These results offer a firsthand report as a guide to address teachers' beliefs through professional development programs. In this study, the belief system of a physics teacher provides an approach to support the development through longitudinal interventions to address science teachers' core beliefs along with the peripheral beliefs. Since core beliefs are more difficult to change and mostly influence peripheral beliefs, teacher education should focus more on core beliefs to develop more sophisticated peripheral beliefs. Teachers' beliefs about knowledge and science can be addressed through implicit and explicit communication of epistemological approaches about inquiry-based teaching and learning. Science teacher education recognizes the significance of professional development of science teachers. As science teacher educators, we need to understand teachers' epistemological beliefs and practices to develop their knowledge and practices of inquiry and to enhance student learning. This study provides the examination of physics teachers' belief systems to understand factors influencing their practices. This study contributes to the knowledge base for the evaluation of teachers' domain-general and domain-specific beliefs along with core and peripheral beliefs to refer to teachers' cognitive and epistemic thinking. This research will suggest further studies within the science education community and the larger educational world to address teacher cognition and practices in different cultures.

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