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Examination of High School Physics Teachers' Professional Identity: A Case Study

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Abstract

This study aimed to explore physics teachers' professional identity through multiple-case methodology. The goal of physics teacher education is to enhance teachers' professional development to address the suggestions of reform-based science education. Science teachers' professional identity has been explored at different grade levels: science teachers defined themselves as content teachers, classroom managers, or isolated workers. In this study, physics teachers' professional identity is analyzed and explained through Wenger's theory of learning. The participants were three male high school physics teachers. Data were collected through interviews, reflections, lesson plans, and classroom observations and analyzed through thematic analysis. The results showed that participating teachers had different identity characteristics in that they were defined as question-oriented, project-oriented, or lecture-oriented teachers. The question-oriented teacher focused on questioning to elicit students' ideas on different types of questions, the project-oriented teacher tended to encourage students to explore the real-life physics through projects, and the lecture-oriented teacher aimed to explain the content through following a smart notebook including all content explanations and sample questions. The analysis through Wenger's theory showed that the relationship between teachers' beliefs and practices was linked to physics teachers' professional identity. The study has important implications to understand development and characteristics of teacher professional identity.

Keywords: Case study, physics teacher, professional identity, Wenger learning theory

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Introduction

Science teaching and learning in the national and international documents make suggestions to focus on three-dimensional learning, in particular, science and engineering practices, disciplinary core ideas, and crosscutting concepts (National Research Council (NRC), 2012; NGSS Lead States, 2013). These standards aim to enhance teachers' and learners' capacity to engage in reform-based instruction to integrate laboratory activities, different forms of modelling (visual, qualitative, and quantitative etc.), scientific argumentation, and communication. These suggestions promote teachers' and learners' engagement in scientists' practices to facilitate "doing science" rather than rote memorization and passive learning (Berland et al., 2016). What are the important characteristics of doing science? How does "doing science" support teachers' and learners' professional development? or Can "learning by doing science" support the development of professional identity for reform-based instruction? The overarching goal of science teacher education is to support science teachers' professional development through content and pedagogy to address the suggestions of standards (Shulman, 1986). However, according to Schleicher (2019), PISA (2018) results showed that Turkey as a developing country had only less than 10% of students as top performers in science; most students scored lower than the average score. These low achievement results indicated that science teaching and learning should have more reform-based features and might need further investigation for students' learning and teachers' work.

Teacher education focuses on the development of teachers' professional identity in an ongoing process through personal, contextual, and community interactions (Lave & Wenger, 1991). Teacher professional identity defines teachers' commitment to construct and reconstruct knowledge and practice of a particular profession (Beauchamp & Thomas, 2009). Individuals' experiences, beliefs, and perspectives contribute to their growth and how they behave and make sense of their work (Beijaard et al., 2004). Professional identity is dynamic and constantly developing through social interactions within a community of learners that can support each other to strengthen professional practices of teachers. Most studies focused on teacher professional identity for science teaching in elementary school, middle school, or pre-service teacher education level (Avraamidou, 2014; Madden & Wiebe, 2015; Timostsuk & Ugaste, 2010). For example, elementary science teachers rarely considered themselves as science content teachers, some teachers preferred to act as classroom managers (Madden & Weibe, 2015). In Timostsuk & Ugaste (2010)'s study, pre-service teachers did not feel any belonging to teaching community that emphasized significance of having a community in initial training.

Some studies on physics education also argued that physics teachers were expected to develop knowledge of physics, knowledge of pedagogy, and knowledge of how to teach physics (Etkina, 2010). Physics teachers focused on conceptual understanding and problem-solving ability rather than enhancing students' appreciation and attitudes about learning and doing physics (Bates et al., 2011; Nissen et al., 2021). These results showed that there was a need to understand physics teachers' professional development from a teacher professional identity perspective. In this study, we considered that experienced high school physics teachers could provide a solid foundation for their professional identity. To facilitate development of reform-based physics education, we needed to address a gap in the literature to understand the professional identity of physics teachers. This research aimed to examine experienced physics teachers to conceptualize their professional development. This study aimed to explain the components of physics teacher identity based on Wegner's (1998) theory of learning. The following research questions guide the study: What are the characteristics of professional identity for experienced physics teachers? How do these characteristics influence physics teachers' professional identity?

Theoretical Framework

Identity is to describe yourself based on cognitive, social, affective and epistemic perspectives (Beijaard et al., 2000). These perspectives are shaped within a culture and society, in which individuals make sense of themselves and their actions in social and political contexts. Individuals describe their roles based on the expectations, requirements, and rules of their work through meaning-making within a specific context by acting on these expectations such as refusing, evaluating, internalizing, and affirming (Liang et al., 2023). Identity is a complex term and includes many connections and negotiations across different dimensions of personal roles (Stets & Serpe, 2013). A teacher has multiple roles including planning, preparation, instruction, management, assessment, and collaborating activities (Renwick,

2023). Teacher identity shapes teachers' "disposition, work engagement, and commitment and professional development" (Liang, Ell, & Meissel, 2023, p.1.). These roles involve many activities and lead teachers to act in different ways as active thinkers, facilitators, or passive observers (Schutz et al., 2018). This process describes identity development as a dynamic and iterative process that occurs between and within individuals and contexts (Cohen, 2010; Melasalmi & Husu, 2018; Trent, 2015).

A teacher's identity is a reflection of the nature of their work. Beauchamp and Thomas (2009) argue that teacher identity is shaped within a process and a result of teacher learning and development. Teachers have challenges between teaching for learning or teaching for the test. This contradiction in teachers' practices creates an imbalance in their planning and teaching and shapes their roles and identity as a support or constrain of their practice (Boyd & Harris, 2010). Teacher resources influence the development of teacher identity; Reflective teacher practice assists teachers to realize and understand their internal dialogue for personal and professional self and mediate their role (Renwick, 2023). Teachers' personal beliefs, views, experiences, and interactions play a role in supporting teacher identity for their career development (Wenger, 1998). Clandinin, Connelly, and Bradley (1999) conceptualize teacher professional identity through three major dimensions: (a) interaction, b) continuity, and c) situation. These researchers argue that personal and social interactions have an influence on individuals' internal and external conditions; personal meaning-making is not separate from past, present, and future experiences and the context that they live. Individuals' interpretations of past and present experiences, and their imagination of the future can influence their identity construction.

Educational society in a country- their cultures, norms, and practices interact with teachers' work. These approaches show that identity is a contradictory, dynamic, and evolving construct and requires teachers to develop resilience (Beauchamp & Thomas, 2011; Schutz et al., 2018). Beijaard et al. (2004) summarize the characteristics of teachers' professional identity as below: Professional identity is:

(1) ongoing and dynamic.
(2) related to a person and his/her interactions with others and the context including social, cultural, political differences.
(3) dependent on active teacher thinking, learning, and emotions based on the goals and the resources.
(4) defined based on sub-identities and roles that are related to construction of teacher's overall identity.

Zeichner and Gore (1990) suggest that teachers' professional development includes their interactions and learning during the teacher education program and while working as a classroom teacher. Therefore, teachers' professional identities consist of components related to experiences, expectations, context, affective factors, reflections, and family roles. Community of Practice (CoP) explores the process of learning and construction of identity as a social practice. CoP is suggested by social-constructivist theory of learning to develop a community of learners, who have community engagement to share knowledge development through producing, practicing, sharing, modifying, and using ideas (Wenger, 2015). Wenger (1998) defines community of practice in terms of joint enterprise, mutual engagement, and shared repertoire. This community of learners has a mutual purpose to do and continues their collective learning and develops collective resources. Identity develops through interactions within a community of learners including colleagues, students, school and teaching community.

According to Lave and Wenger (1991), learning occurs through participation and cooperation in a social context rather than cognitively passive knowledge accumulation and transfer process. Learning changes and restructures the individuals' experiences and making sense of themselves, diverse practices based on the contextual factors, and views, perceptions, and beliefs to contribute to the professional development or professional identity within a community (Lave & Wenger, 1991). Learning occurs by novice participants through being involved in the practices of experts within a community. Learning helps individuals construct knowledge to modify and reconstruct through new interactions to identify themselves (Wenger, 1998). Since individuals have diverse interactions within a community, analyzing their experiences, practices, views or personal philosophies, community relations and negotiations can support understanding their professional identity as a form of learning.

Related Literature

Identity refers to how people see themselves and how they are recognized or accepted by others (Carlone & Johnson, 2007; Stets & Burke, 2003). Avraamidou (2022) argues that identity development is

influenced by social and political factors that may lead to some people to be recognized but others to have lack of recognition. Therefore, research on identity can investigate power relations that may influence participation in a community of practice.

In 1998, Helms explored how science teacher identity was related to teachers' beliefs about the nature of subject matter. As part of a teacher education program, the author worked with five science teachers through a qualitative study and collected data through transcriptions of group meeting discussions, teaching observations, in-depth interviews. The data were analyzed through grounded theory approach to find patterns. The results showed that science teachers identified themselves in terms of actions (excitement), others' expectations (nature of politics), values and beliefs (science vs. faith, philosophy), and what they want to be (scientist) when they talked about the nature of subject matter. The study provided suggestions to understand teachers' pedagogical engagement.

In a recent study, Rushton (2021) worked with five pre-service secondary geography teachers on an environmental education program to understand the development of their professional identities. Data were collected through interviews and participants' reflections and analyzed through reflexive thematic analysis to develop codes and themes through familiarization, coding, theme generation, and narrative writings. The findings indicated that pre-service teachers approached environmental science education in diverse ways: making connections with nature, society, and politics or playful approaches. They also valued and shared their stories on environmental issues: valueing outdoor learning, protecting spaces from damage, coral reefs, sustainability. Teachers tended to facilitate younger students' awareness towards environmental problems to make changes. This study showed the pre-service teachers' identity development in an environmental science education course. The further study suggested the exploration of the ways other science education classes can serve to promote science teachers' identity development.

Participating in professional development courses can assist pre-service teachers to develop a professional stance although they have limited and salient teacher identity at the beginning (Sutherland, et al., 2010). Yuan and Lee (2016) conducted a narrative inquiry to explore the identity development in relation to emotions, reflections, and negotiations of a student-teacher in the process of becoming a teacher. Participant was a last year pre-service language teacher in China, who joined interviews and discussions with the researchers, and kept personal reflections. The narrative analysis was conducted with the participant Ming's data and reported that his negative emotional experiences influenced the process of his learning to become a teacher. At first, Ming described himself as excited and anxious to take the responsibility of being a teacher such as considering students' needs and interests. Second, Ming experienced disappointment about not being able to integrate what he has learned in the teacher education program since mentor teacher resisted to create a passive learning atmosphere in the classroom. He could learn about how power relations could influence the teaching and learning processes, and he needed to be strong and powerful to take constructive actions. Third, his attitude as a student teacher was recognized by his mentor teacher as a good assistant that gave him satisfaction for his work. The participant's experiences enhanced his emotional responses and contributed to the professional identity development.

Avraamidou (2014) conducted a case study to explore a beginning elementary teacher's identity for science teaching. The five-year data were collected through interviews, reflections, assignments, lesson plans, and observations and analyzed through inductive methods. The results showed that the beginning pre-service science teacher developed knowledge of scientific inquiry and enacted diverse strategies such as argumentation, experimentation, and group work among students. Another result was related to the teacher's relationship or communication with others such as family, mentor teacher, and her teachers who influenced her in becoming a teacher. This teacher also discussed the role of gender and context in science and teacher development since there were negative and non-supportive experiences of women in science. The study showed the positive impact of longitudinal data collection to understand teachers' experiences, relationships, and contexts.

Additionally, Timostsuk and Ugaste (2010) aimed to explain 45 pre-service teachers' professional identity. Data were collected through individual and focus group interviews and analyzed through inductive methods to construct the themes of Wenger's (1998) theory of learning. The results reported student teachers' successes and failures. They focused on content coverage using diverse pedagogical

strategies, and they had difficulty finding a teaching community, but they were successful in communicating with mentor teachers and peers to develop themselves. The study emphasized the importance of creating an educational community for the development and preparation of pre-service teachers for future studies.

A study by Menon (2020) aimed to examine pre-service elementary teachers' science teacher identities and self-efficacy beliefs through a science methods course. Participants were 121 pre-service elementary teachers. Among the participants, four elementary science teachers in different content and preparedness levels were selected for classroom instruction. The study was designed and analyzed based on the theoretical framework of Bandura (1977) for self-efficacy and Gee's (2000) identity framework. Data sources included self-efficacy questionnaire, open-ended questionnaire, interviews, reflections, observations, and artifacts. Statistical (repeated measures analysis of variance) and inductive analysis were conducted. The results showed that attending a science methods course enhanced pre-service teachers' self-efficacy beliefs, and their experiences in the course and classroom teaching connected to their self-efficacy beliefs with identity. For example, participants' mastery and verbal experiences were found to be contributor of discourse and affinity identity. The study suggested exploring the relationship between self-efficacy and identity framework in different contexts.

Teacher identity should be linked to develop cultural, pedagogical, and subject matter competence to establish inclusive classroom environments and address diverse student needs (Rodriguez & Navarro-Camacho, 2023). Varelas et al. (2022) studied science teacher identity to focus on multiple identities including race, gender, ethnicity that teachers brought to address equity and justice issues in teacher education. The study focused on teacher learning and identity construction of teachers of color to examine how teachers experience critical pedagogies. The study was designed with a phenomenological approach to understand how teachers experienced and negotiated being teachers of color. Participants were three female first year science teachers (two Hispanic, and one African American teacher). These teachers' application essays to Master of Education program, conversations within the program, and teacher inquiry presentations were utilized as data sources and analyzed based on teacher identity construction framework. The results indicated that these teachers were able to link the conceptions of equity and excellence to their science teacher identity in teaching, reflecting, and lesson design for teaching science, facilitating discourse in the classroom, and addressing multiple identities involving race, color, and gender. The study made suggestions for science teacher education towards equity and excellence framework.

In a narrative case study, Madden and Weibe (2015) studied science teaching of elementary teachers and their teacher identity. Participants were three female second-grade teachers. Data collected through classroom observations, science notebooks, and student interviews. The analysis was conducted by Gee's (2000) framework including nature, institution, discourse, and affinity. The results showed that three teachers defined their teaching in different ways such as hands-on focused, math person, or classroom manager. In terms of institutional identity, although hands-on focused teacher was perceived as teacher of other teachers about science, the other science teachers were defined as extrinsic motivator or classroom leader. Teacher of other teachers had more science related interactions and excitement to science topics whereas math-person found to have didactic instruction and have less interest in science. Classroom-manager or extrinsic motivator liked to talk about science in an informal style since the teacher had a personal interest toward science and aimed to help students listen better. The study suggested exploration of other science teachers to learn how they defined themselves in different frameworks.

These research studies were important to understand the factors that influence and inhibit the development of science teaching identities. The involvement of in-service teachers and prospective teachers in scientific communities and activities can be a useful tool for shaping and developing science teacher identities. Most of the studies focused on elementary teacher education for science teaching, pre-service teachers in general and science education, and induction period of science teachers with a focus on Gee's (2000) framework. Only a few studies focused on in-service science teachers' identity with a focus on Wenger's (1998) theory of learning. These studies were also situated in the elementary school and middle school contexts, leaving a gap in the literature regarding teacher identities for specific science disciplines. An exploration of how physics teachers form and use their teacher identities and the

factors mediating the formation and use of their identities is missing. The current study differs from the previous work to present and compare the experienced physics teachers' identities with theory of learning. This study adds to the literature to explore three male experienced physics teachers' professional identity.

Method

Research Design and Participants

This study aimed to explore how in-service physics teachers understand and describe their professional identity through a multiple case study design (Yin, 2014) using only qualitative approaches. Multiple case study aimed to conduct in-depth analysis for each case to explore their characteristics or perspectives and the patterns across cases (Yin, 2014). This multiple case study was conducted to make a holistic description of physics teachers through in-depth data collection from multiple sources of information and understand the similarities and differences across cases (Merriam, 1998). Three public high school physics teachers were selected from different schools in a metropolitan city in the northwest region of Turkey to be examined and compared. The participants were purposefully selected from 30 physics teachers, who joined one-year long project on teacher identity. Three participating teachers voluntarily agreed to provide data over the course of one year. They were selected as contrastive and illustrative cases to enhance the rich descriptions. These teachers were Ahmet, Mehmet, and Mustafa (Turkish pseudonyms). Demographic information of participants is presented on Table 1. All three teachers were male around 60 years old and had worked for more than 30 years of experience in Turkish Public Schools. They were teaching in public schools and had worked in different kinds of schools including science-based, vocational-based, and normal high schools. They worked in different regions of Turkey before coming to the metropolitan city. These teachers completed four-year physics program and received a teaching certificate by taking pedagogy courses in their university; Ahmet and Mehmet completed the same university in a big city in the east part of Turkey, and Mustafa completed a university in another big city in the northwest region of Turkey. These teachers were teaching all school grades (ninth, tenth, eleventh, and twelfth) that there were 10-25 students in their classes.

Table 1
Demographic information of participants

	Teaching experience	Education Background	University (pseudonymous)	Previous teaching
Ahmet	35	Physics Department + Pedagogy Certificate	East University	Project Schools
Mehmet	33		East University	Vocational Schools
Mustafa	32		West University	Normal Schools

Table 2
Sample interview questions

1. How were your experiences in teacher education program?
2. How do you describe yourselves as a science/physics teacher?
3. How do you define teaching science?
4. How do you think learning is occurring?
5. What supports did you need after you graduated from teacher education program?
6. What supports did you get after you graduated from teacher education program?
7. What is your relationship with students?
8. Are there any facilitating or limitation factors that influence your profession?

Data Collection and Analysis

The main data collection strategy was semi-structured interviews to obtain in-depth information from the participants about their prior experiences, their science teaching orientations, teaching practices, and interactions with others such as students, other teachers, administrators. Each interview took 90 minutes. The sample interview questions are provided on Table 2. The interview questions focused on physics teachers' experiences in teacher education program, their beliefs and teaching orientations, their students' learning, their instructional strategies, and their competency in their work. In addition, the researcher observed these

Table 3
Sample codes, themes, and excerpts from the qualitative analysis

Themes	Categories	Codes	Excepts from Interviews	Data Source
Experience	High school	Emotional	*I decided to be a physics teacher, but not like him* (Mehmet).	Interview
	Teacher education program	Courses	*Attending pedagogy classes were not helpful to learn how to teach physics* (Mehmet).	
	In-service teacher	Curriculum	*Curriculum changed in 2012… I had tried to teach through experiments…There was a lack of equipment to conduct different experiments* (Mustafa).	
		Classroom context	*Classroom environment is not suitable to do experiments* (Mustafa).	
		Student profile	*Physics is considered as a difficult and unachievable subject* (Mustafa).	
Belief	Science	Absolute knowledge	*Books include accepted and validated information, but students believe what is said on YouTube videos* (Ahmet).	Interview
		Political	*Politics cannot be integrated within science since the atomic bomb was a political decision* (Mehmet).	
		Use of experiments	*Students should deal with how and why questions and apply theories through active participation* (Mustafa).	
Community	Interactions with	Students	*I can easily organize students to discuss science topics such as Chaos Theory in physics club* (Ahmet).	Interview
		School/projects	*I organize projects with other science teachers to teach physics. I should teach physics within a social science class as well* (Mehmet).	
		University	*University professors come and discuss physics, atom physics with our students* (Ahmet).	
		Parents	*Parents come and talk to me and ask me to prepare students for the exam without solving complex physics problems* (Mustafa).	
Practices	Instructional Strategies	Triadic Dialogue	*Use of Initiate-Response-Evaluate trio* (Ahmet)	Classroom Practices
		Daily-life examples	*How many meters do I take from the class to teachers' room? Is it distance or displacement?* (Mehmet)	
		Use of board/smartboard	*Openning a question on smartboard* (Mustafa)	

teachers in their classroom and school contexts to take fieldnotes about their practices. The main purpose of the classroom observations was to understand the role of the teacher and instructional strategies. No classroom observation protocol was utilized, but the researcher took fieldnotes based on the teachers' classroom practices. Each teacher's teaching was observed for two lesson hours (100 minutes). Three teachers' interviews, lesson plans, personal statements, and fieldnotes from classroom observations were used to understand teachers' professional identity.

The interviews were audio-recorded and transcribed verbatim for analysis. Since the interviews were conducted in Turkish, the first author read through the interviews and translated important components to English. The interviews were analyzed through thematic analysis (Braun & Clarke, 2006). After reading the responses to the interview questions, the responses were categorized into themes of Wenger's (1998) theory of learning including experience, practice, community, and belief. Table 3 included sample codes, themes and excepts from the interviews. At the end, the case profiles were constructed by the first author to conduct a cross-case analysis to examine the similarities and differences across three teachers in the discussion part.

To establish the ethical standards, the study was designed and conducted through receiving the approval of ethical committee of researcher's university and Ministry of National Education (MoNE) to conduct interviews with in-service physics teachers and observe their classrooms. For trustworthiness of the research analysis, the author used triangulation techniques; the researcher collected data for the purpose of the study through various sources including interviews, lesson artifacts, observations, and written statements. The idea of member checking was used (Denzin & Lincoln, 2011); each participant was also asked to review the interpretations of the data. The author and a graduate student separately read through 30% of the material and identified the connections between categories and codes to establish the interrater reliability. Both the author and graduate student coded the interviews and compared them to check the consistency. After establishing 70% agreement between the raters, disagreements were resolved through discussion.

Findings

Case-1: Ahmet

Experience: Ahmet devoted himself to physics books to solve different types of questions and to help his students. He defined himself as a "question-bank" since he aimed to know all types of physics questions and answer them when students asked. He said, "When I first started teaching, I hesitated with students' questions, and I was angry when I was not able to answer. This forced me to solve a lot of questions. I have been solving all questions for years." He was question-oriented and collected many questions as a guide for students' exam preparation. For his teaching, he said, "High school education in Turkey is very much affected by university preparation: the inability to do laboratories, the lessons are not based on the theory of the course, but always the preparation for university prevails. We must head there" (Interview, 2022/11/09). He emphasized that the curriculum might restrict teachers' teaching or explanation of concepts, he preferred to focus on the details of the concepts. He defined himself as a disciplined person and stated, "It is not a discipline to make students afraid of me, but to help students be organized and study." He added that students' academic background, family status, and interest influenced their approach to physics discipline and stated, "Some students have high interest towards physics, they want to learn particles, quarks, they want to go to CERN. They want to talk to university professors. I need to support them to explore and learn and help me learn as well." He supported and guided his students' physics club activities as an after-class activity to make them engage in science.

Practice: Ahmet's teaching was content-oriented to help students solve problems. During the classroom observations, Ahmet was on board and talking to his students. Teaching resources were white board, smart board, and teachers' personal teaching notes. The teacher explained the physics concepts by drawing figures on a white board and showing visuals and questions on a smart board. The teacher facilitated a triadic dialogue since he asked questions and after he received the responses from students, he evaluated and asked other questions. Typical classroom practices were based on questioning, short student responses and extended teacher explanations (Observation, 2022/11/18).

Community: Ahmet was the oldest and most respected teacher in his school community. He could organize students to work on physics problems and discuss scientific issues. However, he separated his teaching job from physicists work and stated, "Physicists study hard to explain nature, what is going on in space; but I am a teacher at school, and I cannot solve some hard questions in society" (Interview, 2022/11/09). Ahmet considered himself as a teacher at school, but he defined his job as separate from scientists' work. He said, "I am a standard teacher. I show my visual ability in painting, not in science." He emphasized that he did not have a science-related community after school, but he spent time on drawing and painting physical figures. His classroom community lacked the characteristics of dialogic discourse or active learning since the lessons involved the introduction of formulas, drawing graphical representations, and direct teacher explanations with short student responses. The teacher's traditional instruction was related to his emphasis on standard instructional practices to transfer knowledge that linked to teacher's teacher identity.

Belief: Ahmet valued having interest and curiosity to develop scientific knowledge. His approach to science-related activities was limited to traditional books. He defined, "Books include accepted and validated information, whereas students easily believe what is said on YouTube videos" (Interview, 2022/11/09). He emphasized that students could learn through reaching validated information and memorizing accumulated facts. His beliefs about teaching and learning physics aimed to develop good content knowledge through memorization and solving many questions.

Case-2: Mehmet

Experience: Mehmet's experiences as a male physics student had impact on his career choice. Mehmet had negative experiences with a male physics teacher in his high school and stated, "When I saw that strict man was behaving badly to students who could not answer physics questions, I decided to be a physics teacher, but not like him" (Interview, 2022/10/26). His emotional experience enhanced his interest to become a physics teacher. His university professors were also male, and he could develop good content knowledge in their classes, whereas attending pedagogy classes were not helpful to learn how to teach physics. He stated, "There is a problem that physics is taught as the final product of scientific studies, and it is easy to develop alternative conceptions in this way." Mehmet commented on the limitations of teaching physics practices to approach all students as equal, so he aimed to change and develop his practices through attending professional development programs and learning how to prepare good curriculum materials.

Practice: Mehmet's classroom instruction was discussion oriented. Mehmet was walking around students' desks while asking questions to observe what students were doing. Mehmet's facilitation of the discussion started with an open-ended question to explore sets of students' ideas. Students were also asking questions and making extensive explanations to elaborate on each other's responses. Mehmet continued asking conceptual and open-ended questions without providing direct responses (Observation, 2022/11/01). The explanations included examples from real-life events and everyday use of physics concepts. The main element of the lesson was students' responses and teacher guidance to dialogic interaction. White board, smart board, and any book was not used during the lesson. Although some materials were utilized to make demonstrations, no experimental work was included in his lessons.

Community: Mehmet was known as a project-person among science teachers including biology and chemistry teachers to design and enact science projects within their school context. He stated, "We do not have an interdisciplinary curriculum, we are teaching physics without any context. We need to combine science lessons, chemistry, biology, physics, even mathematics to teach concepts. Since we cannot do everything in the classroom, I organize projects with other science teachers to teach physics. I should teach physics within a social science class as well" (Interview, 2022/10/26). He argued that a physics teacher had an important role in students' lives to make them understand their nature and develop analytical thinking skills. He aimed to create a classroom and school environment to motivate and enhance students' interest in everyday physics through data collection, analysis, and explanation. This was also reflected in his classroom community since he aimed to enhance student voice with less teacher talk. Moreover, he emphasized the role of parents in the development of scientific literacy in society. He said, "Parents need to have advanced scientific literacy to support their students'

development as a science person." Mehmet's communicative interactions with colleagues and his students supported him to develop a science community at his school.

Belief: Mehmet valued nature in science. He thought that teaching physics should involve making natural observations, measurements, and connections to daily life. He believed that these teaching strategies could create a disequilibrium in students' thinking to repeat their data collection methods. In addition, he defined science as universal and stated, "Science is not related to ethical, social, cultural, and religious values that could be dogmatic. Socio-cultural values prevent scientific thinking. Politics cannot be integrated within science since the atomic bomb was a political decision. It serves for financial assets" (Interview, 2022/10/26). He thought that scientific products were consumed and used for financial purposes, but his students should learn how to do science for the benefits of the society.

Case-3: Mustafa

Experience: Mustafa described himself as a competent physics student in high school and college years since he completed the physics department as the first rank student. He said, "I believe physics requires questioning. When we think what, how, and why questions, we can do the rest of it with mathematics" (Interview, 2022/11/07). He thought that being a physics teacher was the most appropriate occupation for him since he liked talking about physics. He aimed to attend a graduate school to complete a master program in physics, but he could not continue due to some problems. He said, "I was successful in the graduate school exam, but there were political issues at the universities in 1990s, so I left and continued teaching physics at public schools." He worked in different schools with diverse student profiles including religion-based schools, middle schools, rural schools, and technical high schools. He said, "In most schools, physics is considered as a difficult and unachievable subject; students have a lot of bias towards physics. I think most students in the past -when I was a student- were more ambitious to study physics, but now students tend to choose social sciences. Some students graduate without solving a physics problem." He emphasized that students had low math skills to achieve in physics, but if students had math skills, they tended to study for the exam instead of developing scientific thinking skills. He thought that doing physics experiments was an important component of physics learning to help students learn by doing. He said, "In 2012, the curriculum changed, and we were asked to teach physics through activities. I had tried to teach through experiments for two months by showing the experiments and asking students to answer the questions. There was a lack of equipment to conduct different experiments with all students." Therefore, the teacher preferred to use modelling and virtual simulations during the instruction.

Practice: Mustafa taught physics lessons through lecturing without integrating experimental work. He said, "I am not preparing a lesson plan, but I prepared a smart notebook to give my students to follow during the lesson. Students are not able to take good lecture notes. I ask them to write the definitions, draw figures and solve questions in this notebook. I give homework on this notebook" (Observation, 2022/11/07). The teacher preferred using the question-answer method about the topic to ask questions, receive responses from a few students, and then, ask students to complete the questions on the notebook. The teacher's questions were generally in the knowledge, understanding, and application level. The teacher asked students to solve questions using the formulas. Students needed to listen to the teacher's explanations while answering the questions. For example, he integrated simulations and visual materials such as pictures or videos via smart board. He also used the white board to write explanations and draw figures, but he was not making extensive explanations. He said, "I am not an authoritarian teacher, I give the information that they need to use and work on it." The teacher said that he aimed to manage classroom instruction through a smart notebook and needed more student participation for effective lessons.

Community: Mustafa was known as the expert physics teacher among his colleagues at his school. However, Mustafa indicated that parents could sometimes complain about his teaching style. He stated, "Parents come and talk to me and ask me to prepare students for the exam without solving complex physics problems" (Interview, 2022/11/07). He thought that parents prevented him from giving effective physics lectures in class. He indicated that physics was not only in the classroom, but students also needed to observe real-life physical events and out-of-school science activities to understand what and how something was happening. Thus, his communicative interactions in his classroom were also limited

to smart notebook to cover the content and solve sample questions since he aimed not to exceed the students' and parents' expectations for exam preparation.

Belief: Mustafa defined science as subject to change by making observations of physical and social events and collecting multiple data. He thought that he collected a lot of data about students' learning, and current curriculum and instructional materials forced teachers to teach for memorization without addressing students' learning needs. He added, "Students should deal with how and why questions and apply theories through active participation rather than being passive observers" (Interview, 2022/11/07). He indicated that physics lessons should be taught in laboratories with sufficient equipment for all students. Mustafa defined physics as a dominant positive science and universal that scientific truths could change the social and cultural values to develop systematic thinking.

Discussion, Conclusion, and Suggestions

These three physics teachers' professional identities were analyzed through Wenger's (1998) identity framework considering teachers' experiences, practices, community relations, and orientations to science. The study aimed to explore the following research question: What are the characteristics of professional identity for experienced physics teachers? How do these characteristics influence physics teachers' professional identity?

The results showed that participating experienced teachers had developed different professional identities: question-oriented (Ahmet), project-oriented (Mehmet), and lecture-oriented (Mustafa) teacher identities. Question-oriented teacher identity was aligned with his practices in the classroom and his beliefs about science as accumulated information. Project-oriented teacher identity aimed to collaborate with other teachers on science projects to enhance student participation; he was more student-oriented to increase students' voice in science classrooms. He tended to develop new assessment materials through attending professional development programs. He believed that scientific knowledge had been approached as a financial asset rather than developing scientific literacy, so he aimed to enhance students' interest towards science. Lecture-oriented teacher identity was more lecture-oriented to manage the classroom instruction according to students' and parents' expectations. His beliefs challenged with his practices since he thought that physics should have been taught through experimentation and application. These results showed that although these teachers were aware of reform-minded teaching characteristics, only project-oriented teacher identity facilitated dialogic discourse in the classroom to promote student participation. Question-oriented and lecture-oriented teachers preferred to create a teacher-centered classroom, whereas question-oriented teacher was more disciplined in establishing rules, and lecture-oriented teacher aimed to manage the classroom instruction through science notebook. Project-based teacher attended several professional development programs to learn new educational innovations, question-oriented teacher solved and prepared physics questions for this teaching, and lecture-oriented teacher planned his teaching according to expectations for exam preparation. Like Helms (1998) suggested that these participants defined their positionality as physics teachers referring to their personal characteristics, other's expectations, and their interest towards science projects. These results suggested how teacher development for reform-based instruction was crucial for promoting active learning and for reform-oriented professional teacher identity.

Beauchamp and Thomas (2009) suggested that teacher identity starts to develop in the teacher education program and enhances through being aware of the innovations and understanding their implications for effective teaching and learning. Question-oriented and lecture-oriented teachers continued teaching in the traditional format or enacting teacher-oriented identity after graduating from the teacher education program, but project-oriented teacher valued and taught through discourse that attributed him a more student-oriented teacher identity through his learning of innovative strategies. These teachers attended similar teacher-education programs: they took core physics courses and pedagogy courses to receive a teaching certificate. Since their teacher education programs were content-focused, their identity was shaped by their experiences, communicative interactions, social and physical or school-based factors. For example, question-oriented teacher identity was known as a disciplined elderly teacher, so his lessons focused on solving questions in a silent way, and his students tended to listen to his suggestions. Lecture-oriented teacher was influenced by the pressure of parents to teach for the exam. Project-based teacher was more social in his school to design and conduct science projects to communicate with students and other teachers. This teacher's interest in becoming an active teacher led him to attend

courses and seminars in universities. This finding is related to previous studies that it was possible to support and promote experienced teacher learning to become a reform-minded teacher (Madden & Wiebe, 2015). The K-12 Framework in Science Education also suggests continuous professional development of pre-service and in-service science teachers on scientific practices and nature of science (Avraamidou, 2014; NRC, 2012). Avraamidou (2014) suggested that longitudinal data collection on a pre-service science teacher's identity could provide the process of development of reform-minded identity in later years. This argument is also relevant for in-service science teachers. For example, in the current study, only project-oriented teacher identity had opportunities to join seminars and professional development programs to prepare lesson materials. Question-oriented and lecture-oriented teacher identities were isolated and strived for self-development. This conclusion showed that these teachers did not have a chance to attend a professional development program either in early or late years of their teacher work. These results suggested that physics teachers' development should start in early stages while they were pre-service teachers and continue towards beginning and experienced years in a collaborative process with other teachers and teacher education programs. Our results showed that we need further research to explore how longitudinal professional development programs on reform-based instruction can support in-service physics teachers to develop identities aligned with reform suggestions.

These three case studies indicated that experienced teachers had worked in different teaching and learning contexts, and they had different interactions within school contexts. Teachers' experiences showed how their identity was shaped via their interactions. Ahmet, as a question-oriented teacher was the most respected teacher among his colleagues and students, he had positive relationships with his students since he supported their interest in science in the physics club. However, Mustafa as a lecture-oriented teacher had negative relationships with parents and students, so he limited his teaching to cover the content. Mehmet as a project-oriented teacher had positive interactions with students, other teachers, and outside of the school context on science related issues and courses. Project-oriented teacher had a negative experience with a male physics teacher who undervalued learners' ability to do science, so he aimed to be a responsive teacher for students' needs. Among these teachers, lecture-oriented teacher had more emotional responses to the reactions of others' (such as parents) responses which could contribute to his identity development. These results suggested that in-service physics teachers needed to communicate with other teachers and university professors to design and enact lessons through constructivist pedagogy and to eliminate bias and emotional reactions towards their work (Sutherland et al., 2010; Yuan & Lee, 2016). These interactions can also enhance the equity considerations in teaching and learning science to promote the participation of both female and male learners in physics (Vareles et al., 2022). Project-oriented teacher's reaction to a bad behavior of a male teacher helped him develop culturally relevant strategies to access his students and enhance their participation (Rodriguez & Navarro-Camacho, 2023).

Two teachers' beliefs were related to their practices, only one teacher's beliefs were not in alignment. Question-oriented teacher thought that scientific knowledge was accumulation of validated information and learning occurred through memorization of facts. He taught through triadic dialogue in a teacher-centered format. Project-oriented teacher identity believed that scientific knowledge developed through observations and measurements and required application for data collection and analysis. He aimed to teach through student-oriented instruction. However, lecture-oriented teacher identity believed that learning occurred through observation and application and active involvement, and he taught physics through lecturing. Menon (2020) found that teachers' beliefs and experiences were connected to their identity. However, in our study teachers' meaning of self may be related to or differ from their beliefs or practices. For example, question-oriented and project-oriented teacher identities were contributor of their classroom practice and community interactions, whereas lecture-oriented teacher identity was connected to others' expectations.

This study provided a perspective to understand experienced physics teachers' professional identities. The study was limited to three cases to collect data though a face-to-face interview and classroom observation.These results helped us conceptualize how experienced physics teachers see themselves and how they were viewed by others; we were able to understand these teachers' experiences, beliefs, practices, and communicative interactions. There were both agreements and disagreements on how teachers defined their work and their interactions, their beliefs, and practices. The study showed the

need to focus on development of teacher identity through mentoring. Future studies should focus on in-service physics or science teacher's identity development through longitudinal studies to understand their interactions with students, other teachers, parents as well as in- and out-of-school activities to support teacher learning through reform-based instruction.

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Ethics statement: In this study, I declare that the rules stated in the "Higher Education Institutions Scientific Research and Publication Ethics Directive" are complied with and that we do not take any of the actions based on "Actions Against Scientific Research and Publication Ethics". At the same time, I declare that all the responsibility belongs to the article authors in case of all ethical violations.

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