Chapter 1

General Introduction
1.1. INTRODUCTION

I started working as a lecturer at the teacher education program at one of the public universities in Indonesia, Universitas Negeri Malang, in 2014. Based on my experiences, the students faced difficulties in understanding physics concepts. Moreover, when students engaged in their teaching practice in the school, they lacked confidence in their ability to teach. It was at that time that I became interested in exploring how teacher preparation might support future teachers in developing robust conceptual understandings of physics concepts and supporting them in feeling more confident about their abilities as teachers as well. More specifically, I am interested in how preservice physics teachers’ understanding of physics concepts in the first year of their training influences how they perceive themselves as future physics teachers, which serves as the basis of the development of their identity as physics teachers.

In western countries, there is a growing interest in research into teachers’ identity development, both preservice and in-service teachers, especially in science education. In Indonesia, however, research on teacher identity, and especially in physics education, remains scarce.

The construct of identity is broadly defined as how a person sees herself/himself and is seen as “a kind of person” (Gee, 2000). In physics teacher education, physics teacher identity is used to refer to how students (preservice physics teachers) see themselves as future teachers and how they are seen or recognized by others. This is precisely what I aimed to explore in this research.

To this end, the introductory physics course in the teacher preparation program at Universitas Negeri Malang has been redesigned to implement the multiple representations (MR) approach, in which the instructor emphasizes the use of different representations in physics teaching. This decision was grounded in evidence pointing to the potential of the use of MR in enhancing students’ conceptual understanding (Munfaridah et al., 2021a). In this research, I explore the connection between conceptual understanding and physics (teacher) identity. This comes as a response to an identified gap in the existing knowledge base: there is no evidence about specific classroom practices that might contribute to the development of students’ physics identity. This gap is even bigger in Indonesia, where identity-based research has received very little research attention.

Hence, a research exploration that capitalizes on the construct of identity to examine how the development of future physics teachers’ identity might be supported is both timely and crucial. The role of MR-based instruction as an instructional approach
that might support identity development is the main focus of this research. In this thesis, I present the outcomes of a systematic review study about the use of MR in undergraduate physics education, I provide a framework of physics identity and physics teacher identity, and I provide empirical evidence of how the implementation of MR-based instruction impacted preservice physics teachers’ physics and physics teacher identity.

1.2. RATIONALE OF THE RESEARCH

Humanity is facing major global challenges including public health, food security, poverty, climate crisis and inequalities. These challenges create new needs and expectations from the scientific community, which is called to act upon contemporary socioscientific issues. At the same time, global reports indicate a decline in students’ interest in science and scientific careers (Organization for Economic Co-operation and Development [OECD], 2019). Physics education, which is the scientific field of interest in this thesis, has a critical role to play in addressing these global challenges (Fraser et al., 2014; Pimbley, 1997).

However, physics remains the least popular subject for students in terms of study choices as well as the least diverse field in terms of gender and ethnicity (Avraamidou, 2020). The situation in Indonesia is no exception. An examination of data related to study choices shows that physics programs receive the lowest number of applications among science disciplines (e.g., mathematics, biology, and chemistry) (LTMPT, 2021). This is problematic from a talent utilization perspective (Gonsalves & Danielsson, 2020). A review of the literature showcases that this is attributed to different factors: (a) physics is perceived as a difficult subject (Carlone, 2003); (b) gender stereotypes and biases associating physics with males (Danielsson, 2014); (c) cultural stereotypes that associate physics with ‘cleverness’ (Due, 2014); (d) negative experiences in school physics (Dou et al., 2018); and (e) difficulties associated with the study of physics (Bollen et al., 2017; López & Pintó, 2017).

To better understand these factors, researchers have recently turned their attention to the construct of “science identity” which is broadly used to refer to individuals’ knowledge, views, understandings, and practices related to science (Avraamidou, 2014; Gosling, 2017; Johansson, 2016). This thesis adopts an identity-based framework for the purpose of exploring how preservice teachers learn and develop as future physics teachers, as examined through the construct of “physics identity”. Research studies showed that identity is a determining driver of students’ study and career choices related to Science, Technology, Engineering, and Mathematics (STEM)
(Lock et al., 2013; Shirazi, 2017; Stiles-Clarke & Macleod, 2016). Another set of studies examined how identity shapes teachers’ pedagogical decisions and instructional practices in science classrooms and how it might be used as a framework for the design teacher preparation programs (Avraamidou, 2014).

In physics teacher preparation, which defines the context of this thesis, introductory courses play a critical role in shaping preservice teachers’ experiences. As research studies showed, positive physics experiences in the introductory courses can support the development of students’ physics identities and support them in pursuing physics studies (Stiles-Clarke & Macleod, 2016). However, students do not always gain a genuine understanding of the concepts, practices of inquiry, and mental habits used in the discipline from their experiences in introductory courses. Research evidence points to the fact that students face difficulties in solving physics problems and understanding the physics concepts in introductory physics courses (Freedman, 1996). To address these issues, as Freedman (1996) suggested, we need to rethink the content of the introductory courses in ways that support not only development of conceptual understanding but also development of understanding of ‘thinking like scientists’. This is precisely what the research reported in this thesis aims to do through the redesign and implementation of an introductory physics course framed within an identity-based framework and focusing on the use of multiple representations (MR) in teaching and learning.

1.3. PHYSICS IDENTITY AND PHYSICS TEACHER IDENTITY

1.3.1. Physics identity

Identity has been broadly defined as being recognized as a certain “kind of person” in a given context (Gee, 2000). Brickhouse (2001) described a learning process as “not merely a matter of acquiring knowledge, it is a matter of deciding what kind of person you want to be and engaging in those activities that make one part of the relevant communities. (p. 286)” The people who acquire knowledge, in the end, will use their knowledge to conceptualize how they belong to a certain community. Hence, learning and identity are intertwined in individual development.

Students’ engagement in relevant disciplinary practices can lead them to begin developing their identities in that practice (Brown, 2006) as, for example, physics. One of the most prominent identity models that have been used in science education research is the one developed by Carlone and Johnson (2007), which includes the following three components: (a) competence, which refers to knowledge and
understanding of science content; (b) performance, which refers to the social performances of relevant scientific practices; and (c) recognition, which refers to recognizing oneself and by others as a science person. Grounded within this identity model, Hazari et al. (2010) developed a disciplinary-based identity framework that focuses on physics (Figure 1.1). This model includes the addition of the component of ‘interest’. The framework also deviates from Carlone and Johnson’s model in terms of defining the three other components of identity. Instead of measuring actual competence, recognition, and performance, Hazari et al.‘s framework measures belief in competence, recognition, and performance.

In this study, I used a physics identity framework to examine preservice physics teachers’ trajectories into the field of physics education. A growing body of research on physics identity provides evidence of how physics identity is involved in the various learning aspects of the students. A few researchers examined the factors that might influence students’ physics identity (Hazari et al., 2010; Irving & Sayre, 2013, 2015; Wang et al., 2020). A study conducted by Hazari et al. (2010) showed that specific learning experiences in high school, such as the opportunities to ask and respond to questions, play an important role in the development of students’ physics identity. Other studies reported that students’ perception of what it means to be a physicist also influences students’ physics identity (Irving & Sayre, 2013, 2015). In addition, a set of studies investigated how the positioning of students and teacher in the classroom contributes to physics identity development (Berge et al., 2019; Hazari et al., 2015; Jackson & Seiler, 2017). Building upon these findings, in this thesis, I examine how a specific classroom practice that implements MR might contribute to physics identity development.

Figure 1.1. Physics identity framework (Hazari et al., 2010)
1.3.2. Physics teacher identity

In identity research, physics teacher identity is conceptualized as part of teachers’ professional identity. Luehmann (2007) defined teachers’ professional identity as “being recognized by self or others as a certain kind of teacher” (p. 827). Drawing upon this broad conceptualization, researchers have examined how preservice and in-service physics teachers develop their identity as physics teachers (Demirci, 2015; Hathcock et al., 2020; Purwaningsih et al., 2020). A few of these studies are framed within the Dynamic System Model of Role Identity (DSMRI), which can be used to understand the development of physics teacher identity. This framework, proposed by Kaplan and Garner (2017), consists of four main components: self-perceptions and self-definitions, perceived action and possibilities, ontological and epistemological beliefs, purpose and goals (see Figure 1.2).

(a) Self-perceptions and self-definitions concern the teacher’s perceptions and knowledge of his or her own self-defined characteristics and group memberships and how these are thought to be relevant to the teaching role.

(b) Perceived actions and possibilities refer to the perceptions, intentions, and emotions the teacher can and cannot do to achieve his/her goals in teaching in light of ontological and epistemological beliefs, self-perceptions, and self-definitions.

(c) Ontological and epistemological beliefs refer to the knowledge the teacher holds as true regarding the ‘world’ of teaching and the context within which he or she teaches, and the emotions associated with this knowledge.

(d) Purpose and goals refer to the teachers’ committed purposes for their teaching, their broad as well as specific goals in teaching, and the emotions associated with these.

Figure 1.2 presents a scheme of the DSMRI that reflects the reciprocal and partial overlapping interrelations among the four components as well as the central location of action, which conveys that actions cannot be considered independently of other system components.
Figure 1.2. The Dynamic Systems Model of Role Identity (DSMRI) (Garner and Kaplan, 2017)

According to the researchers, the model is rooted in the assumption that the role identity is domain-specific (e.g., science, humanities, social science) and context-specific (e.g., school, work, family). It continuously emerges within socio-cultural contexts, and thus its components and their relations are mediated by cultural meanings. It is also influenced by the actor’s implicit dispositions (e.g., temperament/traits, unconscious motives, repressed emotions, conditioned contingencies). This role identity was expected to be influenced by the experiences in the introductory course that we used in this study. In doing so, we can begin to understand how specific classroom practices contribute to the development of preservice physics teachers’ identities.

1.4. MULTIPLE REPRESENTATIONS-BASED INSTRUCTIONAL APPROACH

Multiple representations (MR) refer to the capacity of scientific discourse to represent the same concept or process in different modes. Ainsworth (1999) organized MR under two categories: (a) external representations, which are in the form that can be seen by others, such as pictures, verbal descriptions, graphs, symbols, videos, demonstrations, and (b) internal representations or mental models, which cannot be seen by others because they relate to the students’ cognition and they are not externalized. The MR approach is defined as the use of a combination of two or more kinds of external representations simultaneously (Ainsworth, 1999). According to
Sutopo and Waldrip (2014), the MR-based instructional approach refers to a learning process where students are able to construct evidence-based claims, critique claims and representations, and then refine both initial claim and representation.

Opfermann et al. (2017) argued that MR have a great potential in supporting physics learning in contrast to learning with single representations. The use of MR in learning physics addresses different sensory and working memory channels instead of overloading only one channel. Ainsworth (1999) argued that the use of MR can support learning and deep level comprehension if it is provided with complementary information. Hence, the use of MR aims to facilitate the understanding of concepts and the development of problem-solving skills, which is central to this thesis. I argue that this specific teaching approach might serve as a classroom practice that supports the development of preservice physics teachers’ physics identity and physics teacher identity, mediated by strengthening their conceptual understanding and the development of problem-solving skills.

1.5. RESEARCH CONTEXT

The context of this study is a physics education program of a public university in Indonesia, Universitas Negeri Malang. The physics education program is a four-year program for the preparation of high school physics teachers. The participants who enroll in this program typically come from different types of high schools: private schools, public schools, private schools based on a particular religion, public schools based on a particular religion, and vocational schools (Table 1.1). During the first two years of this program, the courses focus on physics content knowledge. In the third and fourth years, the methods courses are introduced which focus on pedagogical knowledge and skills. Next to that, these students have a teaching practice program in- and out-of-the university, where they are provided with opportunities to design and enact physics lessons.

This study was carried out in an introductory physics course in the first year of the physics education program. The physics topics covered in this course include optics and waves, thermodynamics, and electrostatics. This study focused on the topic of thermodynamics which was taught during a two months period. Almost all the participants who enrolled in this course spoke Indonesian as their first language. Quite a few of the participants could speak and understand English, and that was the reason for the instructor using slides and textbooks in English at a particular time. Eighty percent of the participants in the sample in this research were from Java island, and the rest of them were from other islands, such as Borneo and
Madura island (Table 1.1). In addition, more than eighty percent of the participants were female, and less than twenty percent of the students were male. This number indicates the female domination in Indonesian preservice physics teacher programs.

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<th>Table 1.1. Characteristics of the participants</th>
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1.6. RESEARCH PURPOSE

The purpose of this study was to examine how MR-based instruction influences preservice physics teachers’ physics identity and physics teacher identity development. In doing so, the study aims to contribute to an existing gap in the knowledge base in relation to the kinds of instructional practices that might support the development of preservice teachers’ physics identity and physics teacher identity. The study is designed upon the assumption that having a strong conceptual understanding and problem-solving skills will lead to a strong physics identity, as well as physics teacher identity.
For the purpose of this study, in collaboration with the university instructor in Indonesia, I redesigned an introductory physics course that incorporated the use of MR. In this study, I used the MR-based instructional approach which included various activities emphasizing the use of different representations and problem-solving activities of preservice physics teachers. Hence, the main research question that guided this study is the following:

*How does the participation of preservice physics teachers in an introductory physics course that incorporates the MR-based instructional approach contribute to the development of their physics identity and physic teacher identity?*

### 1.7. RESEARCH OVERVIEW

The research project presented in this thesis consists of four interrelated studies. In the study described in Chapter 2, we performed a systematic literature review to critically synthesize the findings of empirical research on the use of MR in university physics education. I selected 24 empirical studies carried out between 2002 and 2019. First, I reviewed each study included in the selection. Following on that, I synthesized the findings of the studies and categorized those in specific themes. The outcomes of this study provided evidence that MR can serve as an empowering learning tool in the teaching of physics in university. Moreover, the use of MR can be used as a tool for understanding how students construct and use MR during problem solving, and how that process might scaffold students’ individual needs. Following the discussion of the outcomes, I identified gaps in the literature and proposed recommendations for future research.

Chapter 3 presents a detailed description of how the learning design with MR-based instruction was conducted in the introductory physics course. In this chapter, examples of the physics problems and how these problems could be solved using different representations are provided. Following on that, I discuss the relation between the use of MR and the construct of preservice physics teachers’ physics identity and physics teacher identity, which I use as the basis of the two empirical studies included in the thesis.

Chapter 4 is devoted to presenting the outcomes of an empirical study on the relation between the use of MR and preservice physics teachers’ physics identity following a quasi-experimental pre-post-test design. The study aimed to provide evidence of how certain classroom practices, such as MR-based instruction, might influence students’ physics identity development by addressing the following research questions:
1. Does an MR-based instructional approach lead to an increase in preservice physics teachers’ actual competence, performance, interest, and recognition as components of physics identity?
2. Does the use of MR predict preservice physics teachers’ physics identity components?

Data from 61 preservice physics teachers were collected with the use of a physics identity questionnaire, conceptual understanding test, and survey of the use of representations. The findings of this study showed how the intervention influenced the development two physics identity components, namely competence and interest.

Chapter 5 presents the findings of a qualitative case study that aimed to provide a more in-depth and detailed understanding of how an MR-based instructional approach might support preservice physics teachers’ physics identity development. Specifically, the study was guided by the following research question:

How do preservice teachers develop their physics teacher identities through an introductory physics course that incorporates MR?

For the purpose of this study, 21 preservice physics teachers were interviewed about their experiences in learning physics with the MR-based instructional approach. The data were analyzed with the Dynamic Systems Model of Role Identity (DSMRI) (see section 1.2.2). The study aims to show the impact of the MR-instruction on the participants’ self-view as future physics teachers and how that was shaped through their engagement in the course.

The last part of this thesis is Chapter 6, which summarizes and synthesizes the results of the previous chapters and includes a general discussion of the main findings of the studies. The thesis concludes with recommendations for future research and practice.

1.8. SIGNIFICANCE

This research aims to contribute to the growing body of knowledge about physics identity research and especially the role that an MR-based instructional approach might play on the development of physics (teacher) identity. In addition, the study aims to shed light on the ways preservice physics teachers begin to develop their identities as physics teachers. From a research perspective, this study can be used as
the basis for understanding the development of physics identity as well as physics teacher identity in the first year of teacher preparation, a critical phase of teachers’ development. From a practical perspective, through this study, I present a teaching approach based on the use of MR that aims to contribute to the development of students’ understanding of physics concepts as well as their physics identity and physics teacher identity. Such a contribution is valuable for the design of introductory physics courses in physics teacher education programs.