Exploring Indonesian preservice physics teachers’ development of physics identity and physics teacher identity
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6.1. INTRODUCTION

The main motivation for conducting this research was to support preservice physics teachers’ development of physics identity as well as their physics teacher identity by redesigning and implementing an introductory physics course that incorporated the use of multiple representations (MR). The purpose of the research project was stimulated by a personal growing interest in the use of MR to enhance students’ conceptual understandings of physics. Conceptual understanding or competence has recently received increased attention by researchers engaged with the construct of “physics identity”, generally used to refer to how one sees herself/himself as a physics person and how he/she is recognized by others (Hazari et al., 2010). My interest, both as a researcher as well as a university instructor, is in the area of instructional practice. Hence, the question I address through this research project 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?

Following a systematic review of the literature on the use of MR in university physics education presented in chapter 2, and through the empirical work presented in chapters 4 and 5, I aimed at supporting preservice physics teachers’ identity development by enhancing their conceptual understanding of physics concepts through an MR-based instructional approach.

In this thesis, I first presented the findings of the systematic review study (Chapter 2). Following that, I described the design and implementation of the MR-based instructional approach in the introductory physics course (Chapter 3). Next, I reported on the findings of an empirical study that examined how the MR-based instructional approach contributed to each physics identity component through a quasi-experimental design study (Chapter 4). In the next chapter, I reported on the findings of a follow-up study that examined the development of the participants’ physics teacher identity based on their experiences in the introductory physics course incorporating the use of an MR-based instructional approach (Chapter 5).

In this final chapter, I first discuss the main findings of each study presented in the chapters of this thesis. Following that, I discuss the significance of this study, followed by the implications for theory, research, and educational practice. I end with a reflection on the limitations of the study.
6.2. MAIN FINDINGS

6.2.1. The use of multiple representations in undergraduate physics education: What do we know and where do we go from here?

I started my research project by reviewing literature about the use of multiple representations (MR) in undergraduate physics education (Chapter 2). Multiple representations (MR) refer to the capacity of scientific discourse to represent the same concepts in different modes, such as verbal, mathematical, pictorial and diagram representations (Russell Tytler et al., 2007).

For the purpose of the systematic review study, I selected and reviewed 24 articles published in international scientific journals from the past 17 years through several steps. The main purpose of this review study was to synthesize the knowledge base, identify gaps and formulate future research recommendations. The review study resulted in five big themes of how MR are used in undergraduate physics education: (a) in what ways does the use of MR in instruction support student learning? (b) what kinds of representations do students use? (c) what difficulties do students face in using MR? (d) What is the relation between students’ use of MR and students’ problem-solving skills? and (e) what is the added value of technology integration in teaching with MR?

In what ways does the use of MR in instruction support student learning? A few studies provide evidence that the use of MR can scaffold students’ learning in physics (Klein et al., 2018; Korff & Rebello, 2012; Maries & Singh, 2018; McPadden & Brewe, 2017; Podolefsky & Finkelstein, 2006; Rosengrant et al., 2009; Susac et al., 2017, 2019; Sutopo & Waldrip, 2014). Specifically, the learning aspects that might be influenced through the use of MR are conceptual understanding and problem-solving performance, which directly related to “competence” and “performance” – two components of physics identity.

What kinds of representations do students use? The reviewed literature shows that students usually employ representations in order to visualize their thinking about physics concepts. Every student has his/her own preference in using representations. Ainsworth (1999) pointed out that one of the functions of MR is that they complement each other. A review of related literature shows that students used different kinds of representations, and they also used combinations of these representations, such as combining equations and verbal explanations, diagrams, and drawings (Chiou & Anderson, 2010; Fredlund et al., 2012; Ibrahim & Rebello, 2013; Kuo et al., 2013).
What difficulties do students face in using MR? Even though researchers reported that the use of MR has the potential to support physics teaching and learning, other researchers pointed to the fact that employing representations could also create difficulties in learning (Bollen et al., 2017; Maries et al., 2017). As reported in previous research, when students were asked to translate from one representation to another, they faced challenges in doing this (Bollen et al., 2017). Hence, the use of MR might be perceived as difficult and result in decreasing students’ interest in physics as they might hinder learning if used without scaffolding.

What is the relation between students’ use of MR and students’ problem-solving skills? A previous study provides evidence that students’ achievement in physics or being competence as a physics learner is inseparable from problem-solving skills (Danielsson, 2014). In reviewing a related set of studies, I found that students have better problem-solving skills after learning with the use of MR (De Cock, 2012; Kohl & Finkelstein, 2006). Other studies have also reported how the use of MR contributed positively to the problem-solving abilities in the physics class (Kohl & Finkelstein, 2005; Meltzer, 2005; Susac et al., 2018).

What is the added value of technology integration in teaching with MR? Researchers engaged with questions related to the value of technology tools in teaching and learning argued that in order to increase students’ interest and promote meaning-making video clips and animations can be used in the classroom (Patron et al., 2017). A few researchers argued about the potential value of the involvement of computer technology in the use of MR in the context of learning and teaching physics (Hill et al., 2015; Kohnle & Passante, 2017; Zacharia & De Jong, 2014), such as supporting students’ conceptual understandings as well as their representational competence.

Summing up the outcomes of the review study, it becomes clear that the use of MR in the context of undergraduate physics education has great potential in supporting physics teaching and learning. It does so by creating positive learning experiences, which in return might support students in developing strong physics identities. Furthermore, a strong conceptual understanding of physics is directly related to the development of a strong physics teacher identity. As Helms (1998) argued, subject matter – in this case, physics content knowledge – contributes to the development of physics teacher identity. Research shows that the lack of physics knowledge caused a lack of confidence among student teachers during their teaching practical in school (Körhasan & Didiş, 2015). Also, Wang et al. (2018) found that problem-solving activities can help students in maintaining their physics identity to face future experiences with physics.
6.2.2. Multiple representations (MR)-based instructional approach in support of physics identity and physics teachers’ identity development: Design considerations

Following the systematic review study, the next step was to design and implement the MR-based instructional approach in the thermodynamics part of the introductory physics course. In a study presented in Chapter 3, I illustrated how this approach was implemented in the context of an introductory physics course.

I offered a general outline of how the instructor implemented this approach, which is as follows: (a) presentation of a physics problem by the instructor using different representations; (b) problem-solving process – students discuss and construct representations through collaborative work with two or three other preservice physics teachers; and (c) presenting the work in a whole-class discussion to get feedback from other preservice physics teachers and the instructor. Here, the instructor played the role of the facilitator and monitored the learning process. Furthermore, I provided examples of the problems and details on how the problems were solved, incorporating the use of comprehensive representations. Hence, the chapter is offered as an attempt to provide a descriptive narrative of the design characteristics of the intervention, which might be useful for physics educators and practitioners.

Connecting with the concept of physics identity and physics teacher identity, I investigated the possible relationship between the various aspects of this MR-based instructional approach and the components of physics identity and physics teacher identity.

6.2.3. Preservice physics teachers’ development of physics identity: The role of multiple representations

Chapter 4 reports on the findings of an empirical study that aimed to examine preservice physics teachers’ development of physics identity following their participation in the MR-based instructional approach in an introductory physics course through a quasi-experimental design. For the purpose of this empirical work I adopted Hazari et al.’s (2010) framework of physics identity which consists of four components: competence, performance, interest, and recognition. This study involved 61 preservice physics teachers who participated in meetings of the introductory physics course during a period of four weeks. Data were collected through a pre- and post-test physics identity questionnaire and a conceptual understanding test as the representation of the participants’ competence. In the post-test, I asked the
participants about the use of MR and their experiences in the course. Statistical analyses were used to compare pre-and post-test scores and to find the correlation of physics identity components with the use of MR.

The outcomes of this first empirical study provide evidence that the MR-based approach, as a specially designed instructional approach, influenced preservice physics teachers’ development of physics identity. More specifically, the findings of the study revealed significant changes in two physics identity components (competence and interest) of the participants after their participation in the course. In addition, this study also showed a positive correlation between post-test scores of these two components with the average score of the survey on the use of representations.

The main finding of this study is that the use of MR can enhance preservice physics teachers’ conceptual understanding, which is in agreement with the findings reported in the review study (Chapter 2). I assumed that conceptual understanding should also influence the development of ‘performance’ as a component of identity, which includes problem-solving processes in physics learning. However, I did not find a significant difference between the pre- and post-test scores on participants’ performance. Regarding the component of interest, the findings showed that the use of technology (e.g., videos and animations) in the course has the potential to enhance this component. This is in agreement with previous studies that the use of multimedia and visualizations in physics has the potential to support students’ engagement (Gilbert, 2010), and that the use of technology is one effective way in enhancing students’ interest in science (Swarat et al., 2012).

Summing up, the findings indicated a change in two identity components (i.e., competence and interest) but no change in the other two identity components (i.e., recognition and performance). Nevertheless, this study can be used as preliminary evidence that the MR-based instructional approach described in Chapter 3 might serve as an example of an instructional practice that supports the development of physics identity.

6.2.4. Physics teacher identity development: A case with Indonesian first-year preservice physics teachers

In the second empirical study (Chapter 5), I performed a case study to examine how preservice physics teachers perceived the development of their physics teacher identity through their participation in the introductory physics course that incorporated the use of MR. I used the Dynamic System Model of Role Identity
(DSMRI) developed by Kaplan and Garner (2017) as the theoretical framework to analyze the interview data. The framework consists of four main components: self-perceptions and self-definitions, perceived actions and possibilities, ontological and epistemological beliefs, purpose and goals. Data were collected through semi-structured interviews with 21 preservice physics teachers focusing on their learning experiences during the course and how these experiences influence their view as future physics teachers.

The analysis of the interviews showed that specific physics learning experiences in high school (e.g., their perception of their learning, and the use of mathematical representations) and in the course (e.g., the use of representations) contributed to the development of specific components of the DSMRI model. Preservice physics teachers viewed that the use of MR in the course helped them to change their view that “physics is always something with mathematics”. This view influenced their formulation of three components of the DSRMI framework: perceived actions and possibilities, purpose and goals, and their self-perception and self-definition. In addition, the findings showed that preservice physics teachers realized that the use of this approach helped them feel more confident, especially about their content knowledge. This relates to the self-perception and self-definition component of the DSRMI framework. As a matter of fact, some preservice physics teachers mentioned that they became more confident in viewing themselves as successful physics teachers in the future.

Correlating with the previous empirical study about the development of preservice physics teachers’ physics identity (Chapter 4), I found some congruences with the findings of this study. The participants stated that they became more confident after the course because they acquired physics knowledge. The engagement with activities initiated by the instructor did the preservice physics teachers realize that those activities bring changes to their competence. As reported in the first empirical study (Chapter 4), students’ competence, as one of the physics identity components, had changed and correlated with the self-identification of the use of representations. Furthermore, another physics identity component that changed is the interest of preservice physics teachers (Chapter 4). This aligns with the findings of this case study (Chapter 5) that preservice physics teachers intended to apply the MR-based instructional approach for their future students in order to make the physics classroom less boring and more attractive to their students. Further, I noticed that components of physics teacher identity (perceived actions and possibilities, and purpose and goals) were affected. This also indicated that preservice physics teachers were more interested in learning with the MR-based instructional approach, so that they want to create the same experiences for their future students. This
finding is echoing how the preservice physics teachers view themselves as future physics teachers, which refers to their physics teacher identity. Moreover, this finding showed the intersection between physics identity and physics teacher identity of preservice physics teachers. In fact, the findings of the thesis showcase that a key link between physics identity and physics teacher identity is conceptual understanding, as illustrated through the construct of ‘competence’ (Chapter 5). This is in agreement with the assumption upon which this study was designed that a strong knowledge set (i.e., conceptual understanding and problem-solving) will lead to both a positive physics identity as well as a positive physics teacher identity.

6.3. CONTRIBUTION

The findings of this study contribute to unique insights into identity-based research about the potential role of specially designed instructional practices in shaping physics identity and physics teacher identity, which has remained unclear in science education research until today. The starting point of this study is that the lack of conceptual understanding directly refers to the components of physics identity: competence, performance, interest and recognition. Following that, I contend that strengthening preservice physics teachers’ physics identity will lead to a strong physics teacher identity. The findings of this study contribute to knowledge about physics identity and physics teacher identity by offering insights into how the development of strong or positive physics identities might be scaffolded with the use of MR in physics teacher preparation. As such, the study contributes to an existing knowledge gap in the literature related to an examination of how and what kinds of classroom practices might impact preservice teachers’ development of physics identities. First, this study provides an overview of the potential of using MR in a course for undergraduate students. Second, this study provides a concrete example of how the MR-based instructional approach can be applied in the physics classroom, which can be used by physics educators. Third, this study provides empirical evidence of how MR-based instructional practices enhance physics identity components. Thus, it can be used as the starting point to improve our understanding of the way classroom practice contribute to students’ physics identity (Hazari et al., 2010).
6.4. IMPLICATIONS FOR THEORY

The findings of this study have implications for theory in relation to the development of physics identity and physics teacher identity through a specially designed classroom practice. As reported in the findings of this study, an MR-based instructional approach has the potential in supporting preservice physics teachers' physics identity and physics teacher identity. Following Hazari et al.'s (2010) framework, one of the physics identity components is competence which refers to how a person perceives his/her ability in physics. From the literature, we cannot only refer to the perceived competence, but we need to consider the actual competence, which is manifested in students' conceptual understanding and problem-solving skills. I chose to focus on actual competence (i.e., conceptual understanding) given research evidence pointing to a mismatch between perceived and actual competence. As Ferla et al. (2010) argued, even though a high perceived competence has an impact on better students’ achievement, they also warned that high self-perceived competence without a mastery goal orientation could turn into lower persistence levels and poorer study results. Likewise, other research studies revealed that students' perceptions of their learning do not always correspond with their actual learning (Deslauriers et al., 2019). Moreover, the relationship between students' achievement and perceived competence is not strong (Kamphorst et al., 2013). This is why in this study, I used the participants’ actual competence in physics instead of their perception of their competence in the form of their conceptual understanding of physics.

Potvin and Hazari (2014) pointed out that conceptual understanding, as one of the manifestations of individual educational outcomes, can be strongly influenced by the conceptualization of an individual as a certain “kind of person”, which is the main construct of identity. This conceptualization includes both external and internal recognition processes that are equally important for identity development. If we just focus on the external conceptualization of identity, where the person is recognized as a “kind of person” by others, they will have an incomplete picture of how they perceive themselves, which is also connected to their study and career choices. Hence, identity development and educational outcomes are mutually influencing each other. Potvin and Hazari (2014) have conceptualized identity as a quasi-trait where it can change over time through certain experiences or circumstances, such as the improvement of an individual's identity by having good experiences in the physics classroom. Hence, my study offers insights on how positive learning experiences in an introductory physics course exerts influences on the individual educational outcomes in the form of improvement of conceptual understanding, which in turn leads to the development of a strong physics identity and physics teacher identity.
6.5. IMPLICATIONS FOR RESEARCH

From a research perspective, the findings of the study have implications for the role of specially designed instructional practices, and specifically the use of MR, in supporting preservice physics teachers’ development of physics identity. A previous study suggested that focusing on conceptual understanding is one of the activities that can promote students’ physics identity (Hazari et al., 2010). Moreover, previous studies have indicated that subject knowledge exerts influence on teacher identity development (Helms, 1998; Woolhouse & Cochrane, 2010). However, a review of the literature shows that there exists a gap in the knowledge base regarding the kinds of classroom practices that might support identity development.

The MR-based instructional approach is framed within learning theories that adhere to common instructional design theories and support deep level understanding (Opfermann et al., 2017). As Levrini et al. (2017) argued, researchers ought to explore further how disciplinary learning can shape the development of identity. This relationship between conceptual understanding and identity aims to provide an inclusive experience where the students can develop both their cognitive abilities as well as their sense of self as learners. This study offers preliminary evidence about this relationship in the context of the university classroom. This is important given that even the use of MR in physics teaching has been advocated and used for more than a decade, there are no studies that examine how the use of MR might lead to identity development (Munfaridah et al., 2021b).

However, as described in the limitations of this study, a follow-up study that uses an experimental design involving a control group and an experimental group would be useful for the purpose of providing evidence of the factors that impacted the changes of physics identity components, and to support our main argument that conceptual understanding can be considered as the prominent factor in the development of physics identity and physics teacher identity. Furthermore, a longitudinal study to gain more understanding of the development of preservice physics teachers’ physics teacher identity is needed, which will provide a more holistic and comprehensive understanding of how identity develops across time and place.

6.6. IMPLICATIONS FOR PRACTICE

Some activities and scenarios in the physics classroom have been reported contributing to students’ identity (Berge et al., 2019). For example, a study from Hazari et al. (2015) showed that contextual cues in the classroom, influenced the
students’ physics identity. Contextual cues intend to “meaningfully incorporating students’ thoughts and contexts (through discussions/activities which included students’ points of view and valued experiences)” (Hazari et al., 2015, p. 744). Such cues can be in the form of: (a) discussions to which students could meaningfully contribute, and (b) hands-on activities establishing real-life contextual relevance. The design of classroom practice presented in this study might be used by physics teacher educators aiming at supporting preservice physics teachers’ identity development. Given the unique cultural characteristics of the context in which this study took place, we recommend that researchers and curriculum designers turn their attention to producing more concrete examples about the use of different instructional practices that support the development of physics identity and physics teacher identity. As illustrated in recent research, students’ identity development might be supported through positive and specially designed learning experiences in the physics classroom (Potvin & Hazari, 2014; Stiles-Clarke & Macleod, 2016).

6.7. LIMITATIONS

Despite the significant insights that this study has produced, it comes with certain limitations. First, as a consequence of the limited sample and context, I realize that the findings of this study cannot be generalized to a larger population or other contexts. However, the sample in this study can be considered as a common population of preservice physics teachers in teacher education programs in Indonesia. Most of the teacher education programs in Indonesia have a similar program and curriculum in preparing preservice physics teachers to be future physics teachers. However, the main aim of this study is not to generate findings that can be generalized beyond this context, but to provide empirical evidence about the classroom practice that might support the development of physics identity in the physics classroom, which might be applicable in other physics courses in other universities contexts as well.

The second limitation of this study is that the quasi-experimental design used in the study reported in Chapter 4 cannot be used to explain the change of physics identity definitely. However, the findings of this study can be used as preliminary evidence that the MR-based instructional approach can be considered as one of the classroom practices that can support some physics identity components (competence and interest). In addition, for two of the physics identity components in the study presented in Chapter 4, recognition and performance, I did not find a significant difference between participants’ scores of pre- and post-test. I acknowledge that the designed intervention in this study might not be able to support those components, especially the recognition. Another factor which may explain this result are the
cultural differences between the context of the original instrument and the context of this study. As Hanel et al. (2018) argued, people in different nations can differ in choosing the options in Likert scale items, although they hold similar ideas about the abstract meaning of the values and their importance.

Lastly, this study provides only a snapshot of how the participants developed their physics identity and physics teacher identity through an introductory physics course. I do not have information if the effects I found are sustainable and are transferred to later courses in the program. To better understand the development process of identity, researchers ought to adopt longitudinal approaches that examine identity across time.

### 6.8. A FINAL NOTE

This thesis presents empirical evidence of how the implementation of an MR-based instruction in an introductory physics course can contribute to the development of preservice physics teachers’ physics identity and physics teacher identity. The findings revealed that not all physics identity components were influenced by the use of this teaching strategy in the classroom. Only two physics identity components have changed after the participation in the course, namely, competence and interest. Considering that the participants in our study were preservice physics teachers who expected to be future physics teachers and the close relationship between physics identity and physics teacher identity, it was indicated in a qualitative study that the use of this approach not only influenced preservice physics teachers’ physics identity but also contributed to their physics teacher identity.

This research could be considered as a preliminary research to explore identity development in Indonesia. Although there is some research on students’ interest, motivation, self-efficacy and other aspects of students in learning physics that are close to the construct of identity, I could not find research that explicitly used an identity-based framework in studying students’ learning process in Indonesia. Therefore, with this study, I am personally intrigued by identity-based research. It is not only because identity has drawn growing interest in the literature in the science or physics education field, but also because a lot of unexplored issues in Indonesia can use identity as the lens in framing those issues, as for example, the underrepresentation of women in physics, intersections between religious identity and physics, as well as issues related to cultural and structural barriers to physics participation. Therefore, this study can be utilized as the stepping stone to the next level in putting forward identity-based research in Indonesia.
In conducting this research, the most profound thing I learned from this study is that becoming a physics teacher is a complex process. It involves many factors at the personal, social, cultural, and professional level. Given that this study focused on the cognitive aspects of the participants’ identities, the social factors remain unexplored, as for example recognition. Specifically, how preservice physics teachers interact with their peers as well as their instructors and how those might influence the development of their identities are important questions that remain unanswered. As physics educators, who work in preparing future physics teachers, we should contemplate attempts to create a better quality of physics teachers in the future. I argue that an MR-based instructional approach provides a starting point for university instructors who aim to adopt more contemporary approaches in supporting preservice physics teachers’ identity development.