Chapter 8
Identity Perspectives in Research on University Physics Education: What Is the Problem Represented to Be?

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8.1 Introduction

Recent years have seen an increased focus on identity in physics, but what do we talk about when we talk about identity? In this chapter, we argue that critical, theoretical attention needs to be paid to the conceptualizations of *physics identities* that are used in research. We focus on physics in higher education settings, the physics that is taught to students in physics majors, bachelor's programmes or physics teacher programmes, but also to students in engineering, chemistry and life science. We discuss and highlight what physics education can learn from using identity perspectives, what problems are expected to be solved by bringing identity to the table, and how some under-used characterizations of the problem of identity in physics, using feminist epistemologies, provide new insights.

In physics education, identity perspectives are to a large extent used with the explicit goal of making physics studies better for students. For this interdisciplinary research to have impact, it needs to speak to both other education researchers and the physics community. In this complex situation, there is a need to discuss how the conceptualizations of identity may imply problematizations that run contrary to the intentions of the researchers. Building on a critical review of the literature and an analysis of empirical examples from our own work, we want to highlight how identity perspectives in physics education implies various problematizations, and how a careful consideration of our understanding of these problematizations are needed

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for identity perspectives to be an effective agent for change in physics education research.

The chapter is structured in four sections. The first gives a background of the field of research in higher education physics, identity research, and the approach that we take for analysing the literature. The second section presents and discusses the four problematizations that we find implied by the different ways of conceptualizing and using identity in the papers we review. The third section further illustrates the four problematization using an analysis of empirical examples from our own research projects, and is followed by a concluding discussion.

8.1.1 Studying Identities in University Physics Education

In science education, increased attention has been paid to identity issues over the last twenty-years, not least evidenced by the diverse contributions to this volume. This goes hand in hand with a growing concern for the sociocultural aspects of education (Lemke, 2001) where identity is seen for example as a way of connecting the social environment to issues such as students' attitudes and choices (Holmegaard, 2015; Tytler, 2014). Identity is also utilized to understand the large problems with equal representation and participation in science (Brickhouse, 2001), where the underrepresentation of women and minority groups is both a historical and present-day problem (Organisation for Economic Co-operation and Development (OECD, 2017a); United Nations Educational, Scientific and Cultural Organization (UNESCO, 2015). Here one influential tradition focuses on the possibilities for students' identification or disidentification with science in school (Archer et al., 2012; Brickhouse & Potter, 2001; Carlone, 2003; Godec, 2018). Other studies have focused on identity negotiations of university students and faculty (Carlone & Johnson, 2007; Ong, 2005; Tonso, 2006).

The underrepresentation of women in physics education has been a concern for many years. Even today, men make up 70–80% of the physics students in many Western countries (American Physical Society, 2018; OECD, 2017b; Universitetskanslersämbetet, 2016), even if the situation varies between cultural contexts (Hasse & Sinding, 2012; Moshfeghyeganeh & Hazari, 2021). The problem is even greater when considering the participation of ethnic or racial minorities, where for example black women are severely underrepresented in physics in the US (Coble et al., 2013; Ong et al., 2018). Apart from participation, many studies have documented gender disparities in results on standardized tests. Reviews of the quite extensive research highlighting gender in physics education have noted a lack of critical perspectives on gender, power and the culture of physics (Danielsson, 2010; Johansson, 2018a; Traxler et al., 2016). Here, a nuanced use of identity concepts is proposed as one way forward. However, along with the growing number of publications in physics education focusing on identity comes the need to analyze and evaluate how identity is used and to what effect. Hence, we want to highlight how different approaches, conceptualizations and methodologies in identity research in physics imply different representations of the "problem" identity are set out to solve.

8.1.2 What Is the Problem of Physics Identity Represented to Be?

In this chapter, we approach the question of identity perspectives in physics education with tools inspired by poststructuralist policy analysis (Bacchi, 2009; Bacchi & Goodwin, 2016) in order to initiate a discussion about the aims and consequences of our uses of identity. This is similar to what Vidor et al. (2020) has done for research on physics and gender and Beddoes (2011) for problematizations of underrepresentation in engineering education. In the framework of poststructuralist policy analysis, the central question for analysis is: "What is the problem represented to be?" (Bacchi, 2009) By phrasing the question in this somewhat awkward way, Bacchi highlights an understanding of "problems" not as given, but rather as inseparable from the process of "problematization", the social construction of some circumstances (and not others) as a problem. Constructions of problems, problematizations, are inherently political and contribute to a specific understanding of the world. Importantly, the point is not to ask how specific policy makers or researchers conceive of a problem, but rather which broader discourses shape a certain understanding (Bacchi, 2015). By taking a step back to question obvious 'problems', a 'what's the problem represented to be' approach urges us to ask how a certain problematization has come to be, which assumptions are inherent in the societal discourses it relates to, what effects this way of representing the problem has, and what questions are silenced or impossible to ask when we conceive of the area in this way.

One example of why this type of broader analysis is important is given by considering how the lack of diversity in STEM education is conceptualized by researchers as well as policymakers. Many governmental organizations highlight the need for a more extensive scientific workforce, where previously underrepresented groups are seen as an "untapped resource" (European Commission, 2004). Representing the problem in this way, as an issue of missed opportunities for expanding the scientific workforce, can be argued to stem from, and relate mainly to, discourses about national competitiveness (Lövheim, 2016; Lucena, 2005). Consequently, researchers have argued that focusing on getting previously underrepresented groups through STEM education (the "STEM pipeline") does not address issues of social justice sufficiently (Archer et al., 2017; Tajmel, 2019). The concerns of disadvantaged groups are not automatically addressed by more of their members getting STEM degrees (Cumings et al., 2014). Hence, while problematizing the composition of the STEM workforce puts diversity on the agenda, it also limits the ways in which social justice is considered and addressed.

Inspired by the "What's the problem represented to be" approach, we discuss the use of identity perspectives in physics education by analysing how different conceptualizations and uses of identity in research papers imply different ways of representing the problem this research is intended to solve. Our analysis constitutes a critical review (Grant & Booth, 2009), based on our knowledge of work in the field and complemented by readings of additional papers found through a literature search. In problematizing the problematizations of research on identity in physics education, we are writing from a specific position as academics within Swedish majority culture, fostered in a Scandinavian critical tradition and the academic fields of Swedish Physics Education Research and Gender Studies. We aim to develop a loving critique, where the role of the critic, following Foucault (1981/2000), is not to pass judgement but to analyse the assumptions of conventional ways of thinking and acting in order to explore how things could be different. In this we do not claim an objective outside position (Haraway, 1988), but are speaking from a position situated within the research discourses that we discuss, even though our perspective is a specific one within these traditions.

The papers included in our critical assessment of the field were in part found using a full-text search on the keywords 'physics', 'identity', and 'students' in Scopus that yielded 182 papers (as of March, 2020). Fifty-two of these discussed social aspects of education to some extent, and of these, thirty-four used identity as an analytical construct in higher education physics and were included in the review. We do not aim for a systematic or exhaustive review, and do not present a categorization of papers. Rather, we want to highlight how various 'problematizations' are implied in the conceptualizations and uses of identity in research, sometimes in multiple ways in the same text.

In studying problematizations with a primary focus on the conceptualization of the identity construct in published research articles, we were guided by three concrete questions:

1. How is the use of identity perspectives motivated and what explicit problems do these motivations point out?
2. What theoretical perspectives are used and what implicit problematizations do these imply?
3. How are the findings interpreted and discussed in relation to possibilities for change?

This last question represents one way of studying the 'effects' (Bacchi, 2009) of problematizations. However, our focus is on the 'discursive' (theoretical) effects, which means that we have not analysed how the research has been used for effecting change in practice, beyond what's stated in the papers. Building on the specific conceptualizations in single papers, our overarching analysis discusses the assumptions, connections and effects of the problematizations implied by broader conceptualizations of identity.

8.2 Four Problematizations

In this section we present and discuss four problematizations that we see as implied in the use of identity in research on physics education. These characterizations are the outcome of analysing the public discourse about research as represented in research papers. As such, the problematizations reflect how identity is conceptualized and used in the discussed papers, but do not describe the motivation or reasoning of the involved researchers. Our characterization thus presents idealized, even simplified, cases, and most researchers use several of these in different contexts (even in the same texts) for achieving the many goals of research in higher education physics. Our overall aim is thus to provide a background for wider discussion of these topics.

8.2.1 Students Fail to Develop Physics Identities

Research has traditionally represented the problem of physics education as one of understanding. Researchers have asked how, and why students (do not) understand physics content. Another focus has been on problem solving strategies, and here a classical take on the problem is to support students in learning to think like physicists (i.e., 'experts', Van Heuvelen, 1991). Inspired by the sociocultural tradition in education, in recent years some researchers have pointed out that we also need to attend to the social aspects of education to "expand the literature on physics expertise beyond the cognitive realm" (Rodriguez et al., 2015, p. 12). A popular way of doing this is by using the framework of situated learning, which points to how learning needs to be considered a question of gaining legitimacy in communities of practice, that is, a question of participation and of constructions of identity (Lave & Wenger, 1991; Wenger, 1998). Here, the issue is not only to 'think' like a physicist, but also to become one.

A number of studies focus on how students develop an (expert-like) physics identity. For example, Irving and Sayre (2015) discuss 'becoming a physicist' for upper-division physics students as acquiring a physics identity and being recognized by the community of physicists. It is common to use communities of practice and related theoretical frameworks to analyse students' development of physics identities in specific contexts and courses. Some examples are interdisciplinary experiences (Rodriguez et al., 2015; Sawtelle & Turpen, 2016), advanced physics courses (Irving & Sayre, 2014, 2015), or the experiences of teaching or learning assistants (Close et al., 2016; Gretton et al., 2017). One motivation for the need to research identity that is present in several of these studies is the problem with attrition in physics; students who develop a physics identity are more likely to stay in the field (Rodriguez et al., 2015). These studies commonly identify the complex negotiations going on as students navigate membership in different communities, for example moving beyond expectations of performing in classroom communities (doing ‘schooling’) towards more meaningful central participation in communities of professional physicists and physics instructors (Close et al., 2016). The representation of the problem that an identity perspective is set out to solve, as it is presented and discussed in these papers, can be summarized in a simplified way as: *Students fail to develop physics identities*. Students may well learn physics content, but that is not enough, they need to identify as part of the physics community to be able to persist and thrive in physics.

In reading these papers, we note that the role and character of the physics community in shaping students’ identities is discussed very little. Shanahan (2009) suggests that this may be a general weakness of the communities of practice framework, where a focus on individuals’ participation “tends to take the norms as given and attends to how individuals navigate those norms” (p. 57). This may represent a foregrounding of ‘agency’ without a critical assessment of the ‘structures’ that influence students’ agency. One example of a critical assessment of structure can however be found in a relatively extensive case study by Irving and Sayre (2016). Here, the authors note that the tendency of universities to try to “Create more physicists in the mold of those that they already have (professors, the majority of who conduct research)” and “the absence of a community of practice of physics teachers within the degree track” (Irving & Sayre, 2016 p. 1195) creates severe problems for one of the students in crafting an identity as a physics teacher.

These works represent a socially informed view of the processes of physics education. However, if the question about physics education and identity is primarily represented as being about students’ “Development of an appropriate subject-specific identity” (Irving & Sayre, 2015, p. 1) other important questions, like the role of the culture of physics, may be passed over in silence. Another issue that may be treated with silence is that the possibilities for developing a physics identity or to navigate the norms of the discipline is not the same for all students. In the problematizations discussed in the following sections, these issues are brought to light more explicitly.

8.2.2 Underrepresented Students Do Not Develop Enough of a Physics Identity

Research in physics education has employed identity perspectives to attend to the glaring issues of underrepresentation of women and other groups in physics. In particular, a careful consideration of identity has been put forward as a way of overcoming the ‘binary gender deficit model’ of studying gender in physics only by comparing men and women (Traxler et al., 2016). In line with this, and parallel to the approaches discussed in the previous section that are concerned with the whole student group, many studies pay particular attention to the identity development of underrepresented students. This can be seen as a more ‘sociopolitical’ (and not only ‘sociocultural’, Gutiérrez, 2013) framing of the questions of identity, where the differing opportunities of students are highlighted.

Quantitative work in this field asks what factors help students (and women in particular) to develop a physics identity (Hazari et al., 2010, 2013). Based on the notions of science identity introduced by Carlone and Johnson (2007), Hazari et al. (2010) developed a model for 'physics identity' used in statistical analysis of questionnaire data that has since been adopted in many studies and also used in other STEM fields (see, for example, Hazari et al., 2017; Kalender et al., 2019a, b; Lock et al., 2013; Verdín et al., 2019; Verdín & Godwin, 2017; Wang & Hazari, 2018; Seyranian et al., 2018). This research is generally motivated by documented problems of underrepresentation and sometimes underperformance in physics. Large-scale quantitative studies provide solid evidence for the critical state of participation and belonging for diverse groups in physics, evidence that is very useful in convincing and calling physicists and physics departments into action. On the other hand, quantitatively comparing students' identities means that identity is operationalized as something that students possess more or less of, where more physics identity correlates with more success in physics (Kalender et al., 2019a; Seyranian et al., 2018). This means that the complex interplay between structure and agency risks being lost in the reporting of such results; the lower measures of physics identity of some students may be read as a deficit of those students. Hence, one problematization implied by the operationalization and measurement of student identity is: Underrepresented students do not develop enough of a physics identity. In particular, this problematization is implied if simultaneous attention is not paid to the role of the culture of physics. When student identification is measured, and the physics environment is treated as a number of factors that can affect identification, the perception of the problem is directed towards students and the amount of identity they possess. This is especially important given the preference for quantitative results among the physics community. Accordingly, there is a risk that presenting differences in physics identity without at the same time examining and critiquing hegemonic structures may limit how physicists and physics educators n conceptualize the responsibility for change.

This problematization does not fully characterize all quantitative work mentioned here. It is however important to consider the consequences of this possible interpretation for which actions are taken. Based on quantitative results showing that explicit discussions of underrepresentation have a statistically significant effect on the measure of physics identity for women (Hazari et al., 2010, 2013), Lock and Hazari (2016) analysed two high school classroom discussions about underrepresentation. They found that the discussion challenged the student's assumptions about the world of science, "Subsequently, the norms in students' figured worlds may change or become less rigid allowing for a new openness to physics identity development amongst female students" (Lock & Hazari, 2016, p. 1). In this example, a positive change was seen in how students figure science. A similar focus can be seen in a study, also focusing on the high school level, that investigated an intervention for physics-interested young women participating in the Physics Olympiad competition, "In order to support their physics engagement and their physics identity development" (Wulff et al., 2018, p. 2). While these approaches highlight important areas for encouraging physics participation, there is a risk that a focus on the identity development or refigured worlds of these students emphasizes this as the only thing that needs to change, absolving science itself.

One way of understanding the silences inherent in this problematization is to consider the broad dimensions of whether identity is seen as something possessed by individuals or rather something that is negotiated in interaction (Pozzer & Jackson, 2015). A focus on the identity development of students may promote a view of identity as a 'personal characteristic' possessed by individuals. This view can make it difficult to simultaneously see more structural, social, and political issues.

While it is common to highlight how physics can be hostile to women along with cultural ideas about 'who fits' in physics, a too strong focus on the development of physics identity among underrepresented students (including women) risks implying (particularly for the uninformed reader) that the solution is to change these students. We may thus implicitly construct the problem as a problem of 'deficits' among these students (Traxler et al., 2016). Silences around the role the physics community plays in reproducing unequal participation in physics risk reproducing the gender problem in physics as a 'women's problem', where the majority culture is left unproblematized. We also risk missing the perspectives of students who resist certain physics identities and do not want to be a part of the physics community as it is presently formed.

8.2.3 Normative Physics Identities Impede Equal Participation

Some socio-politically oriented research on identity in higher education physics uses approaches with an explicit focus both on students' identity development and on the systemic barriers hindering equal participation. This research is often inspired by feminist and intersectional analysis frameworks to investigate power in the culture of physics, which often includes a 'negotiation' rather than 'possession' view of identity (Pozzer & Jackson, 2015). This involves explicitly aiming to avoid the previously discussed risk of framing diversity issues in terms of 'deficit frameworks', for example by adopting what Hazari and Potvin (2005) refer to as the 'culture bias viewpoint' on underrepresentation of women in physics.

The representation of the problem that identity analysis can help us solve here can be characterized as: Normative physics identities impede equal participation. Here, students' identities are contextualized and analysed in relation to a critical view of what is considered normal or desirable in the physics community, highlighting conflicts, power, and resistance.

This framing of equity issues in physics is not new. It was the background for Ong's (2005) longitudinal in-depth study of the identity negotiations of women of colour in physics education. Ong (2005) attends to the complexity in processes of gendering and racialization as well as their intersection, and focuses explicitly on both the agency of the informants to negotiate limiting structures, and how these structures can ultimately be changed. This study highlights the importance of studying identities with a view of the intersection of different power structures (Crenshaw, 1989). Aiming towards understanding the problems of participating in the physics community with a sensibility about the interaction of physics culture, gender and class constructions, Danielsson (2009, 2014) combines the communities of practice framework with discourse analysis and gender theory. This makes it possible to ask for example how the 'doing' of physics in combination with a 'doing' of working-class masculinity "May threaten the idealised portrayal of physics as objective, rational, and disembodied" (Danielsson, 2014, p. 492). Danielsson (2014) asks whether certain identity performances associated with minoritized students can be reconciled with expected or normative physics identity. A similar analysis is done by Gonsalves (2014), who examines 'recognizable' forms of being a physicist in the context of doctoral education. Gonsalves (2014) finds that as competence in experimental physics seems to bear strong masculine connotations, the women physicists always seem to stand out as 'other'. At the same time, stereotypical femininity is constructed in opposition to the purported 'neutrality' of physics, and this means that a recognizable woman physicist position relies on difference both to 'other women' and 'ordinary physicists'.

Hyater-Adams et al. (2018, 2019) draw on earlier notions of physics and science identity (Carlone & Johnson, 2007; Hazari et al., 2010) as well as critical race studies to construct a framework to study race and physics identity. They claim that "Understanding the ways in which Black folks identify as physicists can provide useful information about the facets of the physics discipline that perpetuate systems of oppression" (Hyater-Adams et al., 2019, p. 1). The authors analyse the physics identification of black physicists and students, and recommend that we provide positive recognition for students from marginalized populations. This speaks to the problematization of underrepresented students' troubles with developing a physics identity, as outlined in the previous section. At the same time, the authors also claim that "We must make a significant and intentional effort to break down the harmful ideologies inherent in physics culture", like the idea that physics is "Not influenced by the systems of oppression and marginalization inherent in society" (Hyater-Adams et al., 2019, p. 13). Framing the problem in this way problematizes the culture of physics and thus speaks to the silence in the previous problematization. This illustrates how the problematizations we have sketched here do not necessarily exclude each other.

In all these examples, a central question is how physics culture is biased to find particular groups of students lacking, and how this can be changed. This can be compared to the reinterpretations of who can be an 'expert' or hold a 'science identity' that have been documented by researchers in school settings, where young disadvantaged students take on identities such as a 'community science expert' (Barton et al., 2013; Barton & Tan, 2010). A starting point for reconceiving physics is to rethink the role of arrogance and implicit masculinity that discourage many women (Bremer & Hughes, 2017). Hyater-Adams et al. (2019) also point out that welcoming "Alternative modes of participation" (p. 13) would allow more people to feel at home in physics. This involves thinking about how different physics subjects are valued. Hazari and Potvin (2005) highlight the problem that "Traditional teaching of physics perpetuates elitist elements and does not expose students to all the ways in which physics can be pursued in the world" (p. 17). Some examples are the minimization of subfields such as biophysics, geophysics, and atmospheric physics in introductory teaching. Could more applied physics, or working in a more practical 'embodied' way (as related by the students with working class background in Danielsson, 2014) be brought into the canon of 'celebrated' physics, where theoretical and 'disembodied' fields are accorded higher status (Martin, 2017)? Similar concerns are raised in relation to the result that physics identity is strongly predicted by intrinsic fulfilment career motivations, more available to those "Who come from backgrounds with the luxury of affording knowledge-based motivations" (Hazari et al., 2010, p. 994). Changing the norms of what is seen as required for physics, what motivations are seen as legitimate, what subfields are seen as better, and what identity performances are expected are some of the important changes needed. In these calls for broadening the culture, the problem concerns how we can get more (diverse) people into physics. This is similar to the second problematization; the difference is the explicit emphasis that physics has to change to allow this. However, an additional question that is left out in these approaches concerns the relationship between physics identities and the knowledge produced in physics.

8.2.4 Normative Physics Identities Have Consequences for What Physics Knowledge Is Produced, and the Role of Physics in Society

The problematization highlights the connections between epistemology, identity and social justice. Research in physics education has traditionally focused on students' acquisition of the correct physics knowledge, but also on their understanding of physics in terms of epistemology. Taking an identity perspective means shifting the problematizations to sociocultural or sociopolitical concerns, recognizing that the social environment is inseparable from learning, in particular when it comes to the social justice aspects of education. Both these perspectives are concerned with possible ways of *doing* physics. However, they largely keep silent on the question of what physics *does,* in terms of how physics knowledge operates in the world. We argue that here lies an additional possibility for thinking critically about issues of social justice in a broader perspective than the participation of a more diverse group of people in physics. A possibility to analyse the production and reproduction of physics in line with feminist epistemologies. The question is: Can we analyse identity, knowledge, and social justice together?

As one goal of physics education is to educate knowledge workers with high status and influence in modern societies, it is important to ask how physics education affects the knowledge produced, conveyed, and used by physicists. We draw inspiration from the now 35-year old characterization of feminist approaches to analysing science proposed by Harding (1986). Harding describes five research programmes, from 'equity studies', which ask why there are so few women in science, to elaborations of feminist epistemologies, which puts a critical eye to the very root of knowledge production. Can we adopt a perspective of feminist epistemologies, and articulate it together with identities in physics? Apart from a broadening of physics culture that is welcoming to a more diverse group of people, this would also involve thinking about what this broadening entails for the operation of physics in society.

A central point made by feminist science studies is that science is always linked with social concerns, in motivations, processes and consequences, no matter how 'pure' a field is purported to be (Harding, 1991). It is important to ask whose problems the education of more physicists or the development of new physics will solve. The problem of identity in physics can thus be represented as: Normative physics identities have consequences for what physics knowledge is produced, and the role of physics in society. Attending to this problem, some theoretical arguments for how physics could be reconceived in a feminist way have been proposed (see Bug, 2003; Harding, 1991; Rolin, 2008; Whitten, 2012), but we have hitherto seen very few studies that explicitly and based on empirical data discuss questions of identity and epistemology in physics education.

One study that looks at physics education with this lens is Hasse's (2015) exploration of "The material co-construction of hard science fiction and physics". In this paper, Hasse draws from observations and interviews in an undergraduate physics programme to discuss how the 'future imaginaries' encoded in common ways of performing as a 'good' physics student point to certain ideas about the goals of physics. Hasse argues that certain science fiction-fantasies often motivate physics students as well as physicists, and that these fantasies often are traditionally masculine. In the physics education context she studied, ideas about colonizing Mars served as a motivation for the selected course content. Hasse points out that "If the selected facts are embedded in problems of how to build houses on Mars rather than how to create a less polluted planet Earth it is likely that these choices also guide our scientific concerns" (Hasse, 2015, p. 934). Hasse suggests that we ask "Whose visions of tomorrow's worlds' and 'whose science fiction imaginaries' are actually promoted in Western science education" (Hasse, 2015, p. 936). In this way, concerns about the identities of physics students points to bigger questions about the role of physics in creating a better society.

Another epistemological take on the issue of identities and inequalities in physics is given by Prescod-Weinstein (2020), who discusses who is seen as an objective 'observer' in physics. Prescod-Weinstein points out that racial and gender privilege confer epistemic authority, to the point where black women are seen as less competent observers of their own experiences of racism in physics than their white male colleagues. This represents a kind of epistemological double standard. High levels of evidence are expected for accounts of racism or sexism (which are often dismissed as anecdotal), while the developments of string theory by (overwhelmingly male and white) theoretical physicists are accepted in physics even though the prospect of corroborating experimental evidence for string theory currently seems distant. Perhaps the accusation of racism represents a bigger threat to the epistemology of physics than string theory, since it threatens the notion of physics as a "Culture of no culture" (Traweek, 1988, p. 162), an objective field where the race or gender of its practitioners should not matter. In addition to the question of how to support 'black physics identity' explored by Hyater-Adams et al. (2019), the account given by Prescod-Weinstein implies that it is not necessarily sufficient to build positive identities for previously underrepresented groups in physics. We also need to counter the inherent racism and sexism in conceptions of who a knower is. That is, we need a reform of the implicit biases in the epistemology of physics.

The arguments of Hasse (2015) and Prescod-Weinstein (2020) show how social epistemology perspectives are fruitful when reasoning about social justice in physics. Questions of equity concern both a widened recruitment of underrepresented students, and whose knowledge and priorities are allowed to point out the future direction of physics. Hence, the multiple problematizations and research strategies outlined in the last four sections all contribute to a better understanding and better tools for creating a more just physics education. Of concern however, is where and how we can invoke the different problematizations. The two papers we have taken as examples in this section are published in *Cultural Studies of Science Education* and *Signs*, two journals which are not the go-to venues for most researchers in physics education, but that can be expected to be welcoming for this kind of analysis. In what way is it possible to have these conversations with mainstream physics education researchers and physicists?

8.3 Reimagining Physics Together with Students

In this section, we provide three empirical examples to illustrate the ways of using and conceptualizing identity in physics education we have discussed in the previous sections. We discuss the stories of the trainee physics teacher Emily and the physics master's student Eugenia, as well as the experiences of five students of undergraduate quantum physics. With these examples, we illustrate how the four ways of representing the problem of identity outlined above yield complementary yet intertwined interpretations of the social justice issues at stake in physics. Note that the research was originally conducted in Swedish; quotations have been translated and all names used herein are pseudonyms.

Emily is a trainee physics teacher in her sixth semester, studying to become an upper secondary school teacher. She was interviewed as part of a project investigating what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher programme (Larsson, 2021). At this programme, trainee teachers study most physics courses together with the physics bachelor's programme (physics majors, usually with an elective in mathematics). Emily wanted to become a physicist but could not get into the bachelor's programme. She chose to study physics teaching with the explicit plan to later switch to physics. At the point of the interview, she had however decided to stay in physics teaching. Emily's choice between teaching and other ways of doing physics depended on both her social belonging in the student group and her possibilities of recognizing herself as smart enough to aim for a research career (Larsson & Danielsson, 2022). These negotiations are situated at a physics department where trainee teachers were generally perceived as less competent and ambitious compared to students on a more research-oriented track on the physics bachelor's programme (Larsson et al., 2021). When asked about her dreams about future work, Emily replies:

> Oh, I don't know, I mean, I think I would find it fun to work with research as well. Uh, it's just, hmm. So, number one: That I still think I'm a little too stupid, which uh, which I don't think is really true logically, and I think that if I had heard someone else [say so about themselves] then I would just have said 'no way'. But I still think like that.

That it is important to be intelligent enough to fit in physics, and that women are often deemed as not possessing the right kind of intellect, is a common theme in literature on identity in physics (Francis et al., 2017; Gonsalves & Seiler, 2012; Johansson, 2020).

Throughout the interview, Emily expressed that she was aware of these gendered norms, and in the quote, we see her taking on a reflective stance towards her own experience of not feeling smart enough. Emily's negotiations are also heavily burdened with the status differences between physics and physics teaching. She describes how her choosing teaching puts her in the "Stupid gang", which means choosing to become a less prestigious physics person (Larsson & Airey, 2021; Larsson & Danielsson, 2022). Emily also reasoned about how she wants to use physics to make a difference for other people, and becoming a teacher is one such choice. At the same time, she appreciates the "Exciting stuff in modern physics" and the possibility of "Really getting to understand stuff".

Interpreting Emily's story using the first or second problematization, which focus students' identity development, we may perceive her situation as a student or woman in need of support for developing her physics identity. What can be done to bolster Emily's appreciation that she does have what it takes to become any kind of physicist? Arguing from a 'culture bias viewpoint' (Hazari & Potvin, 2005) and the third problematization, would instead suggest a need to change some of the cultural perceptions of who a physicist should be. Emily's choices are complicated by the strong cultural ideals of expected brilliance (Leslie et al., 2015; Storage et al., 2016) coupled with the perception of these traits as masculine.

The high prestige of research compared to a teaching career also affects the recognition of Emily as a fully appreciated member of the physics community. A further elaboration of this picture comes from the perceived status differences between research fields in physics. In general, the more theoretical fields in physics have higher status, being supposedly purer and more fundamental (Becher & Trowler, 2001; Martin, 2017; Traweek, 1988; Whitten, 1996). Among physics bachelor students it is also common to state the motivation for studying physics as wanting to understand how the world works in some sense (Bøe & Henriksen, 2013; Levrini et al., 2017). Even when student goals are directed towards more practical topics, these are often connected to some kind of frontier thinking, like the dreams of colonizing Mars documented to be common in the physics program studied by Hasse (2015).

In a study based on interviews with international master's students in physics at two Scandinavian universities, an assumed hierarchy between fields could be shown to influence students' negotiations of identities, capabilities, passions and choices (Johansson, 2020). One example is Eugenia, who was conscious of how her interest in solving problems in material physics stood in contrast to more philosophical approaches. Eugenia was interested in creating materials for energy production, aiming at goals like mitigating climate and energy crises. These goals can definitely be considered grand, but are still more 'down-to-earth' than exploring Mars or understanding the universe. Solving societal problems is a more common motivation for studying science among women, but in general less common for physics students than in other STEM disciplines (Eccles, 2007; Sax et al., 2016; Schreiner, 2006). The motivations for physics studies of Eugenia or Emily are thus not the most common or normative among physics students, who are often more 'physics for physics sake' oriented (Levrini et al., 2017).

In light of the fourth problematization, suggesting a feminist reimagination of physics, we see how these stories contain a seed for a reconceived appreciation of the role of physics in society. Trainee teachers like Emily are preparing to teach a new generation of students what the subject of physics is all about. They can empower students to learn physics on their own terms, and make it useful in students' own contexts (Barton & Tan, 2010). Countering the prestige asymmetry in physics (Martin, 2017) and allowing for other motivations or 'modes of participation' (Hyater-Adams et al., 2019) means to value Emily's and Eugenia's motivations and choices as at least as legitimate as others. A reevaluation of what is seen as prestigious or proper ways of doing physics, may also hold the potential for redrawing epistemological lines. A vision of physics aligned with feminist epistemologies (Harding, 1991; Whitten, 2012) is achieved when social, cultural or political matters of concern are seen as a part of physics proper.

Some parts of physics have a particular role to play in relation to the dreams of many physics' students. Among these, quantum mechanics is a subject that is often entered with high expectations. These expectations often do not match the practical realities of courses, and this mismatch has been shown to be unsettling for students (Johansson, 2018b). The special role of quantum mechanics is a result of its extensive pop-cultural aura, its connection to the greatest 'heroes' of twentieth century physics, its sometimes apparently enigmatic results, and its importance for modern technology. Despite this wide appeal of the subject, the teaching of undergraduate quantum mechanics around the world often follows traditional patterns of physics teaching, with lectures, textbooks and tutorials emphasizing the mathematical formalism and students' competence in solving textbook problems (Greca & Freire, 2014). This was to a large extent the case in quantum mechanics classes at two Swedish universities observed in the research project reported in Johansson et al. (2018). In one of these undergraduate classes, negotiations between idealized pictures of quantum mechanics versus the reality of the course played out in a group interview with five male, white students with Swedish background:

Gabriel: In almost every documentary about physics they talk about quantum physics, but they can't explain all the cool phenomena that they talk about because then you say "No, quantum physics" and like "It's too advanced for ordinary people". So there's been expectations and hopes like "Oh, it will be [interesting] learning that some time". Those were the expectations for quantum physics.

Elliot: Then you were also prepared that, at least I was that it would be very difficult because I guess that's what you've heard before. That it is one of the most difficult courses you take, so you were prepared for that, and I think it has been, but also, a terribly interesting course, to kind of finally get to delve a bit deeper into physics.

AJ: But in what way is it difficult?

Ian: I mean it feels very, very abstract in some way. That you know that particles have spin and such, but you don't really know how you should really apply this with bra- and ket-states and all that, if you try to think about it more in reality, kind of. Like, you sit and calculate on it, but what its meaning in real life is, that's what I think can be quite abstract. […]

Bob: It can seem very cool and magnificent when you talk about it in a popular science way, but when you are really there and are doing quantum physics and sort of calculate your raising-, lowering- operators, then it's not that, what should I say, glorious. So, there is a certain difference. I still think it is fun to do it, but you have a completely different idea about what quantum physics is now, when you've been doing it yourself, than you had before.

Using the first problematization, we can understand the last student to speak, Bob, as a majority student who is working on developing a successful physics identity. He has reconciled his previous ideas with a, perhaps, more realistic picture of what doing physics involves: "I still think it is fun to do it, but you have a completely different idea about what quantum physics is now". He is thus moving closer to being a part of the physics community.

Understanding this quote in terms of the third problematization, the culture of physics and its effect on equal participation, we can analyse what lies in Gabriel's reflection that quantum physics is "Too advanced for ordinary people" but that he still wants to learn it. Once again, this reflects the "Widely taken-for-granted notion that physics is difficult and only for the brainy" (Archer et al., 2017, p. 93). Who is excluded by this notion of physics in general and quantum physics in particular as a 'too advanced' subject? And what does it mean to become a physicist as opposed to being one of the 'ordinary people'? The students' discussion also helps us focus the practice of physics in quantum mechanics courses by asking which different modes of doing physics are enabled by the course, and who is included or excluded by this. The course is theoretical, 'abstract', and difficult to relate to everyday phenomena (even though quantum mechanics is the basis for much modern technology). Theoretical ways of doing physics are prioritized, without connecting the content to the various concerns of the students present. At the same time, as Bob reflects, the "cool" or "glorious" phenomena played up by popular scientific accounts of quantum mechanics does not really materialize in the course. Rather, the course allows for very little philosophical exploration in favour of a 'shut up and calculate' approach to quantum mechanics (Johansson et al., 2018). For whom are courses like this designed? Meteorology students, future researchers in physics, trainee teachers, and engineers could all benefit from approaches to quantum mechanics more clearly aligned with their future work.

If we consider this model of teaching quantum mechanics as a reflection of contemporary attitudes in physics, we can ask what wider epistemological consequences this structuring of ‘legitimate’ ways of doing physics has. That is, asking questions drawing on social epistemology, the fourth problematization. A look at the history of quantum mechanics teaching suggests part of an answer. Kaiser (2002, 2014) describes how the teaching of quantum mechanics in the US changed during the Cold War arms race (in which physics was very much enlisted). From initially being concerned with foundational and interpretational issues, the teaching of quantum mechanics turned to a more ‘shut up and calculate’ approach (Kaiser, 2014), with a focus on applicability in the atomic domain (Kaiser, 2002). Kaiser (2002, 2014) argues that this aligned with training physicists for employment in military research. Allowing some extrapolation, the experiences of our Swedish quantum physics students can be understood as the continuation of this practice of imagining physics as part of a solution for defending the nation (Lucena, 2005). Rather than seeing these students’ dissatisfaction with the ‘shut up and calculate’ approach as an obstacle to their formation of physics identities, it can perhaps be understood as an argument for reimagining physics. We need not draw the consequences as far as claiming that standard quantum mechanics education creates uncritical ‘quantum mechanics’, ready for creating weapons of mass-destruction. However, asking whose dreams and aspirations for physics are taken seriously, valued, and eventually financed in research is an important tool for realizing the full critical potential of physics identity research.

8.4 Conclusion

We want to return to the general question of what research in physics education can learn from using identity perspectives, and what some directions for further development of this research can entail. In this chapter, we have discussed the public discourse around identity in research papers in order to highlight the representation of the ‘problems’ that identity perspectives are set out to solve.

In contrast to the common focus on the cognitive learning of students, physics identity research insists that learning needs to be understood from a social perspective. Identity studies have emphasized that everyone’s relations to physics are not the same; the fabric of physics student experiences is convoluted by unique configurations of identities. In-depth investigations of gendered, classed, and racialized identities in physics have illuminated both how underrepresented students struggle with identifying and being identified as physics people, and how the specific culture of physics is a part of the problem which needs to be challenged if we are committed to a socially just education in physics.

The four problematizations and the various approaches employed by the reviewed papers are important in providing a rich and complex image of physics education that challenges the historical legacy and on-going inequalities in physics. We want to emphasize the importance of continuously questioning how the ‘problems’ empirical research projects set out to solve are represented, in published papers as well as other discourse. This means a research reflexivity on the level of political implications of research. Discussing 'radical' re-imaginations of physics may be more or less strategic given the audience, even though the variety of approaches included in the mainstream physics education journals has increased in recent years. We suggest that important strategic questions are made possible by keeping the four problematizations in mind. For example, will the culture of physics necessarily change if more diverse generations of physics students are recruited, or do these students risk being 'assimilated' into reproducing the norms of the field as it is presently formed?

We believe an important, if strategically complicated, opportunity lies in simultaneously examining identity and epistemology in physics. Given the wide-ranging societal influence of the physics discipline, knowledge construction in physics needs to be considered in relation to the 'identity production' going on at the same time. The examples of analysing physics education with the help of feminist epistemologies that we have discussed here can serve as a starting point for further developing these thoughts. Research on physics education committed to a more just and equitable physics stands to gain from asking questions about 'whose knowledge' and 'whose interests' are given precedence in physics.

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