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Editors' Suggestion

How women physics teacher candidates utilize their double outsider identities to productively learn physics

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Underrepresentation of women in physics is a prominent issue in the western countries. Since physics teachers are in a unique position to affect new generations of students, it has been suggested that they are an important part of the solution. In this paper, we explore how trainee physics teachers create spaces for themselves as learners of physics while negotiating their positioning as women and trainee teachers. The empirical data consist of interviews with 17 trainee physics students, and the analysis focuses predominantly on the identity negotiations of three woman students. We find that the women simultaneously submit to and master a "physics nerd" discourse that connects physics with nerdiness, masculinity, and intelligence, which enables them to successfully create subject positions incorporating physics student, teacher-student, femininity, and constructive study practice. This is of particular importance to trainee physics teachers, who will be responsible for creating inclusive and productive physics learning environments for their students.

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I. INTRODUCTION

Vera: I don't feel very threatened by physics, or, well bachelor physics students, because I feel that I have other qualities that they don't have. Like social competence.

The above quote comes from a trainee teacher, Vera, who when learning physics as part of the physics teacher program, straddles two extremes when it comes to academic disciplines: on one hand, physics, which has a pronounced overrepresentation of men and is strongly associated with brilliance; on the other, education, which has a pronounced overrepresentation of women and is weakly associated with brilliance [1]. By emphasizing her social skills, Vera rejects the notion she would feel threatened by man bachelor physics students, who she says believes they are smarter and better at physics than her.

Underrepresentation of women in physics is a prominent issue in the western countries, and because of their unique position to influence new physics students, it has been suggested that physics teachers should be one part of the solution [2]. In this paper, we explore how three women studying to become physics teachers negotiate their positioning as women and trainee teachers to create spaces for themselves as learners of physics.

The discipline of physics has long been studied by feminist science studies scholars, anthropologists, and sociologists. Haraway [3] discusses how the association of physics with logic, rationality, and objectivity connects it with features historically associated with masculinity, at the same time as notions of objectivity and rationality in the discipline render its cultural features largely invisible [4]. The scientist, in general, and the physicist, in particular, are further associated with cleverness and intelligence [5], notions that are also connected to stereotypes of nerdiness in physics [6]. These discourses connecting physics with masculinity, objectivity, and cleverness have also been shown to manifest in a variety of physics practices, including classrooms, reproducing inequitable patterns of participation in school physics [7] as well as university physics [8]. The persistent gender bias in student evaluations of physics teachers can also be understood as related to such discourses [9]. In her quote, Vera hints at these aspects of the culture of physics, suggesting that social skills are not usually a quality of physics students.

Vera is one of the 17 students who were interviewed for a larger project investigating the identity negotiations of trainee teachers learning physics [10]. In this paper, we

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focus on her and two of her friends, whose identity work is circling around performances of feminine femininity that they experience as chafing with what is expected in the physics courses they take. Feminine femininities, when studied from a feminist point of view, have traditionally been understood as defined by male desire and subordination, where "to oppose stereotypical or normalized feminine positioning is to reject the disempowerment that comes with it" [11]. However, in the last decade, "hyperfemininity" has been increasingly understood in queer contexts as a possibility for resistance, where exaggerated or pronounced feminine dress or behavior, together with the reclamation of historically derogatory expressions such as "bimbo" or "slut," can be interpreted as challenging expectations on women to accept their positioning in the heterosexual matrix [12]. In physics education, research has, for a long time, focused on women's underrepresentation [6] and how woman physics students negotiate their identities in relation to masculine norms [13].

Given the dominance of men and masculine connotations of the field of physics, women have been shown to do considerable identity work in order to fit in [14]. Studies that explicitly engage with femininity performances in physics have discussed the difficulties involved in combining studying physics and mainstream femininity. Rejections of stereotypical femininity are common [13] and woman physicists have been shown to sometimes moderate their dress and appearance in order to be taken seriously [15]. These strategies highlight how femininity performances in physics chafe with the presumed gender neutrality of the physics discipline, in contrast to how masculinity, according to Halberstam [16], is often assumed to be nonperformative and therefore neutral [17]. However, woman students also have been shown to perform femininity in relation to the practice of physics, stressing the usefulness of characteristics typically associated with women, such as their abilities in communication [18] or small, dexterous hands [19].

In this study, we consider how performances of femininity are entangled with the learning of physics. We explore the identity work performed by trainees studying to become upper secondary school physics teachers. The focus is on how trainees make meaning of their participation in physics courses where the majority of students are not trainee teachers, with a particular focus on the students' performances of gender. The research question is:

How do three women studying to become physics teachers negotiate their positioning as women and physics experts to create spaces for themselves as learners of physics?

II. THEORETICAL FRAMING

In this study, we view identity as performative, created through and within discourse [20]. From this perspective, identity is seen as coproduced in processes of performance and recognition [21]. This conceptualization of identity has gained a lot of traction in both physics and science education lately and has been shown to be effective for analyzing processes of inclusion and exclusion in the field [22].

Considering identity to be performative means that the position of being, for example, a brilliant woman physics student is not fixed but rather created and recreated in many varying ways in the interaction between students and teachers. However, this does not imply that individuals are free to perform any identity, rather such performances are limited by what is intelligible (read as valid) within a certain context. The notion of "identity work" highlights the struggles involved in positioning oneself and being positioned by others [23].

Within a social environment (such as physics education), there are recognizable ways of being—intelligible identities [24]—that the subject is limited by and dependent on to come into being. To be perceived as an authentic insider, a student has to conform to common and expected ways of acting and talking within the environment. Doing this successfully (mastering the discourse) in turn affords power to be understood as a particular kind of person, like a physics girl, and also to subtly challenge and change group norms. Such change is, however, confined to what can be expressed within the group discourse, and student identities are limited, for example requiring exceptionality, distancing from other "normal" girls, and a high science capital background for the physics girl identity to be recognizable [13]. As such, we come to exist as subjects through processes of "simultaneous submission and mastery," where the "subject might resist and agonise over those very powers that dominate and subject it, and at the same time, it also depends on them for its existence" [25]. Power does not just force us into particular ways of being, such ways of being are also made desirable to us, in that they make us intelligible, both to ourselves and to others [26]. In this paper, we are interested in how the interviewed students construct intelligible identities by drawing on and thus submitting to the discourses of their education, and in the process of mastering such discourses creatively also distort them, creating space for learning physics.

In particular, we focus on gender and how gender identity is performatively constituted via discursive and bodily acts [24], within the normative framework of the physics teacher education. In this perspective, gender does not follow from a certain body, but continuous repetitions and re-enactments create the illusion of a stable gender. In our analysis, we are attentive to the performance of different femininities [11] and how they are created together with positions of "physics student" and "trainee teacher." Conceptualizing a doing of gender in terms of femininities (and masculinities) allows for a way of

thinking about gender where femininity exceeds the female body and where relations between femininities shape gender relations rather than femininity being defined in relation to masculinity and the male gaze [27]. As such, critical femininities scholarship encourages us to go beyond approaches that "always and only [tie femininity] to [the] oppression, subordination, sexualization and objectification" of women [28]. We take "normative femininity" to mean the pattern of symbolic meanings that are embodied in ways of doing woman that goes unnoticed. In other words, the ways of being a woman that passes as normal in a particular context [29]. As such, normative femininity in physics education has been shown to involve the rejection of stereotypical, or hyperfeminine, expressions of femininity which are incompatible with the purported neutrality of physics [19].

III. METHODS AND STUDY CONTEXT

This case study focuses on students attending a Swedish physics teacher program that affords accreditation to teach upper secondary school physics and mathematics (16- to 18-year-olds). The program is composed of three parts: educational science, school placement, and subject matter studies. The trainee physics teachers take two semesters of educational science, one semester of school placement, four semesters of physics, and three semesters of mathematics. The majority of the subject matter courses are taken together with the physics bachelor program and are thus not specifically designed for trainee teachers. Trainee physics teachers can, if they choose an appropriate degree project, receive a bachelor's degree in physics in addition to their teaching degree.

The gender distribution in the physics teacher program is around 20% women; this is the same as for the bachelor physics program. As documented in many other contexts, racial and ethnic identities play an important role in the physics classroom [30] and Swedish life at large [31]. However, information about student ethnicity is not available in the Swedish higher education context, and the collection of such information for research purposes is regulated by law, requiring a level of ethical vetting that was not obtained for this study. We did not collect such information and anticipate that future research that does grapple with this would find whiteness to be a strong unmarked norm in this context.

A. Introducing the trio

The empirical data for this study consist of individual interviews with three women who study to become physics teachers, this group is throughout the text referred to as the Trio. These interviews are part of a larger material of 17 interviews with second- and third-year trainee physics teachers. For the analysis in this paper, we chose to focus on the individual interviews with the Trio: Julia, Vera, and Ellen. These are pseudonyms, agreed on together with the students. Pseudonyms are also used for the other students figuring in the manuscript.

The Trio are friends and part of a trainee physics teacher class of nine students who study physics courses in a larger group of around 50 physics students. This context where the Trio learn physics has been further described in Ref. [2] where a classroom culture of passivity focused on giving the right answers was identified. In this learning culture, predominantly those who appear to already know the right answer and who are perceived as very good at physics are visible and take up space in class. The majority of the students do not ask nor answer questions due to the risk of being perceived as not good enough, reproducing "a norm of passivity, where students prefer to place their active learning outside of the classroom" [2].

B. Data collection

The study reported here is part of a larger project investigating what is involved in being recognized as a legitimate physics teacher-to-be in a Swedish physics teacher program. For this project, all students in year 2 and 3 of the physics teacher program were approached in conjunction with a lecture and asked if they wanted to participate in an interview. In year 2, nine students were asked and six agreed. In year 3, seven students were asked and five agreed. Six additional students who were studying to become teachers but not following the standard study path were recruited by asking around or meeting them at one of the courses. These students take the same courses as the students on the standard path but are studying at a different pace or taking courses in a different order due to personal reasons. The whole material consists of 5 women and 12 men.

The semistructured interviews [32] were carried out in Swedish and lasted between 60 and 90 min. The first author introduced herself as a physics teacher and researcher, interested in issues of equal participation in physics. In compliance with Swedish Ethical Research Standards [33], the students were informed of the purpose of the study, their right to withdraw at any time, and confidentiality. They consented to be recorded during the interview. The interviews were guided by six themes: introduction and background, the choice to become a physics teacher, what a physics teacher should know, trainee teachers compared to other students, the subject of physics, and experiences of the physics teacher program [34]. In this last theme, the students were asked: "What is it like for you to learn physics in an environment dominated by men?" Open discussions about experiences connected to gender followed. Care was taken to let the interviews be guided by what the students gravitated toward as significant in their experiences of studying physics.

The interviews were recorded and transcribed verbatim by a professional transcriber. The transcripts were coded

and analyzed in Swedish. The quotes used in this article have been translated from Swedish by a native English speaker who is also fluent in Swedish, paying attention to the meaning rather than the exact wording of the quotes. Throughout this paper, italic in quotes is used to direct the reader's attention to pertinent parts of speech for the analysis and not for marking stress in the talk of the interviewee.

C. Coding and analysis

In a first open analysis of the whole interview material for the larger project, the Trio interviews stood out as unique in how they described their experiences of being women, trainee teachers, and physics students, and how this seemed connected to a constructive physics study practice. A decision was then taken to focus on these three interviews. The Trio interviews were coded openly and empirically driven, using qualitative analysis software, QRS NVivo 12. Attention was paid to what was signaled as important to the students' identity negotiations as learners of physics. Here, four themes around "nerdiness," "femininity," "passing as competent in physics," and "constructive study practice" stood out, and we decided to focus on these themes in further analysis. The Trio's interview transcripts were then closely reread, and each student's story was summarized. The whole material was then read through and coded in several iterations, where the themes created in each iteration were allowed to guide the focus in the next reading. For example, Julia in her interview talks about being perceived as a laid-back trainee teacher and this stood out as important for her identity negotiations. This prompted a focused rereading of the other two interviews, finding themes of struggling to be perceived as competent. All quotes connected to these themes were collected and reanalyzed, asking how the Trio are negotiating discourses in the physics environment to create spaces for themselves as learners of physics. In the last theoretical step of analysis, these negotiations were understood through the lens of subjectification through simultaneous mastery of and submission to these discourses [24].

The whole interview material as well as the observations and result of the analysis for the larger study described in Ref. [2] as well as earlier empirical studies of physics learning discourses were used as a backdrop to contextualize and deepen the understanding of the Trio's identity negotiations. Throughout the result section, quotes from the larger interview material are sometimes included to provide a background understanding of the environment the Trio are negotiating. For example, quotes from Alex, Magnus, and Finn are included in the beginning of the results section to highlight the difference in how the Trio and their classmates talk about the nerd stereotype. This shows how the Trio are distancing themselves from a position that their classmates are experiencing as comfortable and including. The criteria for including quotes from the larger interview material were that these students in a significant manner discuss the same themes that the Trio are negotiating. These quotes are representative of themes that have been identified in the interview material as a whole.

When the first analysis draft was written up, the first author had a casual meeting with the Trio to discuss the findings. Each theme of the findings was presented in Swedish and discussed with the Trio women. The meeting was not recorded but notes were taken. Overall, the Trio said they recognized their stories in the text and expressed feeling empowered by their experiences being analyzed (Research note, September 28, 2020).

IV. NERDY PHYSICS STUDENTS AND FEMININE TRAINEE TEACHERS

Throughout their individual interviews, the Trio women performed identities of women, trainee physics teachers, and physics learners by drawing on and mastering several discourses, recognizable in the whole interview material, earlier research in physics education research, and in Swedish society at large. This first findings section describes how the Trio women become intelligible by utilizing and distancing themselves from the masculine physics nerd stereotype. We then discuss how the Trio, by utilizing their trainee teacher position, manage to create a constructive study practice counteracting a passive elitist physics learning environment.

A. The stereotype of the physics nerd

All three Trio women positioned themselves during the interviews as social, happy, and feminine trainee physics teachers. By doing so they also, in contrast to most of the other interviewees, explicitly distanced themselves from what they described as the typical nerdy physics student. Throughout the Trio interviews, this stereotype served as a point of reference that the Trio women both distanced themselves from and measured themselves against. The discourse of nerdy physics student is familiar and was highly present in the empirical material at large. Being nerdy was described by several trainee teachers as key to being recognized as a physics student:

> Alex: you can't wear stuff that is too fashionable, because then you seem uninteresting, then you're just like everyone else because I think that er, physicists often end up in that—in that category of nerds before they become physicists. And then you want to distance yourself from the cool crowd who act like everyone else (…) you can wear whatever you like as a physicist, but you can't look too dressed up.

In this excerpt, physics students are portrayed as nerdy, meaning behaving odd or eccentric and not caring about their looks. Similarly, Magnus said that it is "generally more accepted that you are who you are, that you are

yourself" among physics students. Here, some mainstream social norms, like that of looking a bit polished or dressed up, are constructed as restricting the authentic self from being expressed. To "be who you are" implies to act and dress counter to such mainstream norms. Alex elaborates:

Alex: and that's one of the good things with the physics group that you are accepted as a nerd there if that's what you want to be and it's more difficult for a stereotypical cool person to fit in with the physicists, I think.

Alex connects nerdiness with being odd, or eccentric, as well as opting out of what is considered high status outside the local physics student community. Later in the interview, when asked about the overrepresentation of men in the physics program, he explicitly connects this norm with masculinity:

Alex: It's kind of like a clear masculine norm, that you have to act like a man to fit in, I don't know, I don't think everyone is comfortable with that. It feels terrible, but that's what I have observed […]

Interviewer: What would you say, how does it look in practice, can you notice this in your study program?

Alex: Well, if you look at how women dress, or how they look, are supposed to look. They do not look normatively feminine at the physics program. And I think, they cannot look like that if they want to, because then they wouldn't be accepted. I don't think anyone would, that a physicist would be accepted if she was wearing make-up and high heels. I would never, it wouldn't fit in.

The physics nerd culture, as it is described by these students, is open and welcoming for those who may not fit into other contexts. As we see in these quotes, however, there are certain conditions that must be fulfilled to be recognized as belonging to the nerdy physics student community, for example, being "a bit strange" (Finn) not being a "stereotypical cool person" and not look "normatively feminine" (Alex).

We can understand Finn, Alex, and Magnus as citing a common and well-documented (stereotypical) discourse of nerdy physicists and physics students. For example, Gonsalves [19] documented how the physics Ph.D. students in her study recognized stereotypical physicists as "male, highly intelligent geeks that are socially awkward and dress in a uniform fashion" (p. 10) and further how looking dressed up made being recognized as hard-working or committed to physics difficult. Furthermore, among students of physics and computer science, interest and competence have been shown to be closely connected to "neglect for style and corporeal aesthetics," positions less easily taken up by woman students [35]. This discourse, where the position of the "effortlessly clever physicist" is aligned with notions of brilliance and masculinity has also been shown to discourage young women from pursuing physics studies [7]. Although not all of the 17 interviewed trainee teachers in the larger material identify with the physics nerd, all demonstrate awareness of this discourse.

B. Bouncy, happy, and social trainee teachers with a feminist awareness

One of the Trio women, Vera, describes the typical bachelor physics student as a "guy with an ironic T-shirt and patchy beard and a bit stiff." We recognize the man physics nerd in this description, lacking social competence and presenting in an unpolished way. Vera thus draws on the physics nerd discourse, but distances herself from this nerdiness, evident in her choice of words (compare to Alex before "that's one of the good things with the physics group that you are accepted as a nerd there") and also in her tone of voice and body language. The physics nerd is not a position Vera identifies with, something that is further emphasized when she discusses her experiences of sexism in physics. She says that she has grown used to and come to expect sexism in the physics environment and gives one example of such an experience:

Vera: One situation that happened, was when you were one woman and one man in a lab group. So, even if you were both asking questions, the answer was only directed towards the guy in the pair.

Vera explains that even if prejudice about women's incompetence in physics is widespread in society, it is more noticeable among the nerdy men in the physics department:

Vera: [sexism is] something we talk about, and it feels like there is a, a feminist awareness nowadays. So it's almost like something you are expecting to meet, guys who don't have such, uh high expectations about girls' competence, and in the physics department you actually meet such guys. My experience is that, I think that many guys understand women as less smart than men. But in many situations, they know you're not supposed to say certain things, so they hide that a bit. Or, it's more unconscious than explicit. But I feel like there is a lot of guys at [the science faculty that haven't] read about politics on Twitter so much, but they've checked out YouTube clips about black holes so perhaps they haven't got that filter, or whatever you could call it, that men [outside physics] who have similar prejudices have. Ehm, and my experience is that some of these guys, lacking a social filter, is a bit, I don't know. They are very into physics, being smart, it's their highest, the highest status is to be like intelligent. Being right. And they do say some peculiar things sometimes.

Vera describes man physics students as valuing intelligence and "being right" while lacking the filter preventing

other men from expressing themselves in sexist ways. Later in the interview, when asked about her reasoning when choosing physics, Vera says that she hesitated to enroll in the physics teacher program due to her expectations about physics students. She pictured how it would be:

Vera: I mean the kind of men you see on the physics bachelor program. You know, that it would be five of those types that you would have to study with. And that thought didn't seem too attractive, that kind of made me hesitant.

Vera was later "pleasantly surprised," when her classmates consisted of "more bouncy and intense people" rather than man nerd students: "I guess it's more fun (laughing), but I don't know, I just like hanging out with girls."

Similar to Vera, the other two Trio women also describe preferring to hang out with other women rather than socializing with the physics students who are mostly men. Ellen said that she worried that she would be "the only girl, with middle-aged men" and that she was happy to find three women and four men in the trainee teacher class. It was a new experience for Ellen to be part of a group of women friends before she had "been socializing a lot with, kind of guys in general." She has found that the girls in the Trio are "quite open with, what it's like to be a girl in our society" and this has given her a new feminist awareness. She has "started reflecting a bit, about my situation" and discovered that she often finds herself disadvantaged when she is the only girl among man students. When physics problem-solving in groups, she experiences these students interrupting her and not trusting her physics knowledge:

Ellen: And I have just thought that that's the way I am so to speak. But then when I've talked about it, then it's like "hang on everyone" it's like this, it happens so often, that's the way society is.

To Ellen, the fellowship and shared experiences with the other women have made it possible to reformulate her experiences of feeling inadequate in physics in terms of sexist structures in society. She says that without this awareness "you don't even know that there is a problem, and then you can't tackle that *that* is the problem." This feminist awareness makes it possible for Ellen and Vera to understand experiences of not being taken seriously or recognized in physics as a sign of prejudice rather than of a personal lack of competence.

In summary, the Trio women distance themselves from the physics nerd community that man students, like Alex, Magnus, and Finn describe as exceptionally open and inclusive. Vera's citation of a discourse of nerdy physics students is negative and perhaps even deliberately stereotypical. She is masterfully drawing on this discourse to perform an identity that is the opposite of the negative description of the stiff nerd. Vera performs an identity of woman, physics student, and trainee teacher who is socially competent, happy, and, within the interview situation, successful in that it is recognized as legitimate. However, by using the physics nerd discourse to position herself she is also submitting to its logic, meaning her performance as a trainee physics teacher is placing her outside the inclusive physics nerd community other students enjoy being part of.

C. "The stupid gang"

The other two Trio women position themselves in ways similar to Vera where the position of the nerdy, smart, and serious physics student is constructed in opposition to the socially competent trainee teacher. When Ellen is asked how the bachelor physics students perceive the physics teacher program, she says:

Ellen: I noticed that there was a lot of competition among the physics students when we took courses with them at the start. They sort of had to be best at everything—they wanted fives [the highest grade]. You didn't want to risk saying anything yourself, in case they'd think you were an idiot. They kind of—they needed to understand everything perfectly, and they wanted to be good and not make mistakes. And us trainee teachers are a bit more—I don't want to be really stereotypical, but the physicists were generally perhaps not—they are a bit more serious/ambitious and us trainee teachers, if I speak from my own experience, are maybe a bit more social.

Ellen distinguishes between bachelor students who focus on high grades and being smart and competitive and trainee teachers who are less serious and more social. Julia further described trainees as outgoing and that they "like to be noticed and, are like lively, and I feel like they have a lot of humor." To have social competence is something almost all the interviewed students (not just the Trio) strongly associate with the trainee teachers. One example is Dennis

Dennis: Women to a larger degree study physics teaching since it's considered a "softer" strand of physics, so you can still do physics, but you're not expected to become a "super-physicist". And you'll end up in situations that are less demanding in terms of, what should I say, raw physics thought power. And you'll be in situation that are more demanding in terms of, communicating with humans [mm].

We understand the students as drawing on discourses of teaching as a social profession associated with women [36], the teacher program as an easier choice than other programs involving physics, and trainee teachers as more social than other (physics) students. These ways of drawing on simultaneous discourses of the nerdy (masculine) physics student and social (feminine) trainee teacher as opposites introduce a logic of (in)competence in physics as the nerdy physics student is associated with brilliance where the social trainee teacher is not. The Trio women describe how they are perceived as less competent than other physics students:

Julia: At the start of the program, we [the Trio] called ourselves the "The Stupid Gang," but later on we've noticed that that's not true because there were many of

> us who were really good if we compare with the others [the physics bachelors]. I mean we pass all our courses, and we're kind of, well we simply aren't [the stupid gang] but people perceive us that way.

The label of "The Stupid Gang" is something that the Trio ambivalently have accepted and even used themselves sometimes, but the reason they are perceived this way is not their actual exam results, all three do well or really well in physics. Vera, similarly, describes her experience of how acting in explicitly feminine ways conditions the possibility of being recognized as authentically interested in and competent in physics:

Interviewer: I'm thinking about the dominance of men in physics—is that something you've reflected on?

Vera: Absolutely, it feels like you are kind of forced to think about that, when studying in [the physics department]. Ehm, or at least, I thought about it more last year when we were studying with that class, with the physicists. We were hanging out with them, it was more like we were one physics class. And then I felt more like sometimes people think that you, or like they didn't expect that you would come up with the smart answer when you were discussing a physics problem. I have also discussed this with another friend, and it feels like it can make a difference what style you have. If you have more functional clothing or perhaps an ironic T-shirt style as a girl—then perhaps you get more… I mean, then people think that you're really interested in physics for some reason. Compared to if you have a short skirt and—you know—do your make-up and so on—then it feels like people get more—I wouldn't say bimbo—but if there's a scale from nerd to bimbo it feels like you are categorized more on the one side than the other. And aren't really expected to—people don't think you will do well on exams.

Interviewer: Have you experienced this yourself?

Vera: Yes, or rather I think you notice it when you discuss something with someone that they always interpret what you said in the dumbest way possible if you know what I mean.

Interviewer: Yes.

Vera: While, someone, or we have had [small group problem-solving sessions] and then, if you are discussing the answer, someone will say a very similar thing, repeating what I have already said, and then they are listened to.

Vera portrays a spectrum between "nerd" and "bimbo," where "bimbo attributes," such as make-up and short skirts (which she is wearing during the interview), do not make her intelligible as a successful physics student when her statements are interpreted in the "dumbest possible way" or ignored in problem-solving sessions. However, Vera does not outright reject being positioned as "the bimbo" due to her appearance, rather we will see how she accepts or even emphasizes it as a strategy to make herself more legitimate or credible within the masculinized learning space. When asked how she reacts to these situations, she replies that she does nothing:

Vera: I don't feel threatened by physics, or yeah, physics students mostly because I feel I have got other qualities that they don't have. For example, social competence. Sort of daring to speak, daring to ask questions. That sort of thing. I mean lots of people sit there and are really smart and good at physics. And I know that I'm not the smartest person in the room, but I think I've got a good handle on the subject and on top of that I can express myself and so on.

Again, Vera establishes herself as different from the physics bachelor students by emphasizing her social competence. Further, she says that she withholds information about her top grades because "it can be nice for [the man bachelor students], to have that thing. That they feel like they are the best at physics, kind of (…) [because for] a lot of shy physicists it does them good to perhaps, to feel smart." In this way, Vera performs as explicitly feminine, less intelligent, and caring about the egos of man colleagues, creating a feminine position that is the exact opposite of the nerdy man physics stereotype. A dichotomy is constituted where the man nerdy physics bachelor students are attributed a range of low-value characteristics like being stiff, shy, uninterested in appearance, explicitly sexist, and invested in being right. At the same time, Vera is attributed high-value agentic characteristics that are in opposition to these, like being happy, socially competent, not scared to be wrong, caring about her appearance, talkative, and able to ask questions in class. We interpret this as a conscious reclaiming of a kind of feminine femininity close to the stereotype of "the bimbo" that chafes with what is expected in the physics context but that goes well with being a trainee teacher.

To summarize, the women in the Trio simultaneously draw on discourses of learning physics that connect physics with nerdiness, masculinity, and intelligence, and teaching with femininity and social competence. They simultaneously submit to and master these discourses and by doing so constitute feminine positions that imply being socially competent, happy, bouncy, and lively. In contrast to the physics nerd, who has "patchy beard and is stiff" (Vera) and should not be "too dressed up, sort of, care about how you look" and "acts like a man" (Alex), the trainee teachers perform identities characterized by being outgoing, socially competent but less competent in physics, less concerned with grades, lively and caring about their looks. This enables them to resist expectations to perform the right kind of "smart" physics student, and instead successfully inhabit subject positions of physics student, trainee teacher, and positive femininity. However, this resistance is made

possible by their submission to the physics nerd discourse, meaning that they also accept its premises for appearing smart. This is visible, for example, in how the Trio uses the vocabulary of the discourse, not taking offense by words like "bimbo" or choosing to call themselves "the stupid gang." It is further visible in how Vera measures herself on a scale of feminine versus competent, and in how she, to perform as successfully social and feminine among the physics students, also chooses to withhold information about her top grades. In the next section which focuses on how the Trio learn physics, we further discuss how they, by this simultaneous mastery and submission, also subvert these discourses.

V. LEARNING PHYSICS IN A SUB-OPTIMAL LEARNING SPACE

The previous section described how the Trio, to master positions of social, happy feminine, and successful trainee teachers and physics learners, must submit to discourses that associate competence in physics with nerdiness and masculinity. These discourses are part of a physics learning environment where legitimacy is created by performances of intelligence and never being wrong, and competence in physics is connected to the stereotype of the brilliant man physics nerd. In this environment, it is important to not be exposed as not understanding physics [2]. Many of the 17 interviewed trainees say they react to this study environment by being passive, careful not to be wrong, or too visible in the classroom. They choose to not engage fully in trying to learn physics when on campus, to avoid being exposed as not good enough. One example is Magnus:

Magnus: I would say that, at least I feel that you do not always dare to ask for help, because you *do not want it to show that you do not know*. I think there's an underlying thought for most people in this program, that you are a little afraid to ask for help.

This hesitance to let *not knowing physics* be visible was also expressed by the Trio. Ellen, for example, says that, especially in the beginning, she tried to learn the content alone at home, so she could come back and interact with the other students safely knowing that she understood the physics. She also sometimes hesitates before asking questions in class:

Ellen: Sometimes you notice that some lecturers just assume you know something. And then you don't dare to ask, because you don't want to feel stupid.

While this study environment can be understood as suboptimal for all students, it presents double challenges for women. We have seen how performing identities far from the stereotype of the man physics nerd undermines the Trio women's struggle to be understood as competent in physics, even though they pass their physics courses with good grades. On top of this, both women and men among the interviewed trainee teachers reported experiencing or noticing sexism during their physics studies, like women being ignored in group discussions.

In several ways, the Trio women negotiate this learning culture differently from other students. One example is Julia who brings this up when discussing her relationship with the group of women studying physics as part of the bachelor program. Even though Julia now is confident that physics teaching is the right choice for her, she has also seriously considered other futures in physics, like doing research. During the interview she discusses the choice between physics teaching and the bachelor program, and which student groups that choice will land her in. Since trainee physics teachers and bachelor students take almost all physics courses together, she can make the formal change quite easily. However, Julia describes how the bachelor students are distinguished by being very good at physics, and Julia questions whether she could belong to and thrive in that group:

Julia: A lot of the people I can identify with among the physics bachelor students you know, many women, they get the highest grades in all their courses, but it's because they study a massive amount of the time so it doesn't necessarily mean that they are intellectually smarter than me, but of course, you learn a lot when you study a lot, so I don't know—I think I'm kind of mediocre.

While Julia partly identifies with the group of women among the bachelor students, she defines herself as neither smart nor ambitious enough to really belong to this group. She further says that among the bachelor students, authenticity is signaled by many hours of studying and being stressed to the limit of mental health problems and sick leave. In contrast, Julia says about her own way of studying:

Julia: Some periods I also study a lot. For, you know exam period and so on, but I'm kind of—I get really fed up with all of this—and it's often connected to [other students saying that they] got a panic attack and so on and you just—I don't think it's really something to be proud of that you're burnt out, please (laughing).

In these two quotes, we see how Julia is submitting to a discourse of brilliance in physics, evaluating herself in terms of being smart and ambitious enough, while simultaneously distancing herself from how the other women navigate this discourse:

Julia: I enjoy saying you know when you come to a meeting and people ask what have you done today? And I haven't done anything all morning, I've kind of just sat at home with my cat.

Interviewer: And what kind of reaction do you get?

Julia: Yeah (laughing) they usually, there are some people, two friends who are studying on the physics bachelor, they call our life the laid-back teacher life.

Julia's talk about spending time at home with her cat can be interpreted as a resistance toward norms of being

ambitious, smart, and stressed out. As such, she introduces a way of being a woman in physics who is relaxed but still successful in terms of study results. However, Julia's last remark about the "laid-back teacher life" indicates that this bid for recognition is failing in Julia's interaction with the women studying bachelor physics. Rather, Julia is positioned firmly in the group of "laid-back teachers" who do not have to live up to the same standards as the bachelor students despite taking the same courses. This kind of remark was mirrored by the two other Trio Women.

Through Julia's discussion of how she interacts with the bachelor students, two possible positions of studying physics emerge that differ in how they relate to being a woman in physics. Julia says that despite both experiencing sexism and being aware that women unfairly struggle in physics, she "hasn't explicitly felt that it's something restraining me, that I'm a woman studying physics." However, among the bachelor physics students, there are:

Julia: a lot of women [who] like to put themselves in the role of the victim you know: "my education is so difficult and I have panic attacks because I'm burnt out" and they always connect that to them being women. I mean perhaps it's part of it but I don't think it's the whole story.

Interviewer: What do you think the whole story is?

Julia: The whole story is that they are over-achieving performance princesses and that might be a woman-thing but, it's there with the men too, that they want to achieve and take themselves—it might be because of something else—but I feel they take themselves and their education really seriously and that's the only thing that means anything, and then it's kind of obvious that it's going to be difficult if that's the only thing in your life, that gives you and your life meaning, so to speak.

Here, Julia describes the difficult struggle for recognition among the women studying bachelor physics, a struggle that takes place under the premises of a physics student community characterized by elitism, sexism, and nerdiness, which creates suboptimal conditions for learning physics (as illustrated by high stress and burnout). She portrays the women studying bachelor physics as highly ambitious, taking themselves and their education very seriously, and their awareness of an unequal playing field ironically enough just adds to the pressure.

Julia is taking the same courses and studying together with the women she is talking about and is thus sharing the difficult situation she is describing. She is, however, distancing herself from and even questioning the bachelor students' experiences. We interpret Julia's use of the expression "performance princess" together with the word "victim" as her citing a Swedish derogatory discourse that connects women's overrepresentation in burn-out statistics to their exaggerated (individual) demands on themselves. A "performance princess" is a woman who in a hysteric way aims to always perform and appear perfect. This discourse thus formulates the problem of women's overrepresentation in mental health statistics as an individual rather than a structural problem, one that can be solved by women lowering their expectations of themselves. In physics, the performance princess bears similarities to the "exceptional physics girl" described by Archer *et al.* [13]. We interpret Julia's drawing on this discourse as a way to dismiss the bachelor students' struggle, a struggle for "real" physics legitimacy that she herself is unavoidably losing. The position "performance princess," or perhaps the "exceptional physics girl" [13] is available for the woman bachelor physics students (although at a high cost), but not to Julia, as she herself is a "laid-back teacher" and "too mediocre" to aim to be a researcher in physics. While the bachelor students are submitting to the physics learning environment's conditions for legitimacy, Julia is using her position as a feminine, social, and bouncy (and perhaps laid-back) trainee teacher to subvert the association of physics with masculinity and brilliance. This, however, further consolidates her position as not having what it takes to be a successful physicist while simultaneously opening ways of learning physics that are more relaxed.

A. Constructive positions of learning physics

The laid-back trainee teacher position that Julia in the last section described taking (and being put in) in relation to the woman bachelor students was described also by the two other Trio women. In addition to being a way of distancing oneself from the nerdy masculine physics student, we also understand this position as containing an opening for performing physics learning in an active way, within the context of the passive learning culture. A key to this opening is how the Trio negotiate *not understanding physics*. Both Ellen and Vera describe how many fellow students chose to not attend the lectures because they do not expect to understand the content:

Interviewer: Why don't they go to lectures?

Vera: They say they don't understand anything—that they can't take it in. That it doesn't help to sit there and not get anything out of it, because they just sit there and do not understand anything.

When Vera's fellow students do not understand during a lecture, they respond by nonengagement in the lecture or by just not showing up. Similarly, the Trio describe how not understanding during problem-solving sessions has a pacifying effect on the other students, rather than triggering them to search harder for knowledge. As previously discussed, to be able to instantly understand the physics content is constructed as a prerequisite to be successful in the physics classroom. If understanding does not occur immediately, it becomes difficult to remain in an active learning position, and both lectures and problem-solving sessions are rendered useless as arenas for learning.

The Trio women actively resist this assumption and renegotiate physics study practices and the premises of lectures:

Vera: I don't understand any of it either but I think it gives me something to see what they say—you know to see a walkthrough or a derivation of a proof–and you might not understand the proof, but you still see it—we started here, and we finished up here perhaps—so you've seen it once, it helps you to remember things for the future or so that you know what you need to check up on afterwards.

In this quote, Vera is describing how not understanding in a lecture is a cue for *activity* rather than passivity, noting down things she needs to check up on later. Not understanding becomes a starting point for learning. Overall, the Trio describe an active study practice, made possible by being able to endure and accept positions of not understanding, rather than taking a passive approach or not participating at all.

Vera: I think many students are a bit scared of the feeling of not understanding. Ehm, and I've also felt that way. But it feels like it's something I've learned when studying a lot of physics […] I have connected that feeling with, I've felt this way a thousand times before, that I don't understand, and it always ended well because, you study and then in the end you understand.

Vera associates success in physics with studying hard to eventually arrive at an understanding, rather than with always understanding right away or never being wrong. She is thus, together with the other Trio women, in a somewhat successful way negotiating the passive culture to assume positions of active and constructive physics learning.

Another aspect of the laid-back teacher position is that it opens possibilities for the Trio to be critical of their educational program. Ellen says that one way she and her friends are different from other physics students is that they speak up when demands are unreasonable:

Interviewer: You said that, ehm, one difference between trainee teachers and the bachelor students was that among the bachelor students its perhaps more competitive. Are there other differences?

Ellen: (…) I guess we are usually a bit more explicit with being critical of, like lecturers and their pedagogy. And in the same way, being critical of, it's not ok that we must work 50 hours a week, or 60 hours. It's not ok. While, it was my impression, especially in the beginning, that the physicists were a bit more, like well we just have to do that. I want this, so I have to struggle to make it. And we are a bit more, the trainee teachers are a bit more prone to say, but wait, a person of *average intelligence* should be able to pass these courses. Within normal working hours. […] It's not reasonable.

Here Ellen discusses the workload needed for someone of "average intelligence" to pass the physics courses, a quite remarkable way of talking about courses in a high-status subject often assumed to be only for elite students [7]. The bachelor students accept 60-h study weeks (and low-quality teaching, she adds later in the interview), something that is unacceptable to Ellen. This ties to the notion that having what it takes to become a physicist means not being affected by low-quality education, the very talented will learn regardless [37]. The Trio do not accept this premise for being understood as successful, which gives room to interpret the untenable study conditions as being due to the organization of the program rather than themselves not "having what it takes." This is also materialized by the Trio women speaking up against a lecturer projecting the notion that everyone should easily be able to understand the content:

Ellen: last time we were sitting in the back and got really angry at a lecturer that was extremely unprofessional and saying like, everyone knows this, it's very simple. You all know this, even though we didn't. And then you don't dare say, wait stop, I don't know this, because I'm stupid. And then we really spoke up.

On this occasion, the Trio women complained about this lecturer during a student-teacher evaluation meeting. We interpret these vocal interruptions, especially using the expression "average capability," as an explicit struggle against the discourse of the lone man genius as successful in physics.

The Trio women are drawing on and thus submitting to discourses of the man physics nerd and the association of teaching with femininity and social competence. Through their mastery and creative use of these discourses they are also subverting them, opening spaces of learning not available to other students. The Trio women are successful on exams and take up space in the physics classroom, without submitting to the criteria of being right or only letting already understanding physics be visible, thus pointing toward both more active and relaxed ways of learning physics.

VI. DISCUSSION: THE "UNEXCEPTIONAL" PHYSICS GIRLS

Even though issues of underrepresentation of women in physics have been on the agenda for several decades, studies of femininity performances in physics education are rare. When femininity has been analyzed in relation to physics, it has predominantly been in the context of how the two have been defined in opposition and how women must handle this dichotomization to find a place in physics [14]. In this study, we have taken a novel approach by considering how the doing of femininity is entangled with the learning of physics and how this makes constructive learning strategies possible. In contrast to the exceptionality that previous research has shown that woman physics students may need to perform [13], the Trio women in our study have been able to reconcile a position of "unexceptionality," where their participation in physics is not conditioned on top performances and nerdiness. The Trio's doing of femininity combined with the

physics trainee teacher position is associated with a risk of not being recognized as successful physics students, illustrated by Vera's statement that "they read me in the dumbest possible way." However, having already lost the struggle to gain status on the premises of a physics student community characterized by elitism and nerdiness also makes it possible for the Trio to be critical of untenable study conditions and to study in a relaxed and constructive way.

The Trio women display a capability to understand feelings of outsideness as unconnected to their individual abilities, which we interpret as related both to a feminist awareness and their dual positioning as physics students and trainee teachers. As students of both physics and education, the trainee teachers participate in two academic disciplines with very different cultural connotations, providing them with a potential outsider-within perspective on both disciplines. This gives them access to an epistemic position that allows them to recognize and verbalize the disciplinary culture, in contrast to how students who fulfill the normative expectations of a context find this more difficult [38]. While the Trio's resistance to performing the right kind of smart physics student identities is not unproblematic in that it is severely limiting their access to recognition in physics, we would still argue that it is less precarious than the position of the "performance princesses," whose belonging in physics is conditioned on performances of continuous high achievement and stress. The way that the Trio are able to draw on their outsideness to perform subtle resistance is markedly different from how students with outsider identities historically have been reported to either adapt or leave the discipline [37]. We would suggest that this is partly made possible by the critical feminist consciousness shared among these students. However, we would caution to interpret this as a more general shift, since the Trio still firmly are positioned as outsiders to physics on an outbound trajectory from academic physics careers. A further reason that these kinds of negotiations have not been described in the literature might be that there has not been a significant focus on trainee teachers as learners of physics in relation to identity.

The disciplinary culture of physics education that the Trio describe is similar to what Berge *et al.* call a "storyline of mastering physics" where the risk associated with giving the wrong answer makes the physics classroom a less secure place [39]. This educational culture stands in stark contrast to the collaborative physics environment described by Johnson [40], which was found to be particularly inclusive for racialized women. We suggest that the passive study environment described by trainees is not just potentially detrimental to many students' possibilities to identify with the discipline of physics but also in a more direct sense to their learning. Physics education research has long demonstrated how students can progress successfully through traditional university physics education without developing a conceptual understanding of core concepts [41]. In a disciplinary culture that values the "effortlessly clever physicist" [7,42], we see how the need to conceal shortcomings seems to limit students' possibilities to publicly acknowledge *not understanding* and thereby staying open to learning. When fear of being exposed as not understanding makes staying in a learning situation risky and difficult, the heightened pressure can also further lower student performance [43]. The Trio demonstrate a study practice where acknowledging and enduring not understanding is key to actively moving forward in learning physics. We argue that this is enabled by their double outsider position in physics as women and trainee teachers.

In a sense, trainee teachers can be perceived as peripheral in the physics community, given that they are not on an inbound trajectory to become research physicists [44]. However, we would argue that it is important not to just explore this under-researched group of physics students for the insights that their epistemic positioning in relation to physics can provide, but also as a group that has a key position in the broader physics community. As physics-teachers-to-be, they will be part of defining what constitutes a successful physics student (e.g., hard work versus innate ability) and who is recognized as belonging in physics, thus having the possibility to affect how future generations of physics students perceive the discipline. However, if trainee teachers identify with a subordinate position in relation to other physics students (the "stupid gang" or "laid-back teachers"), this might severely limit their possibility to challenge unproductive learning practices and values around physics. Engström and Carlhed [45] found that physics teachers from nonacademic backgrounds took positions of reverence and regard toward physics, which correlated with less inclination to challenge traditional teaching practices. This suggests that trainee teachers who are presented with and accept images of physics as an elite discipline that is only accessible to the most high-performing students might perceive their role as taking a position at the bottom of the hierarchy in order to reproduce and serve the discipline rather than challenge it. We believe the physics learning experiences of trainee teachers to be crucial in shaping their future ability to teach physics in an inclusive way. Can we expect teachers to teach an inclusive, collaborative, and nonelite physics if this goes straight against their experiences of what university physics is like? The particular case of the constructive study practice the Trio create can thus be of wider importance to trainee teachers who are going to be responsible for creating inclusive and productive physics learning environments for their students.

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