Routledge
Taylor & Francis Group

Journal of Science Teacher Education

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/uste20

Swimming against the Tide: Five Assumptions about Physics Teacher Education Sustained by the Culture of Physics Departments

Johanna Larsson, John Airey & Eva Lundqvist

To cite this article: Johanna Larsson, John Airey & Eva Lundqvist (2021) Swimming against the Tide: Five Assumptions about Physics Teacher Education Sustained by the Culture of Physics Departments, Journal of Science Teacher Education, 32:8, 934-951, DOI: 10.1080/1046560X.2021.1905934

To link to this article: https://doi.org/10.1080/1046560X.2021.1905934

© 2021 The Author(s). Published with license by Taylor & Francis Group, LLC.

Published online: 05 May 2021.

Submit your article to this journal

Article views: 1949

View related articles

View Crossmark data

Citing articles: 6 View citing articles

Full Terms & Conditions of access and use can be found at
https://www.tandfonline.com/action/journalInformation?journalCode=uste20

JOURNAL OF SCIENCE TEACHER EDUCATION
2021, VOL. 32, NO. 8, 934–951
https://doi.org/10.1080/1046560X.2021.1905934

Routledge
Taylor & Francis Group

OPEN ACCESS Check for updates

Swimming against the Tide: Five Assumptions about Physics Teacher Education Sustained by the Culture of Physics Departments

Johanna Larsson [a,b], John Airey [a,c], and Eva Lundqvist [d]

[a]Physics Education Research, Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden; [b]Centre for Gender Research, Uppsala University, Uppsala, Sweden; [c]Department of Mathematics and Science Education, Stockholm University, Stockholm, Sweden; [d]Department of Education, Uppsala University, Uppsala, Sweden

ABSTRACT
This study explores the culture of physics departments in Sweden in relation to physics teacher education. The commitment of physics departments to teacher education is crucial for the quality of physics teacher education and the way in which physics lecturers talk about teacher education is significant, since it can affect trainees' physics learning and the choice to become a physics teacher. We analyzed interviews with eleven physicists at four Swedish universities, looking for assumptions in relation to teacher training that are expressed in their talk. We found five tacit assumptions about physics teacher training, that together paint a picture of trainee physics teachers moving in the "wrong" direction, against the tide of physics. These are the Physics Expert Assumption: the purpose of all undergraduate physics teaching is to create physics experts. The Content Assumption: the appropriate physics content for future school physics teachers is the same as that for future physicists. The Goal Assumption: the role of a school physics teacher is to create new physicists. The Student Assumption: students who become physics teachers do not have the ability to make it as successful physicists. The Teaching Assumption: If you know physics then it's not difficult to teach it. We suggest that these five assumptions, if perpetuated without reflection, risk working against high quality physics teacher education. For physics teacher educators, our results can be used as a lens to reflect on the local departmental culture and its effect on teacher education.

KEYWORDS
Pre-service teacher education; physics; culture

Introduction

Concern about the role of physics departments and how they can support the education of physics teachers can be traced back to the beginnings of physics education research (Henderson et al., 2011). Physics teacher education is one clear and direct way for the discipline of physics to have an impact on the teaching and learning of physics that goes on in school. This is important, not just in terms of physics concepts being properly introduced, but also in terms of the serious problems of underrepresentation of both women and minorities in the physics discipline (American Physical Society, 2021; OECD Publishing, 2017a, 2017b; Universitetskanslerämbetet, 2016).

CONTACT Johanna Larsson johanna.larsson@physics.uu.se Physics Education Research, Department of Physics and Astronomy, Uppsala University, Box 513, Uppsala SE-751 20, Sweden.

© 2021 The Author(s). Published with license by Taylor & Francis Group, LLC.
This is an Open Access article distributed under the terms of the Creative Commons Attribution License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

Difficulties in recruiting and training high quality physics teachers have prompted researchers to develop and test a number of different approaches to physics teacher education (Singh et al., 2010; Thomaz & Gilbert, 1989). Previous research has investigated trainee physics teachers' learning of specific physics content (Aiello-Nicosia & Sperandeo-Mineo, 2000; Mäntylä, 2012; Mäntylä & Koponen, 2007), trainees' difficulties and misconceptions in physics (Kaltakci-Gurel et al., 2016; Şahin & Yağbasan, 2012), as well as the epistemological development of trainee physics teachers (Ding & Zhang, 2016; Fazio et al., 2012). In many countries physics departments play a central role in the education of physics teachers, but the attitude and approach of physics departments toward physics teacher education has been shown to vary considerably both within and between countries (Evagorou et al., 2015; T-TEP, 2012; Vollmer, 2003). In this paper we investigate how Swedish physicists who teach physics to trainee teachers *talk* about physics teacher education.

An important question for considering the relationship between physics departments and teacher education is the role of physics content courses in physics teacher education (McDermott, 1990)—what physics should be taught to trainees and why? (see also discussion in deWinter & Airey, 2019). School physics serves a range of purposes, spanning from the narrow aim of preparing students to become future physicists, to the wider aim of creating scientifically literate citizens (DeWitt et al., 2016). The Swedish curriculum for upper secondary school (Skolverket, 2011) in many ways mirrors the curriculum trends in other European countries in that it emphasizes the role of physics in society (Sundberg & Wahlström, 2012). In the current Swedish physics curriculum, teaching in physics should give pupils the opportunity to develop their knowledge of physics, its history, how it is used to solve problems, its significance for both the individual and society, and the ability to use physics to communicate and evaluate information. Thus, the focus of school physics content is different than the focus of university physics courses and it has been argued that this is one of the reasons the transition from university to school physics is not always straightforward (Airey & Larsson, 2018).

In their review of well-functioning US physics teacher programs, Scherr et al. (2017) found two important factors for success: a local champion of the physics teacher education program and a commitment to physics teacher education on the part of the physics department. It has also been suggested that physics departments need to take responsibility for recruiting more highly-skilled students to become teachers. In the words of a recent report, departments should "present teaching as a valid career choice [. . .] develop a welcoming and encouraging environment that shows respect for the scholarship and practice of teaching [. . .] encourage their best students to consider teaching and [. . .] promote teaching as an intellectually challenging endeavor" (T-TEP, 2012, p. 23). In our earlier work, we focused on the Swedish system of physics teacher education (Larsson et al., 2020) and examined the differences in how educators working in the different parts of an educational program, (physics department, education department and school), expressed what they saw as valued and important in their practices. Analysis resulted in the construction of four discourse models—tacit, default positions about the overarching goal of the program adopted by the training staff interviewed. The most important of these models for this paper, that was particularly dominant in the physics department, is the *physics expert discourse model*. The physics expert discourse model is organized according to a particular goal of the education, the implied professional future of the student group as *physics experts*. Here, the physics courses taken by trainees are primary understood as a means to create physics experts, rather than leading to qualified teacher status. In other research, physics faculty have been found to have negative attitudes toward the role of the teacher, viewing teaching as a lesser choice than "pure" physics (Scherr et al., 2015). This is of particular concern since in the US, the support and discussion of teaching as a valid career option by physics faculty, has been identified as an important factor in increasing the recruitment of trainee teachers (Marder et al., 2017). The question that arises is to what extent physics faculty present teaching as a valid career option in Sweden. This knowledge is significant since the way physics staff talk about physics teaching has the potential to affect how existing pre-service physics teachers understand what they should learn and why this is important. It can also affect students' career choice to become physics teachers in the first place. In this study we therefore examine the tacit assumptions in relation to physics teacher training that are expressed in the talk of physicists who teach physics to trainee teachers.

We suggest that such tacit assumptions are intimately bound up with the *culture* of physics as a discipline (Cetina, 2007; Hasse & Trentemøller, 2008; Traweek, 1988). In her ethnographic study of the high energy particle physics community, Traweek (1988) discusses how physics has traditionally been thought of as "culture-less" and disconnected from societal concerns. Traweek identified a widespread belief that physics is an objective science that is framed as having a "culture of no culture". This widely held notion that culture does not matter in physics makes it particularly difficult to see what the culture of physics is actually like (Gonsalves et al., 2016) and is therefore an obstacle to physicists noticing how teacher education may be affected by physics culture. For this study, we draw on Schein's (2010) culture model that was developed as a tool within organizational theory. Schein views culture as "a pattern of shared basic assumptions" (Schein, 2010, p. 18) that are complex and difficult to change. We are thus interested in identifying patterns of shared assumptions in the talk of physics department staff, and how these might influence what is viewed as the correct way to act in relation to physics teacher education. Our research question is:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

Methodological framing

To define culture in the context of our study, we draw on the culture model introduced by Schein (2010) and combine this definition with discourse analytical tools from Gee (2005). For Schein, culture is:

> A pattern of shared basic assumptions learned by a group as it solved its problems of external adaptation and internal integration, which has worked well enough to be considered valid and, therefore, to be taught to new members as the correct way to perceive, think, and feel in relation to those problems. (Schein, 2010, p. 18)

In the context of this paper, the group of interest is physics department faculty and the "pattern of shared basic assumptions" relates to issues of the teaching and learning of university physics. Culturally shared assumptions of a group are typically subconscious and rarely discussed, rather they are implicitly expressed in the behaviors and language of the group. As such, shared assumptions can sometimes only be indirectly observed in such things as how physicists talk about their teaching, departmental rules, how classrooms are designed, etc. In a physics department we might expect such shared assumptions to include ideas about how physics teaching should be carried out, and what the ultimate goal of such teaching should be. By looking for these tacit shared assumptions, a researcher can begin to interpret the cultural expressions of the group (Schein, 2010).

While Schein's culture model tells us to look for tacit shared assumptions in order to characterize local physics department culture, the model is less clear on how to identify these assumptions. To operationalize the culture model, it thus needs to be combined with tools to guide the analysis. In this study we have adopted a discourse analytical framework and we specifically use the concept of discourse models (Gee, 2005). Gee describes discourse models as "images or storylines or descriptions of simplified worlds in which prototypical events unfold. They are our 'first thoughts' or taken-for-granted assumptions about what is 'typical' or 'normal'" (2005, p. 71). Discourse models thus correspond to the shared assumptions in the culture model.

Using Gee's discourse analytical approach means assuming that the things people say make sense to them within their frame of reference and, thus, identifying discourse models involves understanding what is needed for a particular piece of talk to make sense. Looking for discourse models in an interview transcript, then, means looking for what the informants need to take for granted for their story to be comprehensible and coherent. Gee (2005, p. 93) suggests asking "What must I, as an analyst assume that people feel, value and believe, consciously or not, in order to talk (write) act, and/or interact this way?"

Adopting Gee's (2005) discourse analytical tools in analysis further means we take on a discourse theoretical understanding of our data. The assumptions we identify are thus generalizations of patterns we analytically see in physicist talk, but cannot be said to be actual innate properties of the individual physicists (Lundegård & Hamza, 2014).

Context of the study

At the time of writing, physics teacher education is carried out in 18 institutions in Sweden.[1] In the period 2007–2017, on average 79 new physics teachers graduated each year (eligible to teach pupils from age 13). Physics teacher education in Sweden is composed of three parts, educational science, school placement and subject matter studies. The standard (mandatory) combination of subjects is physics together with mathematics, and the usual study program consists of one year of educational science, one semester of full-time school placement and three and a half years of subject matter studies—normally two years of physics and one and a half years of mathematics. For students who have already taken an undergraduate degree in physics, a fast-track path is available—the postgraduate certificate of education—which consists of two semesters of educational science and one semester of school placement.

As they progress through their educational program, trainee physics teachers are taught by education lecturers, school mentors, mathematics lecturers and physics lecturers. In larger, more research-oriented universities that have their own physics and engineering bachelor and master programs, trainee teachers usually take physics together with other program students. However, in smaller institutions that do not have their own physics/

[1]Counting institutions that graduated at least one physics teacher 2017/18 and that have done so consistently over the last three years.

engineering, bachelor and master programs, trainee physics teachers often take their physics courses in trainee-only groups. In this study we have interviewed physicists who teach trainee teachers in both of these scenarios.

The two data sets

The study reported in this paper is based on eleven interviews with physics lecturers who work with trainee physics teachers at four separate universities in Sweden. Building on the findings of our earlier work (Larsson et al., 2020) we return to our original three interviews with physics lecturers and combine these with a further eight interviews with physics lecturers who teach physics to trainee teachers at three additional Swedish universities of varying size and research orientation.

The first set of interviews were conducted in Swedish by the first author with three physicists who teach physics to trainees in mixed groups at a large research-oriented university (Larsson et al., 2020). These interviews are referred to as interview group a. The second set of interviews were conducted in English by the second author (Airey, 2012) with eight physicists at three additional universities. At two of these, trainee physics teachers are taught physics in their own separate groups. This set of interviews will be referred to as interview group b. For further details about the interviewees, see Table 1. In both groups a and b, the semi-structured interviews (Kvale, 1996) lasted between 60 and 90 minutes.

In interview group a, the physicists were asked what trainee physics teachers should learn from the educational program, what they think a good physics teacher is and their views on why students choose (or do not choose) to become physics teachers. The eight interviews in interview group b were originally conducted as part of a study focusing on physics lecturers' literacy goals for their students. Here, one question was physics lecturers' goals for trainee physics teachers and how the lecturers perceived their role in helping trainee teachers reach these goals. Both data sets thus deal with overlapping themes of physics lecturers aims for, and role in helping, educate future physics teachers. Thus, the eight group b interviews form a parallel data set with our three original interviews (Airey, 2012, 2013; Airey & Larsson, 2018, Linder et al., 2014). Care was further taken in the analysis process to account for the different interview contexts, for example, by paying particular attention to the way questions were asked, the relationship between interviewer and interviewee, and the differing teaching contexts.

In summary, the 11 physics lecturers work at four different Swedish universities. At the two larger universities, trainees take physics together with other program students, whilst at the two smaller universities, trainees take physics in dedicated trainee only groups. Further information about interviewees is provided in Table 1.

All interviews were transcribed verbatim in the language in which they were held. All quotes that appear in this paper have had repetitions and false starts removed and quotes from interviews held in Swedish have been translated to English and checked by an English native speaker. In both interview groups, physics lecturers were informed of the overarching goal (improving university physics education) and that their anonymity would be protected. They then signed a consent form, agreeing to be recorded and allowing the transcripts to be used for research. According to Swedish guidelines (Swedish Research Council, 2017) permission from an ethical approval board is not required for interviews with adults as long as sensitive personal information, such as religion, political affiliation, etc., is not registered.

Table 1. A summary of all 11 interviews along with information about the context and teaching situation. In brackets after each interviewee is shown an upper-case L for large or S for smaller university and a lower-case a or b to indicate the interview group. The gender distribution of the whole data set is 20% female.

Group	Interviewee code	Position	University	Teaching details
a	Physicist 1La	Senior lecturer	Large, research centered university.	Main responsible teacher for at least one physics course taken by trainee teachers together with other program groups
a	Physicist 2La	Senior lecturer	Large, research centered university.	Main responsible teacher for at least one physics course taken by trainee teachers together with other program groups
a	Physicist 3La	Physics PhD student	Large, research centered university.	Part of a teaching team in one physics course taken by trainee teachers together with other program groups
b	Physicist 4Sb	Physics PhD student	Smaller, teaching oriented university	Part of a teaching team in one physics course taken only by trainee teachers
b	Physicist 5Sb	Professor	Smaller, teaching oriented university	Main responsible teacher for at least one physics course taken only by trainee teachers
b	Physicist 6Sb	Senior lecturer	Smaller, teaching oriented university	Main responsible teacher for at least one physics course taken only by trainee teachers
b	Physicist 7Sb	Senior lecturer	Smaller, teaching oriented university	Main responsible teacher for at least one physics course taken only by trainee teachers
b	Physicist 8Sb	Senior lecturer	Smaller, teaching oriented university	Main responsible teacher for at least one physics course taken only by trainee teachers
b	Physicist 9Lb	Senior lecturer	Large, research centered university.	Main responsible teacher for at least one physics course taken by trainee teachers together with other program groups
b	Physicist 10Sb	Post-doc.	Smaller, teaching oriented university	Part of a teaching team for at least one physics course taken only by trainee teachers
b	Physicist 11Lb	Senior lecturer	Large, research centered university.	Main responsible teacher for physics course taken by trainee teachers together with other program groups

Analysis

The combined data from interview groups a and b were analyzed together using an analytical question originally proposed by Gee, which in this case means reading through each transcript and asking: "What has to be assumed for this piece of talk to make sense?" An explicit purpose of the first analytical iteration was to explore whether one result of our earlier work, the physics expert discourse model (Larsson et al., 2020), was viable as a lens to understand physicist talk. The physics expert discourse model is organized according to a particular goal of the education, the implied professional future of the student group as physics experts. This was taken up in the first analytical iteration where all 11 transcripts were examined with a focus on what assumptions about the students' professional futures were visible in the material. This resulted in four analytical categories organized according to assumed student futures. These were *Future in research, Uncertain future, Future in teaching* and *Future in engineering*. In a second iteration the materials coded in each future were read though, and a pattern emerged where each future assumption became visible in physicist talk in four ways. First, through explicit discussion of the expected student future, i.e. 'my students are usually engineers'. Second, though talk about the physics subject. Third, though talk about students, and finally, though talk about what students should learn. In the final step of our analysis we used Schein's (2010, p. 18) definition of culture. Here, we asked if and how the emerging structure could be understood as "a pattern of shared basic assumptions" guiding the "correct way to perceive, think, and feel" in relation to physics teacher education. This resulted in the three themes and five assumptions we present in the findings section. For example, looking at talk describing students in the "Future in teaching" and "Future in research" categories, we could see how physicists talked about students differently according to their expected future, and this pattern was generalized to the student assumption.

The analysis was carried out by the first author with each stage of the analysis checked and discussed with the third author. In this process, the data with coding and suggested directions of analysis was presented by the first author and critically questioned by the third author. When agreement could not be reached, the interpretations and coding were reconsidered, and then again revisited and discussed in the next analytical iteration. When agreement on preliminary results had been reached, these were presented to and critically examined by the second author, who originally carried out the Group b interviews. Thus, the patterns of assumptions about teacher education were further tested against the interview data by someone who was quite familiar with the context of the data, but who had not been part of the analysis process thus far. These steps resulted in changing the coding of some quotes, and also reframing of some of the category names. Qualitative analysis software, QRS NVivo 10 was used for coding and analysis.

The analysis builds on close reading and re-reading of the transcripts while trying to make visible patterns of tacit assumptions that may not be apparent at first glance. In general, the findings are based on an understanding of the interviews as a whole rather than on a simple analysis of a few selected pieces of a physics lecturer's talk. This means that as we now move to the findings section, the quotes we use to illustrate our findings are just that—illustrations. These quotes should not be understood as the single origin of any particular result, but rather as examples of themes we identified within the wider dataset.

Findings

The results make visible a number of aspects of physics departmental culture as it pertains to physics teacher education. In what follows, we present the patterns of shared basic assumptions within the three themes that are the results of the analysis of our 11 interviews with physicists who teach trainee physics teachers.

Creating physics experts

In our analysis, most of the talk of physicists made sense based on a tacit assumption that the goal of undergraduate physics teaching is to create physics experts. We saw that physics lecturers—regardless of whether they taught mixed groups of students that included trainee teachers, or groups consisting entirely of trainee teachers—still talked about their teaching as though their students were expected to move from school physics, via undergraduate physics to end up working with expert physics. One way in which this default goal of creating physics experts was tacitly expressed was in the fact that the path to becoming a physics teacher was seldom mentioned in the talk of the physics lecturers we interviewed, even though physics teacher training was an explicit theme of our interviews. This does not mean that the lecturers were unaware that trainee teachers were in their classes, but rather that the way lecturers talked about their students created the impression that those who planned to become physicists formed the prioritized student group. For example, when discussing the mixed group of students that he teaches, Physics Lecturer 11Lb describes the different paths student take after leaving the programme:

> Interviewer: Ehm, ok, do you know what people do when they finish here?
>
> Physics lecturer: Yeah, I've seen some numbers of what people are doing. I know that a large portion of them are working with computers. Like 50%. Somehow, someway with programming or web-based things or something like that. Otherwise I'm not certain if we have any big employers. I think that we used to have some of the government authorities like Swedish Defense Research, but otherwise I'm not certain.
>
> Physics Lecturer 11Lb

Here, working as a physics teacher is not mentioned. Taken alone, one might interpret this quote as a simple oversight, but throughout the whole interview with 11Lb, the teaching of physics to trainee teachers is curiously absent, this despite one of the topics of the interview being trainee physics teachers and that around 10% of the student group are trainee teachers. This pattern was repeated again and again throughout our interviews.

This *physics expert assumption* was further discerned in how physics lecturers talked about the physics content they teach. One example is the talk of physics lecturer 5Sb. When asked what students he is thinking of when answering the questions about his teaching, he says:

> I think for this [interview] I will primarily be thinking about the student who takes introductory physics or physics for, as a future upper secondary teacher [yeah] where they study, well you know basically the same kind of physics as eh a future physicist would. But the students I've had are not future physicists. They are all, basically I would say they are all headed towards being a physics teacher.
>
> Physics lecturer *5Sb*

Here, the students in mind are trainee physics teachers, but the physics they are taught is still referred to and defined by what future physicists need. Another example is physics lecturer 7Sb:

> Interviewer: Do you have different goals for physicists and engineers?
>
> Physics lecturer: Yes, I suppose . . . but only slightly different.
>
> Interviewer: And for the teachers is it the same?
>
> Physics lecturer: Yes, I don't really distinguish between them. You need to understand physics to be able to teach it.
>
> Physics lecturer *7Sb*

In this quote, "the teachers" refer to the trainee physics teacher group. When reflecting on the needs of different student groups, the content appropriate for future physicists and engineers sets the agenda also for trainee teachers. Note that we are not saying that it is inherently wrong that the different student groups take the same physics. What we see in the physicists' talk is a tacit assumption that taking part in the same training as future physicists is sufficient to become a physics teacher. The needs of trainee physics teachers are either discussed as identical to those of physics experts, or left unaddressed. This was a recurring theme throughout our interviews with all eleven physics lecturers. We term this aspect of departmental physics culture the *content assumption*.

The physics expert assumption was also discerned in lecturer talk about the goals of school physics. Themes related to the goals laid out in the Swedish school physics curriculum such as teaching physics for society (Sundberg & Wahlström, 2012), were notably absent. The focus of school physics content was framed in terms of the production of future expert physicists. If explicitly discussed at all, the role of a physics teacher was framed as leading students toward this goal.

> And last, but not least of course, [as a school physics teacher] you have to feel that you have the vision to make at least 80% of your students want to become a physicist after taking your class.
>
> The ideal high school teacher has a very difficult balance to strike between meeting the class goals and at the same time getting students to feel that physics is so much fun that it is something they want to continue with [at university]
>
> Physics lecturer *1La*

Thus, the overarching goal of a school physics teacher was in the interviews expressed in terms of creating more physicists. We term this aspect of departmental physics culture the *goal assumption*.

Characterizing trainee physics teachers

One common response throughout the interviews with physics lecturers teaching mixed groups of students, to any question regarding trainee teachers was "I don't know". Despite having trainee teachers taking their physics classes, many physics lecturers demonstrated an unawareness of, and indeed indifference to, the existence of these students. These lecturers' talk made sense based on an assumption that the goal of physics teaching is to create physics experts and that anything else is peripheral. In the interviews when trainee teachers were mentioned, they were repeatedly referred to as different from the "normal" physics students.

> Interviewer: If we think about the syllabus that you have. Is speaking a part of the syllabus [. . .]?
>
> Physics lecturer: Ah, good question, I should know the answer to that. (laughing) I would say that in a *normal* physics course it is not in the syllabus, but for those who take physics for becoming teachers they have a slightly different syllabus.
>
> Physics lecturer *4Sb*
>
> Interviewer: Do you think what they're taught is more for physics or is it for being a teacher—for their job? Or is there no difference between those things?
>
> Physics lecturer: I think it's a combination because they study first three years like a *normal* physics student and after that . . .
>
> Interviewer: . . . there's an extra year on top.
>
> Physics lecturer *10Sb*

This was true even among the lecturers who taught trainee only groups. This assumption about who the "normal" physics student is fits well with the goal assumption discussed in the previous section. Students who are not striving to work in expert physics are not considered to be "normal" physics students. We could see a tacit assumption across the interviewee talk that the "normal", or "real" physics student is one who wants to become a physics expert.

Furthermore, in the analysis, all of the physicists either directly or implicitly suggest that trainee teachers were less successful than "mainstream" physics students. When trainee teachers were discussed explicitly, they were described as less talented or not as smart as "normal" physics students.

> I would say that [the academic level of trainee teachers] is average, or maybe just below average. Generally. Every now and then we have one or two stars but (. . .). Since the students aren't the top students usually, I mean, they are intermediate level something like that. They don't have the ability to become brilliant in physics.
>
> Physics lecturer *4Sb*
>
> In a way, spontaneously, it is—they have less, they know less. When they start the course. I don't know if it's true but it's in the air that these students are not as good as other students.
>
> Physics lecturer *2La*

Parallel to the construction of the trainee teacher as less capable than the mainstream physics student is the idea that choosing to become a physics teacher is something you do in the absence of other better alternatives or the ability to cope with "real" physics.

> Physics lecturer: Well, I would prefer to believe that those who choose to become physics teachers do so because they think it's fun to be a teacher and they want to become teachers. (. . .)
>
> Interviewer: How do you think it is in reality?
>
> Physics lecturer: I think some start taking bachelor physics and then after a while they find it too hard or demanding, and maybe they think it is easier to become teachers.
>
> Physics lecturer *3La*

Here, when trainee teachers are constructed as differing from mainstream physics students by not having what it takes to continue with physics, the mainstream physics student is at the same time constructed as talented and having what it takes. In contrast, there was no talk at all in the interviews implying the opposite, i.e. that those who choose to carry on in physics might not have what it takes to become a physics teacher. The choice to become a physics teacher is consistently constructed as the easier option. A difference in status is thus constructed where the trainee teacher is placed below a "real" physics student, and the teaching of school physics is seen as trivial. We term this aspect of departmental physics culture the *student assumption*.

Learning to teach physics

Finally, our analysis shows how the physics expert assumption plays out in physicist talk about what is needed to become a school physics teacher. In the interviews, learning to teach physics was above all connected to gaining enough physics knowledge (see the content assumption above). However, the assumed link between mastering undergraduate physics and teaching school physics was not problematized.

> Physics lecturer: I think that you can't really become a physics teacher if you're not really interested, then it's a bit difficult to . . . And if you are interested, then you should be able to, then I don't think it's that difficult to get good at it. Or at least to get to a level that is good enough.
>
> Physics lecturer 3La

In the interviews, becoming a good physics teacher was constructed as something not requiring great effort to achieve. One aspect of physics culture here seems to be the assumption that a genuine interest in physics and in teaching is enough to become a good physics teacher.

> Interviewer: So we've got high level physics here and perhaps it's taught in English and the teachers then have to go and teach it at a different level in Swedish. (. . .) do you see that translation as problematic?
>
> Physicist: Of course it's important that they can do this, but somehow I have the impression that this occurs quite naturally. That's not an issue I think.
>
> Physics lecturer *7Sb*

To summarize this last part of the findings section, in the area of what is needed to learn to teach physics, we could see a basic tacit assumption guiding physicist talk that if you know physics then it's not difficult to teach it. Physics knowledge and interest in physics is enough. We term this the *teaching assumption*.

Discussion

We started this paper by problematizing the relationship between physics departments and physics teacher education, noting that physics departments taking responsibility for recruiting and training highly skilled students to become physics teachers has been identified as a crucial factor for high quality physics teacher education (T-TEP, 2012). Here we suggested that how physics lecturers talk about physics teacher education is significant, since it can affect both what students understand as important and who decides to become a physics teacher. As such we asked the following research question:

> What aspects of physics departmental culture with respect to physics teacher education can be identified in the talk of physicists in four Swedish physics departments?

The answer to our research question is that we identify five tacit assumptions in physics lecturer talk. These are the *physics expert assumption, the content assumption, the goal assumption, the student assumption* and *the teaching assumption*. The *physics expert assumption*, that the goal of undergraduate physics is to create physics experts, was present in the talk of physicists within all four Swedish physics departments we investigated—this despite our interviews including physics lecturers who deal with groups consisting solely of trainee physics teachers. This result is partly a corroboration of our earlier work (Larsson et al., 2020). However, our analysis of the new compiled material provides a deeper understanding of how the notion of creating physics experts can be seen to be an integral part of physics departmental culture.

Limitations of the study

We report on a qualitative case study based on interviews with 11 physicists at four Swedish physics departments. There are thus clear limitations to the knowledge claims and generalizations that can be made from our results. The five assumptions we identify are local patterns in physicist discourses, and we cannot claim these are generalizable to other physics departments, in or outside Sweden. Rather, we aim to present *one* example of local physics culture as it relates to physics teacher education. We suggest that this example is valuable because physicists and teacher educators may recognize aspects of the physics culture we report in their own contexts, and use this account to better understand and reflect on their own practice in a process of naturalistic generalization (Stake & Trumbull, 1982). Further, the five assumptions we identify should not be understood as innate properties of the interviewees themselves. Rather, our interest has been in identifying *shared patterns* that can be found in how physicists talk about physics teacher education regardless of background. By the same token, our analysis process did not seek to ascribe these patterns to individual physicists through demographic data, and the analysis cannot provide information on how individual physicist talk varies depending on teaching context or experience. This is, of course, a further limitation of our study.

Finally, while we suggest that our description of local physicist culture as it pertains to teacher education is valuable, we make no claim that it is exhaustive. Interviews with a few physicists who teach trainee teachers cannot give full access to the ways physics teacher education is approached within a department, and another sample might provide further or even contradicting assumptions. We do however believe that the patterns we identify exist within these environments and thus are valuable to report on and warrant further discussion. Here, we suggest that further investigation, perhaps using an anthropological approach, represents a promising avenue for future research.

Trainee physics teachers swimming against the tide of physics?

The talk of the physics lecturers in our study could be seen to express ideas indicating that a "normal" expected progression is for students to go from school physics, through undergraduate physics and on into expert physics. While the goal of all students learning physics was implicitly assumed to be expert physics, choosing to become a teacher means diverting from the expected path moving backwards to school physics. Physics teachers are thus moving away from the assumed goal of becoming physics experts. In such a system, trainee physics teachers can be understood to be incomprehensibly "swimming against the tide" by wanting to return to school physics. This relationship is illustrated in Figure 1.

Please note that we are by no means claiming that physics faculty actually believe in the five assumptions. Rather, what we are suggesting is that in our analysis we see that the talk of the interviewed physicists plays out as though these assumptions were true. This is important since we argue that in such an environment the unreflected default position for a physicist will be to act as though the assumptions were true—regardless of one's actual beliefs about physics teacher education. Having already discussed the *physics expert assumption*, we will now discuss each of the four further assumptions with a focus on the significance of these aspects of physics departmental culture for Swedish physics teacher education.

The content assumption: The appropriate physics content for future school physics teachers is the same as that for future physicists.

It is common to teach trainee physics teachers together with future physicists and engineers (Massolt & Borowski, 2020; Vollmer, 2003). This way of organizing physics teacher education, where trainee physics teachers learn either the same or a subset of the same physics content that other physics students do, can be thought of as a practical implementation of the content assumption. However, arguments have been put forward that there are clear differences in the level and nature of the content knowledge required by these different groups (Etkina et al., 2018). The content assumption risks becoming problematic for trainee physics teachers if there are important aspects of physics-specific knowledge connected to teaching, like Pedagogical Content Knowledge (Etkina, 2010; Loughran et al., 2012; Sperandeo-Mineo et al., 2006), that trainees are not offered access to.

Another aspect of the content knowledge needed by trainee teachers entails a good grasp of school-level physics as laid out in the school syllabus. Here, drawing on Bernstein (1999), Airey and Larsson (2018) have discussed how physics knowledge needs to be both repackaged and recontextualized by physics teachers for use by students in school and society. Last, there is the question of relevance, which has been thoroughly connected to student motivation and results in the literature (Afjar et al., 2020; Bennett et al., 2016; Gaffney, 2013; Nair & Sawtelle, 2019). For trainee physics teachers to be motivated to learn physics, it has been shown that clear connections between the physics content and a teacher future is significant (Gaffney, 2013). We thus suggest

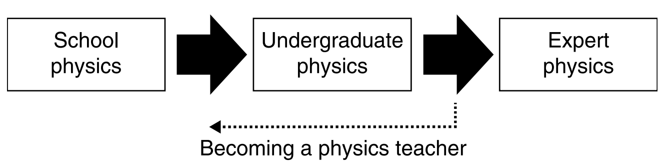

Figure 1. Illustration of how the physics expert assumption means that trainee physics teachers must "swim against the tide" of progression toward expert physics.

that the content assumption risks masking a need for explicit discussion of the relevance of physics content for physics teacher trainees.

The goal assumption: The role of a school physics teacher is to create new physicists

In our analysis, we saw this assumption as stemming from the default position that the role of physics teaching throughout the whole educational system is to produce physics experts (See Figure 1). Transferring this position over to school-level education risks overlooking those parts of the school physics curriculum that describe the role of physics in society (Sundberg & Wahlström, 2012). Only a handful of all the students that school physics teachers meet over the years will become working physicists. The potential risk here is that physics teachers will not be prepared for their main role of teaching "physics for all" if they have only ever met this narrow "physics for physics sake" attitude in their educational program.

The student assumption: Students who decide to become physics teachers do so because they don't have the ability to make it as successful physicists.

Solid research suggests that this assumption is incorrect (see Roloff Henoch et al., 2015) and it is furthermore clearly problematic for teacher education as it applies a deficit model to trainee physics teachers, framing them as lacking in comparison to "mainstream" physics students. If this assumption is reproduced in physics departments, the culture risks working against the recruitment of talented students to become physics teachers. Why would a physics department encourage their most successful students to join a program seen as the home of "unsuccessful" students? If physics departments allow the student assumption to go unchallenged, they risk behaving in a way that directly works against high quality physics teacher education.

The student assumption is further problematic, as it reproduces notions of research in physics as more difficult and "elite" than other paths. The image of physics projected by school physics teachers can affect who perceives physics as a possible career choice. School level students have been shown to associate physics with brilliance and masculinity (Archer et al., 2017), an image that discourages women and minorities from seeing physics as something for them (Archer et al., 2020). For trainee physics teachers, who are preparing to create their own inclusive physics classrooms, identifying and questioning such assumptions are of great importance (Mensah, 2009).

The teaching assumption: If you know physics then it's not difficult to teach it

This assumption may be linked to the fact that teaching physics is something that many physicists have learned on the go, without formal pedagogical training. It suggests that learning to teach physics is not particularly difficult for someone who is interested in or good at physics. It thus ignores the need of trainee physics teachers to practice the transformation of the content of their physics courses to match the desired competences set out in the school curriculum.

The teaching assumption can also be interpreted to subscribe to the idea that good teaching is an art and not something that can be taught or developed to any great extent. Whether you agree with this or not, we believe it is clear that building an educational program on the assumption that its learning goals are trivial will not raise the status of the program. It also will not help students to see the physics teacher program as a meaningful and intellectually challenging choice.

Conclusions

We suggest that the five assumptions we have identified in the talk of physics lecturers, if perpetuated without reflection, risk working against high quality physics teacher education. While these assumptions are just one local example of patterns in physicists talk, we would hope that they can be used in the wider context as tools to further examine and reflect on the culture of physics departments as it pertains to physics teacher education. Here, future work could also examine the presence of similar assumptions, and if so, how they are negotiated by trainee physics teachers. If default physics departmental culture focuses exclusively on the production of physics experts, one potential answer to this problem might be to redefine what a physics expert is. We believe that after some consideration most physicists would agree that understanding the ways in which physics can be taught to those who are not necessarily going to become physicists, is a difficult and complex task that requires a certain type of physics expert. Thus, we suggest that physics departments might examine their assumptions about what the goal of physics teaching is, and if needed, widen their definition of physics experts to include expert physics teachers. If we want the best physics teachers possible, then any tacit attitudes to physics teacher education similar to the ones signaled by the assumptions that we identify need to be challenged. We should not expect good physics students who want to become teachers to "swim against the tide".

Disclosure statement

No potential conflict of interest was reported by the authors.

Funding

This work was supported by the Vetenskapsrådet [2015-01891].

ORCID

Johanna Larsson http://orcid.org/0000-0002-6265-0004
John Airey http://orcid.org/0000-0003-3244-2586
Eva Lundqvist http://orcid.org/0000-0001-8036-6245

References

Afjar, A. M., & Syukri, M. (2020). Attention, relevance, confidence, satisfaction (ARCS) model on students' motivation and learning outcomes in learning physics. *Journal of Physics. Conference Series*, *1460*, 012119. https://doi.org/10.1088/1742-6596/1460/1/012119

Aiello-Nicosia, M. L., & Sperandeo-Mineo, R. M. (2000). Educational reconstruction of physics content to be taught and of pre-service teacher training: A case study. *International Journal of Science Education*, *22*(10), 1085–1097. https://doi.org/10.1080/095006900429457

Airey, J. (2012). "I don't teach language": The linguistic attitudes of physics lecturers in Sweden. *AILA Review*, *25*(1), 64–79. https://doi.org/10.1075/aila.25.05air

Airey, J. (2013). Disciplinary literacy. In L. Östman, R. Säljö, & E. Lundqvist (Eds.), *Scientific literacy: Teori och praktik* (pp. 41–58). Gleerups Utbildning AB.

Airey, J., & Larsson, J. (2018). Developing students' disciplinary literacy? The case of university physics. In K.-S. Tang & K. Danielson (Eds.), *Global developments in literacy research for science education* (pp. 357–376). Springer. https://doi.org/10.1007/978-3-319-69197-8_21

American Physical Society. (2021). *Physics degrees earned by women*. http://www.aps.org/programs/education/statistics/womenphysics.cfm

Archer, L., Moote, J., Francis, B., DeWitt, J., & Yeomans, L. (2017). The "Exceptional" physics girl: A sociological analysis of multimethod data from young women aged 10–16 to explore gendered patterns of post-16 participation. *American Educational Research Journal*, *54*(1), 88–126. https://doi.org/10.3102/0002831216678379

Archer, L., Moote, J., & MacLeod, E. (2020). Learning that physics is 'not for me': Pedagogic work and the cultivation of habitus among advanced level physics students. *Journal of the Learning Sciences*, *29*(3), 347–384. https://doi.org/10.1080/10508406.2019.1707679

Bennett, D., Roberts, L., & Creagh, C. (2016). Exploring possible selves in a first-year physics foundation class: Engaging students by establishing relevance. *Physical Review Physics Education Research*, *12*(1), 010120. https://doi.org/10.1103/PhysRevPhysEducRes.12.010120

Bernstein, B. (1999). Vertical and horizontal discourse: An essay. *British Journal of Sociology of Education*, *20*(2), 157–173. https://doi.org/10.1080/01425699995380

Cetina, K. K. (2007). Culture in global knowledge societies: Knowledge cultures and epistemic cultures. *Interdisciplinary Science Reviews*, *32*(4), 361–375. https://doi.org/10.1179/030801807X163571

deWinter, J., & Airey, J. (2019). What makes a good physics teacher? Views from the English stakeholder community. *Physics Education*, *55*(1), 015017. https://doi.org/10.1088/1361-6552/ab5215

DeWitt, J., Archer, L., & Mau, A. (2016). Dimensions of science capital: Exploring its potential for understanding students' science participation. *International Journal of Science Education*, *38*(16), 2431–2449. https://doi.org/10.1080/09500693.2016.1248520

Ding, L., & Zhang, P. (2016). Making of epistemologically sophisticated physics teachers: A cross-sequential study of epistemological progression from preservice to in-service teachers. *Physical Review Physics Education Research*, *12*(2), 020137. https://doi.org/10.1103/PhysRevPhysEducRes.12.020137

Etkina, E. (2010). Pedagogical content knowledge and preparation of high school physics teachers. *Physical Review Special Topics - Physics Education Research*, *6*(2), 020110. https://doi.org/10.1103/PhysRevSTPER.6.020110

Etkina, E., Gitomer, D., Iaconangelo, C., Phelps, G., Seeley, L., & Vokos, S. (2018). Design of an assessment to probe teachers' content knowledge for teaching: An example from energy in high school physics. *Physical Review Physics Education Research*, *14*(1), 010127. https://doi.org/10.1103/PhysRevPhysEducRes.14.010127

Evagorou, M., Dillon, J., Viiri, J., & Albe, V. (2015). Pre-service science teacher preparation in Europe: Comparing pre-service teacher preparation programs in England, France, Finland and Cyprus. *Journal of Science Teacher Education*, *26*(1), 99–115. https://doi.org/10.1007/s10972-015-9421-8

Fazio, C., Di Paola, B., & Guastella, I. (2012). Prospective elementary teachers' perceptions of the processes of modeling: A case study. *Physical Review Special Topics - Physics Education Research*, *8*(1), 010110. https://doi.org/10.1103/PhysRevSTPER.8.010110

Gaffney, J. D. H. (2013). Education majors' expectations and reported experiences with inquiry-based physics: Implications for student affect. *Physical Review Special Topics - Physics Education Research*, *9*(1), 010112. https://doi.org/10.1103/PhysRevSTPER.9.010112

Gee, J. P. (2005). *An introduction to discourse analysis: Theory and method* (2nd ed.). Routledge.

Gonsalves, A., Danielsson, A. T., & Pettersson, H. (2016). Masculinities and experimental practices in physics: The view from three case studies. *Physical Review Physics Education Research*, *12*(2), 020120. https://doi.org/10.1103/PhysRevPhysEducRes.12.020120

Hasse, C., & Trentemøller, S. (2008). *Break the pattern: A critical enquiry into three scientific workplace cultures: Hercules, caretakers and worker bees*. Tartu University Press.

Henderson, C., Beach, A., & Finkelstein, N. (2011). Facilitating change in undergraduate STEM instructional practices: An analytic review of the literature. *Journal of Research in Science Teaching*, *48*(8), 952–984. https://doi.org/10.1002/tea.20439

Kaltakci-Gurel, D., Eryilmaz, A., & McDermott, L. C. (2016). Identifying pre-service physics teachers' misconceptions and conceptual difficulties about geometrical optics. *European Journal of Physics*, *37*(4), 045705. https://doi.org/10.1088/0143-0807/37/4/045705

Kvale, S. (1996). *Interviews: An introduction to qualitative research interviewing*. SAGE.

Larsson, J., Airey, J., Danielsson, A. T., & Lundqvist, E. (2020). A fragmented training environment: Discourse models in the talk of physics teacher educators. *Research in Science Education*, *50*(6), 2559–2585. https://doi.org/10.1007/s11165-018-9793-9

Linder, A., Airey, J., Mayaba, N., & Webb, P. (2014). Fostering disciplinary literacy? South African physics lecturers' educational responses to their students' lack of representational competence. *African Journal of Research in Mathematics, Science and Technology Education*, *18*(3), 242–252. https://doi.org/10.1080/10288457.2014.953294

Loughran, J., Berry, A., & Mulhall, P. (2012). Pedagogical content knowledge. In J. Loughran, A. Berry, & P. Mulhall (Eds.), *Understanding and developing science teachers' pedagogical content knowledge. professional learning* (Vol. 12, pp. 7–14). Sense Publishers. https://doi.org/10.1007/978-94-6091-821-6_2 .

Lundegård, I., & Hamza, K. M. (2014). Putting the cart before the horse: The creation of essences out of processes in science education research. *Science Education*, *98*(1), 127–142. https://doi.org/10.1002/sce.21086

Mäntylä, T. (2012). Didactical reconstruction of processes in knowledge construction: Pre-service physics teachers learning the law of electromagnetic induction. *Research in Science Education*, *42*(4), 791–812. https://doi.org/10.1007/s11165-011-9217-6

Mäntylä, T., & Koponen, I. T. (2007). Understanding the role of measurements in creating physical quantities: A case study of learning to quantify temperature in physics teacher education. *Science & Education*, *16*(3–5), 291–311. https://doi.org/10.1007/s11191-006-9021-2

Marder, M., Brown, R. C., & Plisch, M. (2017). *Recruiting teachers in high-needs STEM fields: A survey of current majors and recent STEM graduates*. American Physical Society. http://www.aps.org/policy/reports/popa-reports/stemteachers.cfm

Massolt, J., & Borowski, A. (2020). Perceived relevance of university physics problems by pre-service physics teachers: Personal constructs. *International Journal of Science Education*, *42*(2), 167–189. https://doi.org/10.1080/09500693.2019.1705424

McDermott, L. (1990). A perspective on teacher preparation in physics and other sciences: The need for special science courses for teachers. *American Journal of Physics*, *58*(8), 734–742. https://doi.org/10.1119/1.16395

Mensah, F. M. (2009). Confronting assumptions, biases, and stereotypes in preservice teachers' conceptualizations of science teaching through the use of book club. *Journal of Research in Science Teaching*, *46*(9), 1041–1066. https://doi.org/10.1002/tea.20299 .

Nair, A., & Sawtelle, V. (2019). Operationalizing relevance in physics education: Using a systems view to expand our conception of making physics relevant. *Physical Review Physics Education Research*, *15*(2), 020121. https://doi.org/10.1103/PhysRevPhysEducRes.15.020121

OECD Publishing. (2017a). *Distribution of graduates and entrants by field: Share of graduates by field and gender*. https://stats.oecd.org/Index.aspx?QueryId=79587

OECD Publishing. (2017b). *Education at a glance 2017: OECD indicators*. http://dx.doi.org/10.1787/eag-2017-en

Roloff Henoch, J., Klusmann, U., Lüdtke, O., & Trautwein, U. (2015). Who becomes a teacher? Challenging the "negative selection" hypothesis. *Learning and Instruction*, *36*, 46–56. https://doi.org/10.1016/j.learninstruc.2014.11.005

Şahin, E., & Yağbasan, R. (2012). Determining which introductory physics topics pre-service physics teachers have difficulty understanding and what accounts for these difficulties. *European Journal of Physics*, *33*(2), 315–325. https://doi.org/10.1088/0143-0807/33/2/315

Schein, E. H. (2010). *Organizational culture and leadership*. Jossey-Bass.

Scherr, R. E., Plisch, M., & Goertzen, R. M. (2015). Physics teacher production: Patterns of institutional engagement and faculty theories. *Physics Education Research Conference 2015*(1), 303–306. https://doi.org/10.1119/perc.2015.pr.071

Scherr, R. E., Plisch, M., & Goertzen, R. M. (2017). Sustaining physics teacher education coalition programs in physics teacher education. *Physical Review Physics Education Research*, *13*(1), 010111. https://doi.org/10.1103/PhysRevPhysEducRes.13.010111

Singh, C., Moin, L., & Schunn, C. (2010). Introduction to physics teaching for science and engineering undergraduates. *Journal of Physics Teacher Education Online*, *5*(3), 3–10.

Skolverket. (2011). *Läroplan, examensmål och gymnasiegemensamma ämnen för gymnasieskola 2011* [Curriculum for the upper secondary school 2011]. Regeringen. http://www.skolverket.se/publikationer?id=2705

Sperandeo-Mineo, R. M., Fazio, C., & Tarantino, G. (2006). Pedagogical content knowledge development and pre-service physics teacher education: A case study. *Research in Science Education*, *36*(3), 235–268. https://doi.org/10.1007/s11165-005-9004-3

Stake, R. E., & Trumbull, D. (1982). Naturalistic generalizations. *Review Journal of Philosophy and Social Science*, *7*(1), 1–12.

Sundberg, D., & Wahlström, N. (2012). Standards-based curricula in a denationalised conception of education: The case of Sweden. *European Educational Research Journal*, *11*(3), 342–356. https://doi.org/10.2304/eerj.2012.11.3.342

Swedish Research Council. (2017). *Good research practice* (No. VR1710). https://www.vr.se/english/analysis/reports/our-reports/2017-08-31-good-research-practice.html

Thomaz, M. F., & Gilbert, J. K. (1989). A model for constructivist initial physics teacher education. *International Journal of Science Education*, *11*(1), 35–47. https://doi.org/10.1080/0950069890110104

Traweek, S. (1988). *Beamtimes and lifetimes: The world of high energy physicists*. Harvard Univ. Press.

T-TEP. (2012). *Transforming the preparation of physics teachers: A call to action*. American Physical Society. http://www.phystec.org/webdocs/2013TTEP.pdf

Universitetskanslerämbetet. (2016). *Kvinnor och män i högskolan (2016:16)*. https://www.uka.se/publikationer–beslut/publikationer–beslut/rapporter/rapporter/2016-10-14-kvinnor-och-man-i-hogskolan.html

Vollmer, M. (2003). Physics teacher training and research in physics education: Results of an inquiry by the European Physical Society. *European Journal of Physics*, *24*(2), 131–147. https://doi.org/10.1088/0143-0807/24/2/354