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Storylines in the physics teaching content of an upper secondary school classroom

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ABSTRACT

Background: Physics is often seen as a discipline with difficult content, and one that is difficult to identify with. Socialisation processes at the upper secondary school level are of particular interest as these may be linked to the subsequent low and uneven participation in university physics. Focusing on how norms are construed in physics classrooms in upper secondary school is therefore relevant.

Purpose: The purpose of this paper is to identify discursive patterns in teacher–student interactions in physics classrooms.

Design and methods: Three different physics lessons with one class of students taught by three different teachers in upper secondary school were video-recorded. Positioning theory was used to analyse classroom interaction with a specific focus on how physics was positioned.

Results: We identified seven different storylines. Four of them (‘reaching a solution to textbook problems’, ‘discussing physics concepts in order to gain better understanding’, ‘doing empirical enquiry’ and ‘preparing for the upcoming exam’) represent what teaching physics in an upper secondary school classroom can be. The last three storylines (‘mastering physics’, ‘appreciating physics’ and ‘having a feeling for physics’) all concern how students are supposed to relate to physics and, thus, become ‘insiders’ in the discipline.

Conclusions: The identification and analysis of storylines raises awareness of the choices teachers make in physics education and their potential consequences for students. For example, in the storyline of mastering physics a good physics student is associated with ‘smartness’, which might make the classroom a less secure place in general. Variation and diversity in the storylines construed in teaching can potentially contribute to a more inclusive physics education.

KEYWORDS

Physics; discursive patterns; storylines; science identity

Introduction

In this paper we explore teacher–student interactions in physics classrooms in upper secondary school. The conceptual starting point is that students learn much more than just the content being taught in science teaching and learning activities. They also learn

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about norms and values and who they can (and want to) be in relation to those norms and values (Brickhouse 2001; Wickman 2006; Östman 1998). Gore (1995) expresses this as follows: 'Educating is naming, communicating, and upholding norms – norms of behaviour, of attitudes, of knowledge' (172). Gore further claims that 'unless teachers can effectively exercise power to present and reinforce particular norms, teaching would not be a purposeful endeavour' (ibid. 172). However, the teacher is not the only actor who upholds norms in the science classroom, for any conversation unfolds through the joint action of all participants (Davies and Harré 1990), including the students in the classroom. For example, a playful approach to physics is a norm that has been found to be introduced and upheld both by teachers (Berge and Danielsson 2013; Hasse 2002) and by students (Berge 2017; Due 2014). In the study presented in this paper we investigate the physics classroom from a discursive perspective (Davies and Harré 1990) in order to unpack what is made possible and desirable in physics classrooms.

Our deeper examination of physics classrooms in the upper secondary school is partly motivated by widespread cultural perceptions of physics as inaccessible. Previous research has found that it is seen as a discipline with difficult content (Nyström 2007; Due 2014; Hazari, Cass, and Beattie 2015) that is difficult to identify with (Bøe and Henriksen 2013). The perceived difficulty of the discipline is also linked to perceptions that physics is not for everyone (Nyström 2007). Further, at the upper secondary school level (age 16–18) physics has been found to be strongly associated with mathematics and formulas and perceived as abstract (Due 2014). The difficulty in recruiting young people to physics education and professions is often pointed out as the key as to why more research is needed to unpack how students relate to and construct physics (Due 2014; Hazari et al. 2010). The processes of socialisation in the physics classroom at age 16–18 are particularly interesting because it is the last step in the school system before these students enter university, where women tend to not choose physics to the same extent (Andersson and Johansson 2016). The Natural Science Programme¹ in Sweden, which contains significant amount of mathematics, chemistry and biology in addition to advanced physics courses, is also interesting because it is balanced in relation to gender (Anderhag, Emanuelsson, Wickman, and Hamza 2013), but as shown before the students still have traditional conceptions of physics as something for the boys (Due 2014; Nyström 2007).

Since conversations unfold through the joint action of *both* teachers and students, the potential continuities of discursive practices between different classrooms deserve attention. In this paper we explore such discursive patterns by using a framework based on positioning theory (Harré and van Langenhove 1999) to analyse one class of students' interactions with three different physics teachers. The aim of the paper is to identify the discursive patterns of school physics that unfold in teacher–student interactions and show how continuities of patterns between different situations in different classrooms are construed.

Background

Science education research has a long tradition of studies exploring students' development of conceptual and procedural understanding in interactions (Alexopoulou and Driver 1996; Heller and Hollabaugh 1992) and supporting the development of such

understanding through research-based teaching and curriculum development (Clement 1993; Siorrenta and Jimoyiannis 2008). However, over the last twenty years the science identities of students as producing and being produced by sociocultural discourses about science has gained increased attention in science education research (seminal papers include Brickhouse, Lowery, and Schultz 2000; Carlone 2004). Studies focused on student identities and engagements have often been motivated by the difficulties in recruiting and retaining science students, in particular women and minorities. Following the work of Brickhouse, Lowery, and Schultz (2000) on how four middle school African American girls engage with science, a large number of studies have scrutinised the affordances and constraints of narrating and performing science identities for different students (Calabrese Barton et al. 2013; Carlone 2004; Carlone et al. 2015). These studies show how student identification and engagement with science is produced in complex layers of interaction between a student's background and cultural resources and a particular science setting (Archer et al. 2017; Barton, Tan, and Rivet 2008). For example, Archer et al. (2016) found that working-class, ethnically diverse boys were able to take up positions of scientific expertise in informal science education settings through performances of 'muscular intellect', that is confident, arrogant displays of knowledge and intelligence. However, these performances also reinforced dominant elitist representations of science (Archer et al. 2016) and reproduced dominant discourses of science as authoritative, brainy and masculine (Archer, DeWitt, and Willis 2014). Similarly, Carlone, Scott, and Lowder (2014) identified broad cultural patterns in different science classroom settings. School science can be produced as active, playful and driven by curiosity and playfulness or as tightly mapped onto traditional discourses of schooling, creating different affordances for students' engagement and identity formation. The cultural norms of the science classroom are, thus, produced in an entanglement of discourses of schooling and of science (Archer et al. 2017; Carlone 2004).

In line with the studies concerning identity and the cultural production of science, we explore what is made possible and desirable within a science education setting. In doing so, we are inspired by studies focused on how the norms and values of science are discursively produced. Norms and values in science education are an outcome of power and ideology (Östman 1998). The importance of the students' voice in science classrooms is well documented; if students are allowed a voice they will construct their own 'meaning and value' in science classrooms (Laux 2018). An analytical challenge is that the values and norms of physics can be partly hidden, in particular given that physics is often perceived as a 'culture of no culture' (Traweek 1988). However, norms and values can be studied by how they manifest themselves through language (Gyberg and Lee 2010; Lundqvist, Almqvist, and Östman 2009; Östman 1998). In science education the use of words is highly situated; students need to learn not only new words but also new relationships between familiar words and their consequences in use (Wickman 2006). For example, Wickman (2006) illustrates how aesthetic judgements have normative consequences in the science classroom: 'A positive normative aesthetics was hence related to experiences of what (objects, events, action) should be included in doing science in class. Negative aesthetic judgements dealt with what should be excluded' (99). In our study we seek to strike an intermediate level in analysis, between students' negotiations of individual physics concepts and the (re)production of broader cultural patterns of science.

Teacher–student interactions in science classrooms have been investigated with a focus on communicative approaches with the starting point that learning language successfully comes through having to communicate real meaning (Mortimer and Scott 2003). Mortimer and Scott have found various forms and functions of discursive interactions, for example instances of dialogic and authoritative discourse. The communication forms in a science classroom are often found to be authoritative, where attention is focused only on one point of view. Nevertheless, Scott, Mortimer, and Aguiar (2006) showed how both the dialogic and the authoritative pattern of interaction are necessary in order for students to engage in meaningful understanding of scientific conceptual knowledge, and that the tension between the approaches is an inevitable characteristic of meaning-making in science. Further, they showed that teachers may not be aware of how they constrain dialogue thereby limiting the amount of participation by students (Scott, Mortimer, and Aguiar 2006). Here, we have chosen to use a discursive perspective (Davies and Harré 1990) to study partly hidden socialisation in physics classrooms. Within this framework it is possible to distinguish what is morally acceptable and what is not in a particular context, since any conversation unfolds through the joint action of all participants in a reciprocal fashion. An important strength of this research approach is that it recognises the constitutive force of discourse and in particular of discursive practices, and at the same time ‘recognises that people are capable of exercising choice in relation to those practices’ (46).

In positioning theory, the structure of conversation is understood as tri-polar, consisting of speech acts, positionings, and storylines. The first construct, *speech act*, is a form of semiotic resource such as an utterance or a gesture used in communication. The second construct, *positioning*,² is the discursive process that people use in conversations to arrange social structures (Davies and Harré 1990). A positioning is always twofold, in that a positioning of someone else also implies a positioning of oneself. Positioning can also be deliberate, inadvertent, presumptive and taken for granted (Harré et al. 2009, 10). The third construct, *storyline*, is linked to a cultural context beyond the actual conversation and unfolds as participants are engaged in positioning themselves and others through speech acts (Davies and Harré 1990). There is conceptual fuzziness around the concept of storylines since the concept has been used very differently in different analyses (Herbel-Eisenmann et al. 2015). Harré and van Langenhove (1999) give very broad examples of storylines such as ‘instruction’, ‘good-student’ and ‘the victim’. However, storylines can also link conversation to the cultural context of science education. In Ritchie’s study (2002), a group of children doing science together were investigated. The children’s activities included positionings of themselves and others. Three storylines of slightly different characters constituted the children’s interaction: the storyline of the preparing of a creative toy design, the good-student storyline and the victims of male dominance storyline. Another example of how storylines can be used to characterise discursive pattern is Berge and Danielsson’s (2013) study of how university students handled problem solving in physics. Three storylines captured how the students balanced goals depending on whether the primary goal was to solve physics problems, to learn physics, or to prepare for the upcoming examination. Two storylines captured who was the ‘ideal physics student’ in this context; it was someone who had mastered both physics content and was humorous.

In this study we follow the way Berge and Danielsson use positioning theory (2013), which pays specific attention to how the physics content is positioned in the conversation. This is an unorthodox use of positioning theory, which usually explores how individuals are positioned. We argue, however, that it is appropriate to broaden the analytical focus to include the physics content since the understanding of what physics is a dominant theme in physics conversations (Berge and Danielsson 2013). This approach adds new nuances to the work of other researchers in the learning sciences (for example, Anderson 2009; Arnold 2012; Ritchie 2002) since we analyse how both individuals and content are positioned. As such, the strength of the approach is the deliberate focus on content, following a European tradition of Didaktik (Hudson 2007), in contrast to work that predominantly have focused on the conversational structures (see for example work by Mortimer and Scott 2003; Mercer, Dawes, and Staarman 2009 on dialogic classrooms). This paper addresses the following research questions: Which storylines of school physics are prominent in teacher–student interactions in the classroom studied? Are there continuities between different situations in different classrooms? By continuities we refer to similarities between different situations (here presentations by three different teachers) in terms of if/how storylines relate to each other and how and by whom storylines are introduced.

Methodology

Empirical framing and data collection

We explored continuities and contrasts between three different cases in upper secondary school in a class of students with three different teachers. The data collection (and the related research) in this paper form part of a larger Swedish research project, *X*, that involves purposive sampling of teachers and classrooms and documenting classroom activities through video recordings, field notes and complementary interviews as the empirical design. We followed a class of students attending the second year of the Natural Science Programme in upper secondary school in Sweden. About 15% of the students choose the Natural Science Programme, that has been referred to as ‘the royal road’ (Kungsväg) in that it makes students’ eligible for all higher education programmes in Sweden and has a reputation as the most difficult programme (Anderhag, Emanuelsson, Wickman, and Hamza 2013).

The class studied consisted of 27 students, 15 of them female. Our ethnographic work indicated that the students could be described as hardworking and talented, which is a common description of students in this upper secondary program (Nyström 2007). The class had physics lessons with three different teachers within a very short period: their regular teacher, an experienced substitute teacher, and an inexperienced substitute. Their regular teacher, here called Ann-Sofie, had more than twenty years of experience as a physics teacher and was popular with her students. The experienced substitute teacher, here called Lennart, was a retired physics teacher with a lifetime of working experience. The inexperienced substitute, here called Hjalmar, had studied to become a chemistry science teacher in upper secondary school. Only a few years earlier he had been a student at this same school. He had taught this class several times and knew some of the students very well.

The three cases of classroom interaction were chosen from a data set of seven different lessons that were video-recorded using two video cameras (one in the front of the classroom and one in the back). Lennart was the teacher in one of these video-recorded lessons, Hjalmar was the teacher in two; Ann-Sofie taught the remaining lessons. All teachers wore a minimicrophone, while six dictaphones were placed among the students. Typically all lessons started out with some sort of presentation or lecture that lasted between 5 and 40 minutes. Usually the presentation consisted of a new physics concept being introduced and/or one or two textbook problems being solved on the whiteboard (in line with description made by Juuti and Lavonen 2016). Then the lesson continued with students solving different textbook problems or doing laboratory work. The students usually worked by themselves or in pairs at these times, but sometimes also in groups of three.

We have focused on the presentations since classroom discursive patterns were explicitly constituted and negotiated by the teachers together with their students at these times, in contrast to when they tried to solve textbook problems by themselves. All presentations were first transcribed verbatim and read to obtain an overview of the data. Three comparable cases that consisted of video-recorded presentations lasting 21–25 minutes at the beginning of a lesson from each classroom were selected for deeper analysis, see Table 1.

In order to be able to compare and contrast expected and unexpected patterns in teacher–student interaction the three presentations, all thematically varied and comprehensive, were transcribed a second time to capture important body language such as what the teacher drew on the whiteboard in the classroom. The excerpts used to illustrate the analysis have all been translated from the original Swedish and carefully edited for credibility and readability in English.

Analytical process

In order to discern storylines in teacher–student interaction, we engaged in an analytical process with three main stages: first, coding speech-acts; second, categorising speech acts as storylines; and third, identifying continuity between the presentations. In the first stage, we reviewed the three video recordings in conjunction with the transcripts. However, our subsequent analysis relied primarily on the transcripts. The video was used mainly to clarify the text; for instance, if reference was made to what had been written on the whiteboard or if a question was directed towards a particular student. We tried (if possible), in line with Berge and Danielsson (2013), to code every speech act as a form of positioning, using three analytical

Table 1. An overview of the physics content presented within the three presentations.

Ann-Sofie's presentation (21 min)	A physics problem was solved on the white-board that concerned a bouncing ball which was related to the laboratory practical the week earlier. Other physics topics discussed were impulse and the law of conservation of energy.
Lennart's presentation (22 min)	Linear momentum and impulse was introduced for the students on the white-board. Other physics topics discussed were vectors/scalars and SI-units.
Hjalmar's presentation (25 min)	Conservation of mechanical energy and different forms of collisions were introduced for the students. Thereafter a physics problem was solved on the white-board that concerned a book sliding on a plane and where the friction coefficient was un-known.

questions: how are the physics content, the students and the teacher and the positioned? For example, in the beginning of Ann-Sofie's presentation she said:

But you will start the repetitions [for the exam next week] early today of chapter five and then I thought, well, we'll take this one that some of you solved earlier in the week on Tuesday, when you were given a ball, a ruler and you got a scale. And some of you weight your ball so I use a 100 gram ball, I don't know how much yours weighted. Can you help me by telling me how one should go about in order to be able to calculate the impulse on this ball? That comes from the floor. You let it go, it bounces back and I want to know how the impulse can be calculated? Go, Ester.

When coding this particular excerpt we identified how Ann-Sofie in the first sentence positioned physics as the knowledge the students need to know on their future exam (which was not at all the case in the dialogue that followed). In the rest of the quote she talked about a specific physics problem where she specified the weight of the ball so everyone would get the same numerical answer. This could be interpreted as physics is positioned as getting the correct answer when solving physics problems. The students on the other hand are positioned as expected to do a test next week and later on as being able to solve the problem with a bouncing ball correctly. It is not clear who 'owned' the problem-solving or the prospect of giving a correct answer because Ann-Sofie framed the task as a problem she would solve with the students' help but later in the quote she handed over the problem-solving exclusively to Ester (who had raised her hand). In our second analytical stage, we reviewed our coded transcripts in which the conversation was coded as different positionings and categorised every speech act as a constituent of a particular storyline, using the storylines described in Berge, Danielsson, and Ingerman (2012) and Berge and Danielsson (2013) as a starting point. Naturally, these storylines were modified and adjusted to represent the narrative forms that existed within the context of these three presentations. As expected, both understanding physics concepts and the ability to solve textbook problems were positioned as important. The seven coded storylines and their different characteristics are described in the next section. In our third analytical stage we focused on continuities between the three presentations. Using the storylines from Ann-Sofie's presentation as a starting point we compared and contrasted similarities and differences to Lennart's and Hjalmar's presentations.

Results

We could identify seven different storylines. Four are what we call 'physics lesson constituting storylines', representing what teaching physics in an upper secondary school classroom can be. The other three storylines are narratives that represent relationships between the individuals within the classroom and physics as a discipline, so-called 'community constituting storylines' (Berge and Danielsson 2013). These narratives should, of course, be seen in relation to the social context of the presentations.

Storyline 1: dealing with physics problems in terms of reaching a solution to textbook problems

In storyline 1, physics is positioned primarily as a means to solve problems, typically from the textbook, in order to find the correct answer through calculation. In this storyline, the desirable physics student can solve textbook problems correctly, that is, can get the right answers. This does not necessarily imply conceptual understanding, as earlier research has shown that students can often solve mathematical physics problems without the associated conceptual understanding (see, for example, Thacker 2003). We observed this storyline being enacted when various physics problems were solved on the whiteboard, as happened during all three analysed cases. In Ann-Sofie's case, the topic was related to a laboratory practical the previous week that involved calculating the impulse on a bouncing ball. During the subsequent presentation, this practical was transformed into a textbook problem to solve on the whiteboard. In Lennart's case, shorter problems were solved between long descriptions of linear momentum and impulse. In Hjalmar's case, he solved a textbook problem together with the students on the whiteboard. The problem concerned finding the friction coefficient when a book slides on an inclined plane. In all these discussions there were times when a correct answer became the main goal. For example:

1. Ann-Sofie: Metre per second . . . Then we have the velocity when it hits the ground. How did you calculate the velocity when it goes upwards?
2. Ester: Well, then we used the same formula . . .
3. Ann-Sofie: Yeah . . . but?
4. Ester: We had another . . . so we had a start . . . we had a final speed that was zero, because it stops at 80 and turns, and the distance was 80 centimetres, that is 0.8 metre, so we just changed the values.

Ester had begun to explain her solution to the problem of the bouncing ball orally, with guidance from Ann-Sofie who was making notes on the whiteboard. Ester interpreted Ann-Sofie's question (1) as a request to give the numerical values she had used rather than to explain the calculation procedure. This can be interpreted as Ester enacting the storyline of reaching a solution.

Actual numerical values were also given prominence in Lennart's problem solving:

5. Lennart: So, let's take an example: if my mass is 71 kg and I'm moving with the velocity of . . ., how fast can you run? Do I manage 5 m/sec, what is my momentum then? Well, it is $P = M * V$, then $= 71 * 5$ and I get 355 kg m/sec, so it's not that difficult at all on the whole.

Here the concept of momentum was positioned as easily accessible, as it was easy to calculate given the right formula. Noteworthy here is that although Lennart used his

own weight and a value for velocity that is feasible (over short distances at least) the value of 355 kg m/sec is still relatively abstract.

The calculation became even more abstract at the end of Hjalmar's presentation:

6. Hjalmar: $F \cdot \mu / F_N$ equals the coefficient of friction, F_μ is equal to F_1 and F_N is equal to F_2 , so that is why I can put F_1 here and F_2 there and solve for μ . Any questions so far? No? And now, Felicia, maybe you can see why I didn't round off carefully, because we can delete it [F_G] here. We have F_G on both sides, which means we can delete F_G altogether, because F_G divided by F_G is 1 – brilliant right?

In this excerpt Hjalmar shows it is not important to round off values correctly because that would be unnecessary work and would not change the answer in the end. Again, the problem solving became very abstract: F_G did not represent gravitational force any more, but was positioned as an unknown factor that could be ignored. Part of this storyline is to position physics as the solving of purely mathematical equations; using the right formula may be sufficient to solve textbook problems at this level of education.

Storyline 2: dealing with physics in terms of gaining conceptual knowledge

In storyline 2, physics is positioned as phenomena that can be made understandable through conceptual discussions using examples from everyday life (Berge and Danielsson 2013) or conceptual metaphors (Haglund, Jeppsson, and Schönborn 2016). In this storyline the desirable physics student not only knows how to solve textbook problems mathematically but also understands the concepts behind the formulas. Thus this storyline can be interwoven with the first storyline of dealing with textbook problems in terms of reaching a solution, as happened when Ester tried to solve the problem of the bouncing ball:

7. Ester: And then we thought that we should check how, what the velocity is when it meets the floor, sort of.
 8. Ann-Sofie: Okay, why is that interesting?
 9. Ester: The formula to calculate, well, but momentum.
 10. Josef: Yeah
 11. Ann-Sofie: Momentum.

In this excerpt Ester described how she solved the physics problem (7) when Ann-Sofie asked for clarification of what happens when the ball hit the ground (8). The storyline of gaining conceptual knowledge became interwoven with the storyline of reaching a solution when Ann-Sofie asked what was happening and why. The problem solving then became something more than merely mathematical reasoning. On several occasions this sort of question from Ann-Sofie challenged the storyline of dealing with textbook problems only in terms of reaching a solution. As such, the first two storylines were often mixed in her presentation.

The storyline of gaining conceptual knowledge was dominant in Lennart's presentation:

12. Lennart: [...] And kinetic energy, is that a vector or a scalar?
13. Pia: Vector.
14. Lennart: It's a scalar, it doesn't have a direction so because, if we are to study, for example, bodies that collide with one another, then we cannot decide with the help of kinetic energy which direction they are going to move after the collision. And that's when we need some sort of concept, a vector concept that we can use, and that's where momentum becomes relevant ((writes momentum on the board)) and momentum, it's a very simple definition, it's equal to, maybe we should ((writes ' $= m \cdot v$ ' on the board)). Mass times velocity, or ... yeah it should be velocity.
15. Albin: What's short for momentum?

In the excerpt above the concepts 'linear momentum' and 'impulse' become very central in themselves, as concepts required to understand collisions (14). Albin's question (15) about which letter represents³ momentum in formulas can be interpreted by saying that he is constructing momentum as the abstract notation used in formulas, introducing the first storyline again. However, Lennart answered with a continuation of the storyline of gaining conceptual knowledge as he contextualised the phenomena momentum: 'it is really obvious that somebody with a big mass, if somebody weights 100 kg and he bumps into me then I go away in a much worse way than if the one who comes at me is a small child who weighs 5 kg'.

Hjalmar also used examples from everyday life to make the physics understandable: 'For example, a car collides often so that two cars, well, two cars seldom collide and then go in different directions, usually they stick together and make a wreck and then the wreck moves towards the ditch or another direction'. The most prominent characteristic of this storyline was that, as in the quotes above, real-life experiences were used to explain the logic of physics, in contrast to using physics to understand everyday life.

Storyline 3: dealing with physics as empirical enquiry

In storyline 3, physics is positioned as a method of investigating reality. In this storyline the desirable physics student is careful not to be led astray by theoretical physics models, it is the real-world objects, with certain properties and constraints, that are under investigation. A strong focus on what is possible in the real world ought to be guiding the reasoning is most relevant here. For example, when solving a physics problem about an ox dragging a box on the ground (Berge and Danielsson 2013), one of the properties of the ox is that it cannot fly. The idea to solve such a problem in three dimensions would accordingly be based on an unrealistic interpretation of reality, however, within Newtonian mechanics a flying ox could be a possible physics problem to calculate. To solve the problem with the ox in three dimensions would lead to

unnecessary work, but in other cases neglecting reality makes the problem easier (neglecting friction for instance). As a part of this storyline Ester carefully referred to the conditions of her specific ball as she explained how to solve the problem with a bouncing ball, and in doing so, she positioned the task (and physics) as primarily a laboratory practical. Ester continued this storyline when she emphasised that her data was rounded off. She could have said 'm' for mass from the beginning and made the problem more abstract but she chose not to. However, this storyline was not continued by Ann-Sofie, who replied by summarising how far they had come in the process of solving the task, and thus emphasised what was most relevant in relation to reaching a correct answer in Ester's reporting so far. Later, Albin returned to the storyline of empirical inquiry when he asked if it was okay to ignore friction: 'I was thinking, since this is a practical task, should we just neglect friction?' This question made Ann-Sofie think aloud. She first said that the friction was negligible, then changed her mind for a second and decided to calculate the friction in air, and then changed her mind again and said that this was 'too difficult', and ended her reasoning by saying that she thought the friction would be negligible. She then ended this storyline of physics as an empirical inquiry and initiated the storyline of dealing with textbook problems in terms of reaching a solution again by asking another student about an equation on the whiteboard. This third storyline could have been dominant in Ann-Sofie's presentation, since the physics problem with the bouncing ball had been a laboratory practical the week before. Instead the problem of the bouncing ball became more of a mathematically focused task and part of the storyline reaching a solution to textbook problems. This storyline is not present during Hjalmar's or Lennart's presentations.

Storyline 4: dealing with physics in terms of preparing for the upcoming exam

In storyline 4, physics is positioned as what the students need to know for their future examinations, and the desirable physics student performs well on these examinations. This storyline was present during Ann-Sofie's presentation. Early in her presentation she positioned the lesson as giving the students a 'head start' in the revision they all needed to do before the upcoming examination and thus framed the whole lesson as a form of preparation. This storyline did not recur until a student (Ester) brought up the subject of the examination again at the end of the presentation. Ann-Sofie asked the students which way they felt was the easiest to solve the physics problem of the bouncing ball: using the laws of motion or using the energy principle. She thus positioned the students' preferences as the most important when choosing how to solve similar problems. We interpret this utterance as part of the community constituting storyline of feeling the physics (described in the next section). Ester, however, returned to the storyline of dealing with physics in terms of preparing for the upcoming examination:

16. Ester: I get that if you make the test to assess the energy principle and those things, then maybe you should use those formulas.
17. Ann-Sofie: Exactly.

18. Ester: But on the national test, or the course test, will they indicate what we should use? Well, or will it be seen as wrong, then? (even though you . . .)

Ester was eager to discuss what formula to use in the context of the examination rather than what method felt best to use (16, 18). Ann-Sofie's response was that none of these principles would lead to the wrong answer, but Ester persisted in asking what the questions in the examination would look like, and this storyline dominated the conversation until the end of the Ann-Sofie's presentation.

This storyline is less relevant in a discussion with a substitute teacher since it is the regular teacher who has beforehand knowledge about the exam questions, so it is not surprising that it was not present during Lennart's presentation. However, a version of this storyline was enacted during Hjalmar's presentation in the form of a focus on what would *not* be tested, and was therefore less important to talk about. This form of rationalisation occurred in Hjalmar's briefing when he explained that he chose not to include a long proof in order to save the students' time. The same thing happened when Ann-Sofie decided not to include air friction in her calculation because it would have been too complex (at this level of physics). Within the storyline of dealing with physics in terms of preparing for the upcoming examination, it is also important *not* to teach (or learn in the long haul) more physics than is needed, and consequently the desirable physics student accepts shorter explanations.

Storyline 5: mastering physics

The remaining three storylines concern the relationship between the individuals in the classroom and physics, or what can be called 'community constituting storylines'. In storyline 5, which was enacted in all three presentations, physics is constituted as a subject that a student in this class can master. Here, the desirable physics student is positioned as knowledgeable, or simply smart, and thus as an insider in relation to physics. Examples of utterances constituting this storyline have been presented in previous excerpts, for example, when Lennart said that the definition of momentum was *simple* in the excerpt above (14), positioning the students as knowledgeable in relation to the physics presented at this level. He used similar language when he said that his momentum was *obviously* bigger, which again could be interpreted as him positioning the students as mastering physics at this level since he expressed an assumption that this was obvious for everyone in the room. However, these positionings by Lennart were not taken up by the students.

This storyline was more subtle in Ann-Sofie's presentation. She asked the students as a group questions like 'Did we get this?', and 'Do you remember this formula?', thus indicating that students may or may not have mastered the knowledge. In Hjalmar's presentation some of students positioned themselves as mastering physics. When Hjalmar had problems explaining the concept of the resultant that was needed to solve the textbook problem, one student, Albin, pointed out that the forces drawn on the whiteboard were equivalent with the resultant F_G : 'So F_2 times the resultant is one way and that is backwards as *I understand it*, you could if you could, if you only had F_1 and F_2 you could do F_G ?'. Albin used the words 'as I understand it' when he (correctly)

contradicted what Hjalmar had drawn on the whiteboard (which was incorrect). In addition to informing Hjalmar about the mistake he had made on the whiteboard, Albin also talked about physics as something *he* understood, thus positioning himself as mastering physics. This was one of very few instances in our data set when a student used the pronoun 'I'. In the same presentation Lisa also positioned her own view about how to solve the problem as valuable: '*I was just thinking F_G , I guess we rounded it [F_G] off, but we don't need to do that until we have an answer.*'

Storyline 6: appreciating physics

In storyline 6, physics is constituted as enjoyable and beautiful, and in this storyline, the desirable physics student is someone who is able to appreciate this beauty, someone who has a taste for physics (Anderhag, Hamza, and Wickman 2015). Examples of this are when Hjalmar called a part of a solution 'brilliant' and Ann-Sofie exclaimed 'neat' to the students repeatedly during the lesson, which is a fairly common way to demonstrate in class by teachers what should be included in doing science (Wickman 2006). Another example is when Ann-Sofie expressed particular satisfaction with one of Ester's explanations. Ester had used mainly body language to describe the relationship between the kinetic energy and the potential energy of the bouncing ball, an explanation that would not have worked in a written examination. Ann-Sofie responded with joy and affection, 'That was really good, even I have nothing to add to that. It goes like this, do you get it? That was a really good explanation.' Here this storyline is intertwined with the storyline of mastering physics: At the same time as enjoying Ester's model, Ann-Sofie positioned Ester as a knowledgeable physics student. Similarly, by expressing appreciation of the beauty of what was included in the physics lessons Ann-Sofie also positioned herself as the expert who has nothing to add to the model. The way Ann-Sofie and Hjalmar positioned physics as beautiful was not taken up by the students.

Storyline 7: having a feeling for physics

In storyline 7, physics is constituted as something you can have a feeling for or not. The desirable physics student is positioned as having an intuition for physics. One example of this storyline was when Ann-Sofie asked the students if the solution 'feels okay', and thus positioned a step in a solution as potentially pleasing emotionally. Another example of this storyline was when Ester concluded that there must be a negative value upwards or downwards and Ann-Sofie responded by asking if it 'felt good' to have a negative value for the impulse? Ester said that the two impulses had different directions, but that it felt wrong when you looked at it. Ann-Sofie continued this storyline by saying that it does not have to feel good, but an impulse can be negative because it has a direction. In both these examples, the desirable physics student should have a feeling for physics but also be able to make rational judgements about whether this feeling can be trusted. This storyline is characterised as a community constituting storyline in that this 'feeling' can be shared among physicists. This contrasts with earlier descriptions of science classrooms that privileged precise empirical descriptions, but bore resemblance to how professional physicists relate to physics as also including the intuitive (Marton, Fensham, and Chaiklin 1994; Shavinina 2004).

Continuities between the three presentations

At a first glance the three presentations might appear quite different from each other: Ann-Sofie's presentation consisted largely of problem solving, in Lennart's presentation the talk mainly concerned ways to understand physics concepts better (by using examples from reality) and in Hjalmar's presentation it became very important to find the right answer to one specific physics problem. However, when we compared and contrasted the storylines in the presentations similarities became apparent, as shown in Table 2.

Two physics lesson constituting storylines, reaching a solution to textbook problems and gaining conceptual knowledge, co-existed and dominated all three presentations. These two storylines were sequentially connected, which was the case in Ann-Sofie's presentation: although the talk concerned problem solving to a significant extent Ann-Sofie repeatedly introduced the storyline of gaining conceptual knowledge into the conversation. She did this primarily through questions like 'Why is that interesting?' and 'How do you know that the collision is inelastic?'. The storyline of mastering physics, appeared also in all three presentations, which indicates that the storyline of mastering physics seems difficult to avoid in higher level physics classrooms.

When looking for how and by whom storylines are introduced we noticed that the same person may swop between different storylines and introduce a new storyline within the same sentence, as in Anne-Sofie's reply to Albin when he introduced the storyline of empirical inquiry by saying 'I was thinking, since this is a practical task, should we just neglect friction?'. Ann-Sofie answered that friction is negligible (which we coded as dealing with physics in terms of preparing for the upcoming exam), decided to calculate the friction and thereby followed Albin in his attempt to explore a real-world object, and then changed her mind again and said that it was too difficult (dealing with physics in terms of preparing for the upcoming exam). More commonly, however, in our analysis was that a person other than the speaker introduced a new storyline, for example when Albin attempted this above. Likewise, in Ann-Sofie's presentation Ester pushed the storyline of preparing for the upcoming examination and made this storyline dominate the conversation at the end of the presentation, although Ann-Sofie did not immediately reply within the same storyline. The storylines in our analysis were also often *intertwined* with each other (Berge and Danielsson 2013), that is, occurring

Table 2. An overview of storylines described, most dominating storyline, i.e. quantitatively most coded in **bold**.

	Ann-Sofie's presentation	Lennart's presentation	Hjalmar's presentation
Physics lesson constituting storylines	reaching a solution to textbook problems gaining conceptual knowledge preparing for the upcoming exam dealing with physics as empirical enquiry	gaining conceptual knowledge reaching a solution to textbook problems	reaching a solution to textbook problems. gaining conceptual knowledge preparing for the upcoming exam
Community constituting storylines	mastering physics having a feeling for physics appreciating physics	mastering physics	mastering physics appreciating physics

simultaneously. For instance, when Lennart (14) explained the importance of direction when bodies collide with each another (which we coded as dealing with physics in terms of gaining conceptual knowledge) and at the same time he called a definition 'simple' which we interpreted as a part of the storyline of mastering physics. Likewise, Hjalmar (6) solved an equation on the whiteboard (which we coded as dealing with physics problems in terms of reaching a solution to textbook) when he added that Felicia now *might understand* his earlier calculations, thereby positioning Felicia in the storyline of mastering physics.

The students acted differently within the storylines in Lennart's and Hjalmar's presentations. In Lennart's presentation the students asked detailed questions about definitions, like Albin's question about which letter represents momentum (15). In Hjalmar's presentation the student enforced the storyline of gaining conceptual knowledge using the same kinds of questions used by Ann-Sofie:

19. Felicia: Can you give an example?
20. Hjalmar: Example?
21. Felicia: Yeah?
22. Hjalmar: Well, what should we do as an example? If you roll, we'll take two marbles again[. . .]. If you want to say this in a neater way you can say that 'the objects stick together after the collision.' Yes?
23. Albin: I'm thinking of the example of a train collision, the train continues . . .
24. Hjalmar: For example, a car collides often so that two cars, well, two cars seldom collide and then go in different directions, usually they stick together and make a wreck and then the wreck moves towards the ditch or another direction. Hopefully it moves towards the ditch so no one else that travels the road gets hurt. Do you have any more questions on collisions or can we move on to the existing inclined plane? Yes?
25. Albin: What do we use this for?

Hjalmar was reluctant to engage with Felicia's questions and tried to change the topic (24) but Albin continued to ask questions (25) pushing the storyline of gaining conceptual knowledge further. Here Hjalmar answered that they needed to learn about collisions in order to be able to calculate problems with collisions, ending the storyline about gaining conceptual knowledge. We can see a connection here between being the person asking the questions within the storyline of gaining conceptual knowledge and the storyline of mastering physics; Albin (25) positioned himself as knowledgeable in Hjalmar's lesson when he replicated Ann-Sofie's way of asking questions (8). But this speech-act had another effect as well: it introduced the storyline of gaining conceptual knowledge again and contributed to continuity between the three classrooms.

Discussion

The seven different storylines that were prominent in teacher–student interactions are in line with previous research in science education. For example, the first three storylines *reaching a solution to textbook problems*, *gaining conceptual knowledge* and *dealing with physics as empirical enquiry* can be interpreted as representing fairly common teaching methods in upper secondary school physics (Due 2014; Juuti and Lavonen 2016). The fourth storyline *preparing for the upcoming exam* can be understood as representing the well-known problem of students learning only for the test (Redish 1994). However, these storylines capture more nuances than a simple representation of different teaching methods. In fact, the storylines are interrelated. This is illustrated by how none of the storylines would dominate a whole presentation, and by the way the same speaker could shift between two different storylines in the same sentence. This continual shifting demonstrates some of the complexity of what is happening within one presentation, irrespective of the topic of the lesson. Furthermore, the storylines hold complexity within them. The storyline of preparing for the upcoming examination, for instance, ultimately boils down to teaching what the students will be tested on, and thus what they may leave aside and yet be successful. This rationalisation of teaching has two sides, demonstrated in Hjalmar's lesson as saving the students' time, and in Ann-Sofie's lesson as not involving the class in too complex an explanation. This might create the impression in students that it is important not to teach more physics than needed thus potentially creating a culture of learning where striving for more knowledge is not valued. However, more positively it could also point to the importance of trust in the teacher–learner relationship in that students trust the teacher to present knowledge in an order and at a pace that will make learning physics a more purposeful endeavour.

The last three community constituting storylines of *mastering physics*, *appreciating physics* and *having a feeling for physics* all concern how the students are supposed to relate to physics and thus become 'insiders' (Berge, Danielsson, and Ingerman 2012) in the discipline. The storyline of mastering physics shares many similarities with the physics discourse described previously by researchers such as Traweek (1988), Due (2014) and Nyström (2007) in which being good at physics is associated with 'smartness', 'logic' and 'masculinity'. This storyline can also be manifested in its inverse form, with physics is positioned as something that you may not be able to master. Thus, this storyline means that there is 'risk' in answering teachers' questions incorrectly and making the classroom a less secure place in general. This storyline is reinforced by how often school physics is perceived as a fixed body of knowledge, with answers that are right or wrong (Carlone 2004).

In the storyline of appreciating physics, Ann-Sofie and Hjalmar taught the students to see the beauty in physics in the same way as other teachers in science education have been found to do (Anderhag, Hamza and Wickman 2015; Wickman 2006). However, in our analysis none of the students' speech acts were coded within this storyline, in contrast to how both teachers and students contributed to the other six storylines. One interpretation of this is that this behaviour was not taken up by the students because they did not experience the presented physics as beautiful. If this is the case, it would be unfortunate since developing a 'taste for science' is related to the learning

processes as well as to positive attitudes and future interest in the field (Anderhag, Wickman, and Hamza 2015).

The storyline of having a feeling for physics concerns physics intuition, which is highly valued, especially in the context of cutting-edge physics research (Marton, Fensham, and Chaiklin 1994; Shavinina 2004). While intuition is perceived as the hallmark of an accomplished physicist, it is also something that needs to be learnt (Singh 2002). However, the relationship between intuition and learning physics is problematic. In the context of learning introductory mechanics, students' everyday understanding, their intuitive grasp of mechanics from everyday experience, often leads them astray. Students' alternative conceptions of mechanics phenomena are well documented (see for example, Clement 1993; Hake 1998). Substantial effort has been put into making use of students' intuitive understanding in productive ways so as to bridge the gap between their alternative conceptions and their scientifically accepted counterparts (DiSessa 2015; Grayson 1994). Consequently, learning when intuition can be trusted and when it cannot be trusted is part of learning to approach physics problem solving like a physicist (Singh 2002). Thus we can understand Ann-Sofie's invoking the storyline of having a feeling for physics as an aspect of socialising students into a physicist's way of approaching the world.

The identification and analysis of storylines raises awareness of the teaching choices teachers make and the potential consequences for students. Which storylines are made available in classroom interaction may offer students different views of the value teachers put on different aspects of the physics content and of who counts as knowledgeable in physics. An awareness of how different storylines can be used for different purposes enriches teachers' ability to make informed decisions in their professional practice. This is not to say that one storyline is by definition better or more useful than another, or that certain storylines should be avoided. On the contrary, variation and diversity in the storylines offered in the classroom contributes to an inclusive physics education that allows for a plurality of views of what constitute physics knowledge and knowledgeable physics people. The range of storylines concerns both how concepts are negotiated, as described in the storyline of dealing with physics in terms of gaining conceptual knowledge, and somewhat broader cultural patterns, as in the three community constituting storylines. Thus, the use of storylines strikes the intermediate level, between students' negotiations of individual physics concepts and the (re)production of broader cultural patterns of science, in our analysis, as we intended. A major strength of the use of storylines as an analytical unit is their ability to reveal the relationship between these levels in classroom interaction.

Who is then the desirable student in the physics classroom? The answer is elusive since it depends on the ongoing storyline, which might shift in the next speech act. It is noticeable that only five students' names are visible in the transcripts and citations (Ester, Josef, Pia, Albin and Lisa). This is not a coincidence. In this classroom five students talked considerably more when it came to answering teachers' questions and asking their own and four of them were represented in this study (Albin, Ester, Josef and Lisa; also described in Mendick Berge and Danielsson 2017). Although the interaction in presentations has been analysed, the role of target students (Tobin and Gallagher 1987) is beyond the scope of this paper. An interesting further development would be to analyse the role of target students in how storylines are construed and contested.

Notes

1. On completion of their compulsory schooling (nine years), almost all youth in Sweden continue their education with a three-year upper secondary school program.
2. There is an apparently synonymous use of position and positioning in research using positioning theory (Herbel-Eisenmann et al. 2015). Here we have chosen to use the term positioning to stress that it is a process.
3. In Swedish notations are less obvious than in English. For example, the concept 'force' is called 'kraft' in Swedish but the (English) letter 'F' is used in equations.

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