



Curriculum Emphases, Mathematics and Teaching Practices: Swedish Upper-Secondary Physics Teachers' Views

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Abstract

This article addresses physics teachers' views about physics teaching in upper-secondary school. Their views have been investigated nationwide through a web-based questionnaire. The questionnaire has been developed based on several published instruments and is part of an ongoing project on the role of mathematics in physics teaching at upper-secondary school. The selected part of the results from the analysis of the questionnaire reported on here cross-correlate physics teachers' views about aims of physics teaching with their view of physics classroom activities, and perceived hindrances in the teaching of physics. Three hundred seventy-nine teachers responded to the questionnaire (45% response rate). The result indicates that teachers with a high agreement with a *Fundamental Physics* curriculum emphasis regarded mathematics as a problem for physics teaching, whereas teachers with high agreement with the curriculum emphases *Physics, Technology and Society* or *Knowledge Development in Physics* did not do so. This means that teachers with a main focus on fundamental theories and concepts believe that mathematics is a problem to a higher extent than teachers with main focus on the role of physics in society and applied aspects or physics knowledge development do. Consequences for teaching and further research are discussed.

Keywords Curriculum emphasis · Mathematics and physics · Teaching strategies · Upper-secondary physics

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Introduction and Theoretical Framework

Science teaching, particularly chemistry and physics teaching, is subject to ongoing discussions concerning aims, goals, relation to modern society and ways of teaching so that more students find physics interesting and meaningful. In this article, we report on upper-secondary physics teachers' views on aims, characteristics and challenges related to physics teaching and their teaching habits, specifically in relation to their attitudes to physics and mathematics.

Different science teaching traditions have previously been described in the literature. A common tradition is 'traditional school science' (Zacharia & Barton, 2004) in which knowledge is transferred to learners through lectures and precisely planned experiments. The goal of science teaching in this teaching tradition is that 'students have to memorize scientific knowledge and procedures within the structure that was established' (pp. 203–204). However, there are also other teaching traditions such as 'progressive school science' and 'critical school science' in which the goals of school science are more related to citizenship. In line with such different foci and aims of school science, Roberts (1982, 1988, 1995) introduced the concept of 'curriculum emphases' defined as:

a coherent set of messages to the student about science (rather than within science). Such messages constitute objectives which go beyond learning the facts, principles, laws and theories of the subject matter itself—objectives which provide an answer to the student question: 'Why am I learning this?' (Roberts, 1982, p. 245)

Roberts has described seven curriculum emphases which all give different rationales for learning science. These seven emphases have been reduced to three by van Driel, Bulte and Verloop (2008) in a survey of teachers' curricular beliefs. These authors combine 'Solid foundation' and 'Correct explanations' (Roberts, 1995) into 'Fundamental Chemistry' which describes an emphasis where fundamental theories and concepts are taught as an essential basis for future understanding or further studies. Traditional science teaching is characterized by these curriculum emphasis (see e.g. van Driel et al., 2008, p. 109). The emphases 'Science/technology/decisions' and 'Everyday applications' (Roberts, 1995) were merged into 'Chemistry, Technology and Society' due to the interrelationship of applications of science and technology with students' everyday lives and decision-making. Finally 'Knowledge Development in Chemistry' (van Driel et al., 2008), is a combination of the curriculum emphases 'Scientific skill development', 'Structure of science' and 'Personal explanation' (Roberts, 1995). van Driel et al., (2008) argue that present-day chemistry teachers combine these emphases in project-oriented work focusing on scientific processes, particularly the role of chemistry and evidence-based argumentation in socio-scientific issues. These three curriculum emphases described were later transferred and developed to encompass also biology and physics by de Putter-Smits, Taconis, Jochems, and van Driel (2011) in measuring secondary school science teachers' curriculum emphases.

In these previous studies on chemistry and science teachers' support for different curriculum emphasis, the study by van Driel et al. (2008) shows that for Dutch chemistry teachers, the strongest support was for the emphasis 'Fundamental

Chemistry', and the study by de Putter-Smits et al. (2011) shows that the Dutch biology teachers gave most support to the curriculum emphasis 'Science, Technology and Society' while the physics teachers gave most support to the emphasis 'Knowledge Development in Science'. In addition, van Driel et al. (2008) show that for pre-university education, the curriculum emphasis 'Knowledge Development in Chemistry' was viewed as more important than for senior general secondary education. de Putter-Smits, Taconis, and Jochems (2013) in studying context-based science teaching found that four of eight teachers believed that students actively can learn in an environment strictly led by the teacher, which they state stands in contrast to prior research results stating that a more student-centred teaching strategy is vital for students' active learning. They discuss and advocate for further research into teachers' professional development.

In the science education research field and in policy discussions, there are ongoing discussions related not only to the aims of school science but also to choices of teaching strategies, and possible hindrances for meaningful learning for students and how they could be overcome. One example is a recent report from PISA 2015 where Mostafa, Echazarra, and Guillou (2018) discuss the relationship between various science teaching strategies and students' science-related outcomes. They report on relations between the different teaching strategies: inquiry-based science teaching, teacher-directed instruction, adaptive teaching with teacher feedback, and students' science performance, and attitudes towards science for the participating countries.

For upper-secondary school physics, previous studies describe the special role of mathematics in the teaching and learning of physics (cf. Pospiech, Michelini, & Eylon, 2019; Uhden, Karam, Pietrocola, & Pospiech, 2012) that have to be considered when discussing teaching strategies and hindrances in physics teaching. The study reported on here continues this line of research that has a special focus on the role of mathematics in physics teaching (cf. Hansson, Hansson, Juter, & Redfors, 2015, 2019; Turşucu, Spandaw, Flipse, & de Vries, 2018). Mathematics is often spoken of as a necessity for physics; e.g., mathematics is the language of physics (Pask, 2003). One strand of this line of research focuses on students' problems in transferring mathematical knowledge to new and applied situations during physics teaching (Kaiser & Sriraman, 2006; Krey, 2014; Kuo, Hull, Gupta, & Elby, 2013; Michelsen, 2006; Torigoe & Gladding, 2011; Uhden et al., 2012). This is also emphasized in a Swedish study by Due (2009) where students state that to succeed in physics, it is necessary to focus and practice mathematical solutions of physics problems. However, there is also research not only focusing on problem-solving but physics teaching in general, e.g. from the perspective of the role of mathematics skills among students. Analysis of the TIMSS advance study (IEA, 2014) discusses the decrease in students' mathematics knowledge as an explanation for the decline in Swedish students' results in physics (Angell, Lie, & Rohatgi, 2011). Thus, mathematics has been reported as one obstacle in the teaching of physics, but there are also other hindrances such as curriculum overload. Angell, Guttersrud, Henriksen, and Isnes (2004) describe that Norwegian physics' teachers view using mathematics to describe physical phenomena as the most problematic issue in the teaching and learning of physics. After that come fast progression and extensive curriculum in the courses, followed by using laws and mathematics in problem-solving. The pupils (grades 12–13) had a quite different view as they regarded fast progression and extensive curriculum content the most problematic aspects in school physics and they did not regard mathematics as such a major problem as the teachers did.

There is a need for further research on why science teaching is diverse and teaching shows different curriculum emphases (cf. Belo, van Driel, van Veen, & Verloop, 2014; Johansson, Andersson, Salminen-Karlsson, & Elmgren, 2018). The general picture is that relationships between teachers' views, curriculum emphases, classroom practices, problems and possible student shortcomings need further studies in order to generate more knowledge about aspects that constitute teaching conditions in science classrooms. In this article, we extend this line of research by adding a special focus on the role of mathematics in relation to the different curriculum emphases. In so doing, we took a nationwide look on Swedish upper-secondary physics teachers' views to find factors explaining diversities in science teaching in relation to curriculum emphases.

The study presented here is part of an ongoing project on the role of mathematics in upper-secondary physics teaching. This article aims to describe how individual upper-secondary physics teachers' curriculum emphasis relates to their teaching strategies and views on shortcomings and problems in physics teaching, with a special focus on mathematics. The research questions posed are:

- Which aims, in terms of teaching and learning physics, are viewed important by the physics teachers?
- What, according to the teachers, characterizes their teaching?
- What do they view as hindrances for high-quality physics teaching?

Methodology

Context of the Study

Physics in Swedish upper-secondary school is almost exclusively studied by students taking the Science and the Technology programmes. Most students who study physics take one or two courses and very few take three courses.¹ Upper-secondary physics in Sweden is outlined by a national curriculum (Swedish National Agency for Education, 2011) which specifies aims, core content and knowledge requirements. The section 'Aim of the subject' in the curriculum ends by specifying that:

Teaching in the subject of physics should give students the opportunities to develop the following:

- 1) Knowledge of the concepts, models, theories and working methods of physics, and also understanding their development.
- 2) The ability to analyse and find answers to subject-related questions, and to identify, formulate and solve problems. The ability to reflect on and assess chosen strategies, methods and results.
- 3) The ability to plan, carry out, interpret and report experiments and observations, and also the ability to handle materials and equipment.
- 4) Knowledge of the importance of physics for the individual and society.
- 5) The ability to use a knowledge of physics to communicate, and also to examine and use information. (Swedish National Agency for Education, 2011)

¹ Statistics for school year 2018 from www.skolverket.se.

Core content contains both concepts and models (e.g. concerning ‘Motion and force’), but also content referring to ‘The nature, working methods, and mathematical methods of physics’. Regarding mathematical methods the curriculum says that in Physics 1 the teaching should cover the core content “Identifying and studying problems using reasoning from physics and mathematical modelling covering linear equations, power and exponential equations, functions and graphs, and trigonometry and vectors’. A similar formulation is present in the core content for Physics 2 (but with slightly different mathematical concepts): ‘linear and non-linear functions, equations and graphs, and derivatives and vectors’ (Swedish National Agency for Education, 2011). The Swedish curriculum is goal oriented and does not state how core content and aims should be combined, how much time should be allocated to specific aims or core content, or how to work with aims and/or core content. This means that views and decisions by the local schools and the teachers are important for the emphasis of the teaching.

Instrument and Method

A web-based questionnaire was constructed with 154 items to answer the research questions. It opened with background information of the respondent (15 items) including age, gender, work experience, education, what subjects and courses the respondents teach. The questionnaire was then divided into three parts related to:

- A) views of curriculum emphasis of physics education at upper-secondary school (39 items),
- B) views of the nature of mathematics and physics (46 items), and
- C) teaching strategies in physics and the role of mathematics (54 items).

In these parts, altogether 19 questions were posed, each with 1–23 items to respond to, adding up to a total of 139 items appraised through a 5-point Likert scale. Questions from previously published studies were translated, adjusted and combined to cover the scope of this study together with new questions.

Part A of the questionnaire is based on van Driel et al.’s (2008) aforementioned adaptation of Roberts (1982, 1988, 1995) ‘curriculum emphases’ with additional questions from de Putter-Smits (2012). Part B of the questionnaire is about physics teachers’ views about the nature of mathematics and physics influenced by Grigutsch and Törner (1998), and a set about science in society and research as depicted in Chen (2006). Part C of the questionnaire is about physics teachers’ views on teaching strategies, shortcomings and the role of mathematics in physics teaching and it was generated based on TIMSS Advanced (IEA 2014) and other published instruments (Angell et al., 2004; Buabeng, 2015). Various competences, concepts and areas of mathematics relevant to physics were addressed. The analysis presented here uses responses to questions from parts A and C of the questionnaire, see Tables 1, 2 and 3.

Table 1 contains items analogous to those by de Putter-Smits (2012) and van Driel et al. (2008), adapted to physics. The curriculum emphases used for physics teaching in this study are *Fundamental Physics* (FP), *Knowledge Development in Physics* (KDP) and *Physics, Technology and Society* (PTS).

Table 1 Question and 23 items from part A of the questionnaire, adapted from de Putter-Smits (2012) and van Driel et al. (2008). The items are related to the curriculum emphases Fundamental Physics (FP), Knowledge Development in Physics (KDP) and Physics, Technology and Society (PTS)

To what extent do you agree with the following statements on physics teaching?

I think it is important to learn to perform physics calculations because the students can use it to solve physics tasks.	FP
I think that physics students should start by learning abstract formulas as a basis for developing physics knowledge.	FP
I think that during laboratory work, such as when measuring speeds, it is important that the students focus on getting good measurements.	FP
I think that the main reason why knowledge about forces is important for the students is that it is such a fundamental concept in physics.	FP
*I think that knowledge of the conservation of energy is important because it enables students to understand several physical phenomena.	FP
I think it is important to use variables and units to show the internal coherence between physical concepts.	FP
I think that the primary task of physics teaching is to prepare students for further studies in physics, science or technology.	FP
I think that students should develop basic skills before they can work with applications.	FP
I think it is important that current social issues that concern physics are discussed during my lessons.	PTS
I think it is important during my lessons to address pros and cons for society with the development of new products (such as mobile phones).	PTS
I think it is important during my lessons to clarify the relationship between societal issues and physics areas.	PTS
During my lessons, I want to highlight the role of products based on physical applications in the students' everyday lives.	PTS
I think that it is an important task for physics teaching that students learn to use physics knowledge when they make personal decisions about e.g. food, health and energy use.	PTS
I think that it is an important task for physics teaching that students learn to use physics knowledge as a basis for personal opinions on societal issues such as fossil fuels.	PTS
I think that it is an important task for physics teaching that students learn how economics (rapid and large-scale production) is associated with environmental and safety concerns.	PTS
I think that it is an important task for physics teaching that the students learn that the problem-solving strategies used by physicists, chemists and biologists are similar.	KDP
I think that it is an important task for physics teaching to ensure that students learn that physicists design and use models as tools for solving theoretical and practical problems.	KDP
I think that it is an important task for physics teaching to ensure that students understand that physical knowledge is never definitive, but can always change.	KDP
I think that an important goal of physics teaching is that students learn how physicists develop knowledge.	KDP
I think it is an important task for physics teaching to ensure that students understand how modern research leads to new knowledge in physics.	KDP
* I think it is an important task for physics teaching that students can develop insight into the socio-historical development of physics.	KDP
I think that it is an important task for physics teaching that students can learn to see overarching constructions and contexts in physics.	KDP
I think it is an important task for physics teaching that students realize that human qualities, such as creativity and ambition, play an important role in the development of physics knowledge.	KDP

*Item excluded in the analysis (see below)

Table 2 relates to classroom practices and teaching approaches adapted from Buabeng (2015). Table 3 relates to problems and the quality of physics teaching adopted from Angell et al. (2004) and Buabeng (2015), respectively.

Table 2 Question and associated 12+2 items from part C of the questionnaire, adopted from Buabeng (2015) and TIMSS 2015 (IEA, 2014) respectively

How often do the following practices happen in your physics classroom?

- I present new materials on the whiteboard
 - I demonstrate problem-solving on the whiteboard
 - I lay emphasize on mathematical presentation of concepts
 - * I lay emphasize on qualitative thinking and presentation of concepts
 - I use demonstrations and discussions to illustrate concepts/ phenomena
 - I use students' suggestions and ideas in teaching
 - I engage students in context-based activities
 - Students work with physics problems individually
 - Students work with physics problems in groups
 - Students have opportunity to explain their own ideas
 - Students do experiment by following instructions from the teacher
 - Students plan and do their own experiment
 - Students memorize facts and principles
 - Students use scientific formulas and laws to solve routine problems
-

*Item excluded in the analysis (see below)

Data Collection

The aim was to countrywide let as many physics teachers at upper-secondary school as possible respond to the questionnaire. In order to manage this, we contacted the communication unit at the Swedish National Agency for Education which sent us a register of all active upper-secondary schools in Sweden that had a science programme. The register was last updated in June 2016 and based on the information provided by the study counsellors at the respective upper-secondary school to the Swedish National Agency for Education. Email addresses of physics teachers at the schools were obtained via the school's administration or the schools' websites.

A link to the questionnaire was initially sent to 866 teacher addresses. If teachers receiving the questionnaire were not physics teachers, they were asked to inform us in order to be excluded from the project. The sum of the remaining invalid addresses after the complementary search and addresses to teachers who were not teaching physics was 27, and these were deducted from the 866 addresses initially sent to. Eight reminders were sent during the three and a half months the questionnaire was open and the resulting count was 845 recipients. The total number of completed questionnaires eventually received was 379 rendering an answering frequency of 45%. All teachers responding to the questionnaire were offered a lottery ticket.²

² A digital lottery ticket 'Triss' from the state-owned company *Svenska Spel* with opportunities of high winnings.

Table 3 Questions and associated 18 items from part C of the questionnaire, adapted from Angell et al. (2004) and Buabeng (2015). Authors' translation of the Swedish questionnaire

What do you think is particularly problematic for students who are studying physics at upper secondary school? (Angell et al., 2004)

*Learn many new concepts

Understand reasoning and deductions involving mathematics

Use laws and theories in computational tasks

Use mathematics to solve physics tasks

High pace

Much to learn

*Laboratory work

See the connections between physics theories and the real world around us

Discuss physics qualitatively

Sometimes it is seen that the following limits the quality of physics teaching. To what extent do you agree? (Buabeng, 2015)

*Students' perception of physics as a subject

Students' lack of mathematics knowledge

Parents' view that physics and mathematics are difficult

Society's view that physics and mathematics are difficult

The connection between mathematics and physics

A too extensive curriculum

Not enough teaching time

Inadequate laboratory equipment

Lack of technical support

*Item excluded in the analysis (see below)

Analysis and Results

Curriculum Emphases

Teachers' views concerning curriculum emphases were measured with 23 items on the questionnaire with the three scales FP (8 items), PTS (7 items) and KDP (8 items), as depicted in Table 1. Based on a dimension reduction by factors (PCA, with varimax rotation, KMO = 0.83), two items were excluded (one from the FP scale and one from the KDP scale) from the further analysis since their main contributions were in relation to another scale than theoretically expected. The corresponding item to the first excluded item was also excluded by de Putter-Smits (2012). The Kaiser-Meyer-Olkin measure of sampling adequacy (KMO) was 0.83 and thus, the data set was deemed suitable for factor analysis.

Each of the three scales was then subjected to an analysis of internal consistency based on the value of Cronbach's alpha for each scale. Based on the Cronbach alpha values (0.66 for the FP scale, 0.84 for the PTS scale and 0.72 for the KDP scale) and due to the item-to-total correlation, we decided to keep all the remaining items.

The teachers' mean scores per scale (FP, PTS and KDP) were calculated. The higher the mean value is, the stronger the individual has marked agreement with the scale. The

results are presented in Table 4. Generally, the teachers were positive to all three curriculum emphases. Concerning the FP and the PTS scale, the teachers agreed to the same extent. However, the support for the KDP curriculum emphasis was substantially higher than for the other scales.

Teaching Strategy

Teachers' teaching strategies were measured with 14 items (see Table 2). A dimension reduction by factors was conducted (principal component analysis, PCA, with varimax rotation). The KMO was 0.73 and the data set was deemed suitable for factor analysis. The factor analysis together with a qualitative analysis resulted in one item being excluded as it was the only item with no clear contribution to a single factor. We decided on the two-factor solution to the factor analysis due to a qualitative analysis. The items in factor 1 (6 items) were used as a scale measuring *Student-centred teaching* (Active students and focus on understanding), and the items in factor 2 (7 items) were used as a scale measuring *Teacher-centred teaching* (follow teacher and focus on routine problems), see Table 5. Each of the two scales was then subjected to an analysis of internal consistency based on the value of Cronbach's alpha for each scale. Scale 1 had a Cronbach alpha value of 0.70 and scale 2 had a Cronbach alpha value of 0.65. Based on the item-to-total correlation, we decided to keep all the remaining items.

Thus, the focus when scoring high on the scale *Student-centred teaching* is on students being active in the learning situations and an emphasis on understanding, e.g. in terms of explaining ideas and context-based activities. The teacher uses the students' ideas and the students work in groups, design their own experiments and discuss. Opposite, when scoring high on the scale *Teacher-centred teaching*, the teacher describes new areas of physics and solve problems at the whiteboard. The students work individually following the teachers' instructions. They work with routine problems and learn facts and principles by rote.

Mean values for each teacher on the two scales measuring teaching strategy were created, see Table 5. The table shows the means and standard deviations of the teachers' responses. The teachers' answers indicate that they have a teacher-centred practice to a higher extent than a student centred. The results do however not point to any extremes, indicating that the teachers seem to strive for a combination of teacher- and student-centred teaching.

Shortcomings and Problems in the Teaching of Physics

The teachers' perceived problems for students when learning physics and issues constraining the quality of physics teaching were measured with 18 items on the

Table 4 Mean score (min 1, max 5) and SD per scale. See Table 1 for items in the scales

Scale	Mean	SD
FP	3.71	0.50
PTS	3.74	0.57
KDP	4.22	0.44

Table 5 Mean score (min 1, max 5) and standard deviation (SD) per teaching strategy scale

Scale	Items	Mean	SD
Scale 1: Teaching strategy: Student-centred teaching	<ul style="list-style-type: none"> - I use demonstrations and discussions to illustrate concepts/phenomena - I use the students' suggestions and ideas in the teaching - I engage the students in context-based activities - The students work with physics problems in groups - The students have opportunities to explain their own ideas - The students plan and conduct their own experiments 	3.39	0.46
Scale 2: Teaching strategy: Teacher-centred teaching	<ul style="list-style-type: none"> - I go through new content at the board - I solve problems at the board - I emphasize a mathematical exposition of concepts - The students work individually with physics problems - The students do experiments by following my instructions - The students learn facts and principles by rote - The students use physical formulas and laws to solve routine problems 	3.66	0.38

questionnaire (see Table 3). A dimension reduction by factors was conducted (principal component analysis, PCA, with varimax rotation). KMO was 0.72 and thus, the data set was deemed suitable for factor analysis. Based on the factor analysis and a qualitative analysis of the items' contributions to the factors, two items were excluded (with an additional item requiring further analysis) and the five-factor solution chosen. The five factors were used as scales measuring shortcomings and problems perceived by the teachers. Cronbach alpha values for the five scales were in the span 0.73–0.86 (in Table 6) after removing the further analysed item from scale 3 due to the item-to-total correlation and the qualitative analysis based on the items' contributions to the factors.

The teachers' mean score per scale were calculated, see Table 6. The results indicate, even though the differences are not substantial due to the distribution in the material, that the teachers thought the main problem in the physics teaching was too much content to cover in too little time and that practical issues were not as big a problem. Mathematics knowledge and views of mathematics and physics were equally, but not alarmingly, problematic in relation to physics teaching and student learning.

Relations Between Curriculum Emphasis Orientation and Teaching Strategies

A comparison of means concerning the teaching strategy scales for teachers with a mean below respectively above the mean value for each of the three curriculum emphasis scales was performed. Concerning the relation between agreement with FP and teaching strategy, the result shows that teachers having mean values above the mean on the FP scale have higher mean values also for Teaching strategy Scale 2 (teacher-centred teaching) than other teachers have (see Table 7). This difference is statistically significant (t test, level of significance 0.01).

Table 6 Problems and shortcomings as related to five scales

Scale (Cronbach's alpha)	Items	Mean	SD
1: Mathematics (0.75)	<ul style="list-style-type: none"> - Students' lack of mathematics knowledge - Understand reasoning and deductions involving mathematics - Use laws and theories in computational tasks - Use mathematics to solve physics tasks - The connection between mathematics and physics 	3.47	0.62
2: Curriculum overload (0.74)	<ul style="list-style-type: none"> - A too extensive curriculum¹ - Not enough teaching time - High pace - Much to learn 	3.76	0.68
3: Views of mathematics and physics (0.86)	<ul style="list-style-type: none"> - Parents' view that physics and mathematics are difficult - Society's view that physics and mathematics are difficult 	3.46	0.84
4: Qualitative understanding (0.73)	<ul style="list-style-type: none"> - See the connections between physics theories and the real world around us - Discuss physics qualitatively 	3.56	0.79
5: Practical issues (0.73)	<ul style="list-style-type: none"> - Inadequate laboratory equipment - Lack of technical support 	2.83	0.96

¹ If the item were to be removed, the Cronbach alpha value is raised by 0.01. The item was nevertheless decided to remain in the scale after a qualitative evaluation

The results were opposite for teachers agreeing to a high extent with a PTS emphasis (above the mean on the scale) have higher mean value (t test, level of significance 0.01) for Teaching strategy Scale 1 (student-centred teaching), see Table 8. The same is valid for teachers agreeing to a high extent with a KDP emphasis (t test, level of significance 0.01), see Table 9.

Relations Between Curriculum Emphasis Orientation and Shortcomings and Problems in the Teaching of Physics

A comparison of means for teachers with a mean below and above the mean value for each of the three curriculum emphasis scales concerning their perceived problems for students when learning physics and issues constraining the quality of physics teaching, i.e. the five scales from the 'Analysis and results' section, have been performed. Significant differences for the FP scale, with levels of significance below 0.05, were found concerning scales 1 (mathematics is a problem) and 3 (views of mathematics and physics are a problem) (Table 10). Teachers with a high agreement with FP tend to view

Table 7 Teaching strategies in relation to curriculum emphasis FP

	FP mean	<i>N</i>	Mean	Std. deviation
Scale 1: Teaching strategy: Student-centred teaching	≥ 3.71	197	3.39	0.47
	< 3.71	163	3.39	0.45
Scale 2: Teaching strategy: Teacher-centred teaching	≥ 3.71	199	3.74	0.37
	< 3.71	164	3.57	0.38

Table 8 Teaching strategies in relation to curriculum emphasis PTS

	PTS mean	<i>N</i>	Mean	Std. deviation
Scale 1: Teaching strategy: Student-centred teaching	≥ 3.74	180	3.49	0.44
	< 3.74	184	3.30	0.46
Scale 2: Teaching strategy: Teacher-centred teaching	≥ 3.74	183	3.67	0.39
	< 3.74	184	3.66	0.37

mathematics as a problem in the physics teaching. Also views on mathematics and physics are viewed as problems by these teachers. Table 11 shows significant differences between teachers with agreement below and above the mean on the PTS scale concerning problems and shortcomings. Teachers with a high agreement with PTS think that the views of mathematics and physics and practical issues are the most problematic issues for teaching physics. There were two significant differences in the comparison of agreement with KDP and the scales measuring perceived problems and constrains, see Table 12. A high agreement with KDP means that the main problems for physics teaching are too much content and too little time and students' qualitative understanding. No other significant differences were found in the data.

As Tables 10, 11 and 12 show, the only scale occurring twice is scale 3, i.e. views of mathematics and physics, in Tables 10 and 11. The rest of the scales is spread over the three curriculum emphasis scales implying different aspects of importance in the physics teaching.

Discussion and Implications

In previous literature, different teaching traditions and curriculum emphasis have been described. The 'Traditional school science' tradition is characterized by the curriculum emphasis 'Foundational physics' and teacher-centred lectures, and the goal for students is 'to memorize scientific knowledge and procedures' (Zacharia & Barton, 2004). For upper-secondary physics, this kind of teaching often means a focus on solving standard physics problems (often appearing at the end of a chapter in physics textbooks) (see e.g. Due, 2009). This teaching tradition has been found problematic for different reasons; for example, students can often solve such problems without understanding the concepts and theoretical models used (Hobden, 1998).

Table 9 Teaching strategies in relation to curriculum emphasis KDP

	KDP mean	<i>N</i>	Mean	Std. deviation
Scale 1: Teaching strategy: Student-centred teaching	≥ 4.22	178	3.46	0.45
	< 4.22	185	3.33	0.46
Scale 2: Teaching strategy: Teacher-centred teaching	≥ 4.22	177	3.69	0.40
	< 4.22	189	3.64	0.36

Table 10 Significant differences between scales 1–5 and agreement with FP

	FP mean	<i>N</i>	Mean	Std. deviation	Sig. (two-tailed)
Scale 1: Mathematics	≥ 3.71	193	3.53	0.67	0.04
	< 3.71	164	3.40	0.54	
Scale 3: Views of mathematics and physics	≥ 3.71	199	3.56	0.81	0.02
	< 3.71	163	3.35	0.86	

In this article, we have reported from a study on Swedish upper-secondary physics teachers' support for the three curriculum emphases 'Fundamental Physics' (FP), 'Knowledge Development in Physics' (KDP) and 'Physics, Technology and Society' (PTS) (cf. van Driel et al., 2008). It was found that the teachers overall were positive to all three curriculum emphases. However, the support for the 'Knowledge Development in Physics' curriculum emphasis was substantially higher than for 'Fundamental Physics' and 'Physics, Technology and Society', with which the teachers agreed to a similar extent. It is interesting that 'Knowledge Development in Physics' and not 'Fundamental Physics' is the one with the highest degree of support, as 'Fundamental Chemistry' was for the Dutch chemistry teachers (van Driel et al., 2008). This result is however in line with the results by de Putter-Smits et al. (2011) where the physics teachers supported the 'Knowledge Development in Science' emphasis.

The results from this study of Swedish upper-secondary physics teachers might be an indication of a shift away from traditional science teaching traditions, where teachers have developed support also to other aims of physics teaching. Both 'Science Technology Society' and 'Socio-scientific issues' approaches (with similar goals as the curriculum emphasis 'Physics, Technology and Society') and 'Nature of Science' approaches (with similar goals as the curriculum emphasis 'Knowledge Development in Physics') have reached increasing support in international science education research and in policy documents. This study shows an almost equal support for PTS and FP and most support to KDP. KDP might be a smaller step away from traditional physics teaching and might therefore function as a bridge between FP and PTS approaches to science teaching. The KDP emphasis includes 'Nature of Science' (Erduran & Dagher, 2014; Lederman, 2007; McComas, 2017) aspects, and such knowledge could be valued both in the perspective of educating future scientists and in relation to a more citizen-oriented teaching. It could also (though this is seldom the case) be coupled to labwork and to a teaching focused on concepts and models (see e.g. Hansson & Leden, 2016). It might be natural for science teachers to couple KDP to the preparation of future

Table 11 Significant differences between scales 1–5 and agreement with PTS

	PTS mean	<i>N</i>	Mean	Std. deviation	Sig. (two-tailed)
Scale 3: Views of mathematics and physics	≥ 3.74	180	3.59	0.86	0.05
	< 3.74	186	3.35	0.81	
Scale 5: Practical issues	≥ 3.74	181	2.94	0.99	0.03
	< 3.74	186	2.72	0.93	

Table 12 Significant differences between scales 1–5 and agreement with KDP

	KDP mean	<i>N</i>	Mean	Std. deviation	Sig. (two-tailed)
Scale 2: Curriculum overload	≥4.22	179	3.88	0.67	0.003
	<4.22	184	3.67	0.67	
Scale 4: Qualitative understanding	≥4.22	179	3.71	0.84	0.001
	<4.22	188	3.43	0.72	

scientists, which is in line with the results from the study by van Driel, Bulte and Verloop (2008) who found that KDP had more support in respect to the course preparing for university studies than in respect to the general course. Thus, the support for KDP among Swedish physics teachers might be due to the fact that the teachers in our study teach at the science programme and/or the technology programme, both preparing for university studies in science/technology. The fact that KDP received more support than PTS indicates that this can be the case and that ‘Nature of Science’ perspectives, which are in focus in many of the KDP items, are viewed as a means to prepare for future science studies, rather than as a means to become an active citizen.

The analysis of the investigated physics teachers’ views of teaching strategies gave that the teachers on average could be said to marginally favour teacher-centred teaching compared with the other scales of student-centred teaching. The fact that both strategies came out quite similarly in not radically favouring teacher-centred teaching is in concurrence with Swedish students’ responses to PISA 2015 questions, which places Swedish science teachers below, but only marginally so, and close to the OECD average for teacher-centred teaching (Mostafa et al., 2018, p. 43). Concerning perceived shortcomings and problems, the study shows that teachers view *curriculum overload* related to allotted time as the main problem in physics teaching. *Knowledge of mathematics* and *views of mathematics and physics* were less problematic and *practical issues* were not a problem at all. It concurs somewhat with the results for physics teaching in Norway (Angell et al., 2004), where the fast progression and the physics curriculum were put forward as problems to be looked into. The Norwegian teachers found using mathematics to describe physical phenomena the most problematic issue, whereas the Swedish teachers found it less problematic.

The result of the study reported on here points to relations between teachers’ support for the different curriculum emphases on the one hand and on the other hand their reported teaching approaches and views upon shortcomings and problems in the physics teaching. As discussed above, the teachers on average could be said to marginally favour teacher-centred teaching compared with the other scale of student-centred teaching. However, the results show differences coupled to teachers’ agreement with different curriculum emphases. Teachers with high agreement with ‘Fundamental Physics’ (FP) tend to view *mathematics* and *views on mathematics and physics* as problems in physics teaching (Table 10). These teachers also agree to a higher extent with items implying *teacher-centred teaching* strategies (Table 7). Teachers with a high agreement with ‘Physics, Technology and Society’ (PTS) think that *views of mathematics and physics* and *practical issues* are the most problematic issues for teaching physics (Table 11). These teachers agree to a higher extent with *student-centred*

teaching strategies (Table 8). Finally, high agreement with ‘Knowledge Development in Physics’ (KDP) means that the main problems for physics teaching are *curriculum overload* and *students’ qualitative understanding* (Table 12). These teachers agree to a higher extent with items implying *student-centred teaching* strategies (Table 9). Thus, this study shows relations between the curriculum emphasis supported by teachers, their teaching approaches and the hindrances perceived in their teaching.

Mathematics has often been reported a problem in the teaching of physics. In this study, mathematics is still viewed a problem, but not the biggest problem. It is also the case that it is mostly a problem for teachers with a high agreement with FP, whereas teachers with high agreement with PTS and KDP did not view mathematics as an equally big problem. The reason why mathematics is viewed as a bigger problem by FP teachers is open for further investigation. However, the traditional physics teaching culture most often means a focus on calculations. For upper-secondary physics, Due (2009) has reported on a focus on mathematical solutions of physics problems, and similar, but in a university physics course on quantum physics, Johansson et al. (2018) show how a “‘shut up and calculate’-culture” is being reproduced with the result that discussions on epistemology and on science’s role in society are excluded (p. 222). It might be that in classrooms led by teachers emphasising PTS and KDP, the role of mathematics becomes different. Thus, the possible shift away from traditional science (physics) teaching including its dominating focus on a FP emphasis, that this study might be an indication of, might also have as a consequence that mathematics is not viewed a problem to the same extent anymore. Such a possible shift is supported by the difference between the results from the Swedish teachers in this study and the Norwegian teachers in the study from 2004 (Angell et al., 2004), since these two countries have similar teaching traditions (Mostafa et al., 2018, p. 43).

An interesting question then becomes how mathematics is used and handled by teachers and students in classrooms with a KDP or PTS curriculum emphasis. Another interesting question is how differences on teaching and attitudes among the teachers affect the actual physics teaching and students learning of physics. Hence, the results reported on here calls for further and detailed analysis of practices in physics classrooms, with detailed qualitative investigations of relationships between curriculum emphasis, teaching strategies (including how mathematics is used and handled by teachers and students) and students’ learning outcomes. Such research is ongoing and will be published by the authors in future publications.

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