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Teachers' and principals' reflections on student participation in a school science and technology competition

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ABSTRACT

Background: The European Union asks for renewed pedagogies in schools according to teaching strategies and necessary competences for the twenty-first century, instead of the often-used transmissive pedagogies. The national Swedish competition in science and technology for grade eight, The Technology Eight, provides an opportunity for teachers to work with instructional strategies in line with suggested pedagogies.

Purpose: To investigate teachers' and principals' reflections on the competition in schools.

Sample: Seventeen secondary school teachers and three principals from districts in the south-western part of Sweden participated in the study. All teachers had long experience of the competition, and their classes had reached at least the regional finals during the last year.

Design and methods: Semi-structured interviews were recorded, transcribed verbatim, and then analysed using content analysis. Focus was put on why the teachers decided to participate, how the teachers integrated the competition in their education and roles of the principals.

Results: There were various reasons for participating in the competition. Teachers reported development of twenty-first-century skills such as better cooperation between the students. They also noticed an increased interest in science and technology and how learning in the subjects was stimulated. Furthermore, the teachers found participation in the competition to be positive for them too. They integrated the competition in ordinary education and gained teaching ideas as well as found connections to the curriculum. Participating in the competition seemed to be a tradition in most of the schools. The principals' role was to facilitate the organisation around the competition and to provide social support.

Conclusions: Participation in a school competition was considered as an instructional strategy with several positive outcomes. Use of this strategy can be supported by earlier suggestions to use pedagogies that are opposite to transmissive methods, enhancing students' development of important skills for the future.

KEYWORDS

Principals' reflections; school competitions; STEM; teachers' reflections

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Introduction

In many developed countries, there is a problem with young people's low interest in science education (e.g. Fitzgerald, Dawson, and Hackling 2013; Hofstein, Eilks, and Bybee 2011; Holbrook 2003; Osborne and Dillon 2008). This has also been reported in international studies (i.e. the ROSE project, Schreiner and Sjøberg 2004). Students' choices of STEM (Science, Technology, Engineering, Mathematics) education depend on several factors such as interest, family, cultural influences and quality of teaching (Tytler 2014). However, the teacher's role, in general, (not only in the teaching of STEM subjects) has been emphasised as the most important factor for student achievement (Hattie 2008). Being aware of the intention of teaching, varying and adapting to students interests are examples of teaching abilities that support students' learning (Hattie 2008).

During the past few years, the European Commission has pointed out the need for change in instructional strategies in teaching science (EC 2007), as noted by Osborne and Dillon (2008). Transmissive methods in teaching have been criticised for failing to emphasise practical problem-solving and critical thinking (Brown, Collins, and Duguid 1989). Lyons (2006) found in his study that students encountered transmissive pedagogies in teaching, and that the content was decontexualised. Lyons suggested that this could be a factor influencing students to perceive school science as a field difficult to understand and thus, not interesting. Hannafin and Land (1997) argued that learning systems that encourage students to engage in divergent reasoning, problem-solving and critical thinking are needed.

Hence, in this study, we present how teachers and principals reflect on the usefulness of participation in a STEM competition as an instructional strategy. We argue that this can be one instructional strategy for stimulating students' interest in learning STEM and supporting their development of problem-solving and critical thinking.

Competitions in science and technology

International studies from U.S., Canada, Japan, Australia and Europe show statistical significance between students who participated in competitions and their future choice of graduate studies in science and technology (Fisanick 2010; Sahin 2013; Woolnough et al. 1997). Results have indicated that participation has been successful in stimulating interest in science and technology. The phenomenon of competition has been around for a long time, organised by prominent organisations, such as the Royal Society in Britain and the American Museum of Natural History in the US, as well as various companies, for example, Siemens.

From a Swedish perspective, a government commission was appointed in 2008 to investigate the efforts made to change the trend of students' low interest in learning science and technology (Teknikdelegationen [the technology commission] 2010). When the commission presented its survey, the multitude of various competitions earned a chapter of its own. However, the commission mentioned that research on the phenomenon of competitions were lacking.

Purpose and enactment of participation in school science and technology competitions

Analysis of earlier studies on using competitions in STEM education identified seven possible motivations for teachers to use them, as the competition is assumed to:

- stimulate interest in STEM
- stimulate the learning of twenty-first-century skills such as problem-solving, collaboration, communication and analytical thinking
- support career decisions
- stimulate knowledge about how research is conducted
- connect to curriculum and tests
- be conducted because of expectations from school administration
- be because teachers have a competitive nature

Teachers in Fisanick's study (2010) strongly agreed that science fair competitions promoted students' interest in science. Researchers (Huang, Chiu, and Hong 2016; Law, Lee, and Yu 2010; Sahin, Gulacar, and Stuessy 2015) argued that participation in STEM competitions has positive effects on students' problem-solving and critical thinking skills. The teachers in Fisanick's study (2010) also believed that competitions provided opportunities for students to develop communication skills and to interact with each other. Collaboration, communication, problem-solving and analytic thinking are examples of skills that have been defined as twenty-first-century skills (Bell 2010; Jerald 2009).

Researchers have also argued that participation in science competitions supports students in their decisions about science careers (Abernathy and Vineyard 2001; Sahin, Gulacar, and Stuessy 2015). Furthermore, Fisanick (2010) found that teachers believed that competitions provided opportunities for students to learn about how research is conducted.

All the reasons mentioned so far relate to effect on students. However, Fisanick (2010) found in her study that teachers' motivations to engage their students in competitions could also stem from curriculum and standardised test requirements. Finally, another reason could be based on school administrators' expectations or competitive nature of the teacher.

The only discussion found on of *how* teachers use competitions in STEM teaching during their enactment in the classroom was made by Verhoeff (1997). He discussed how some educators used competitions as breaks from the regular curriculum, while others argued that competitions can motivate students and should be based on what is taught in school and hence, incorporated into the curriculum.

The role of principals

The connection between school competitions and the role of principals has, to our knowledge, not been discussed specifically in research, apart from Fisanick's (2010) study where teachers felt that participation in competition was expected of them.

However, the role of principals is important for STEM education from a generic perspective, although reports from this perspective are few. The emphasised arguments are that:

- support from principals in STEM education is of importance
- principals often lack a STEM education themselves
- teachers need practical support from principals

Holdren, Lander, and Varmus (2010) presented arguments about the importance of support from principals to achieve successful STEM education. Furthermore, Holdren and colleagues (2010) claimed that principals often lack understanding of STEM fields or STEM education and argued that if principals had greater awareness of these subjects, they would be more likely and more able to nurture rich STEM learning experiences and expertise in their schools. The effect of principals lacking STEM education was also discussed in a recent study by Lochmiller (2016) who explored how principals provided feedback to teachers in mathematics and science. They focused on pedagogy and not on content understanding, and were anchored in their earlier experiences as teachers. The conclusion was that principals must recognise how their own position in a particular subject subculture influences the feedback they provide to classroom teachers. In a study by Fulton and Britton (2011) of STEM and teachers learning through communities, it was emphasised that teacher teams need the support of principals and administrators in practical issues. It was argued that it is important that the teacher teams are provided with space and time to meet, as this empowers them to make decisions based on student needs.

Theoretical perspective

The theoretical framework in this study is related to the construct Pedagogical Content Knowledge (PCK) since knowledge about instructional strategies are considered to be part of this construct (Shulman 1986, 1987). Research on PCK has grown since Shulman first presented the notion in the 1980s, and it has been discussed, developed and used by several researchers (e.g. Gess-Newsome 1999; Kind 2009; Nilsson 2014). In 2015, a new model of teachers' professional knowledge was presented by Gess-Newsome. The author presented the model as a consensus model of teachers' professional knowledge and skills (TPK&S). The model is complex and consists of several parts and interactions. Compared to earlier models of PCK (e.g. Magnusson, Krajcik, and Borko 1999), students' role is emphasised and presented as students acting as amplifiers and filters. Responses from students are connected to PCK as they influence what occurs in the classroom (Gess-Newsome 2015). The author claimed that students' responses could have an effect on, for instance, the choice of instructional strategies. If a teacher meets resistance from students, it may result in decreased willingness to implement new instructional strategies. It could also be assumed that if students respond positively to implementation of activity-based instructional strategies, it would strengthen the teachers in their choice of using these kinds of strategies in their teaching. Furthermore, the TPK&S model has an additional section about classroom practice compared to the PCK model presented by Magnusson, Krajcik, and Borko (1999). Gess-Newsome (2015) presented that the classroom context, for instance, can depend on access to materials, support, school culture, amount of time available for planning, etc. All of the factors can influence teaching decisions; however, not all of the contextual features are within the control of the teacher (Gess-Newsome 2015). In this study, sections about the role of students acting as amplifiers and filters and classroom practice are used, in particular, in the data analysis.

Aim and research questions

Since studies on aspects of competition in science and technology are few, knowledge about teachers' purposes of choosing to participate with their classes is an interesting gap to fill.

The competition *Teknikåttan* (in English *The Technology Eight*), covering both science and technology, has long tradition in Sweden, and schools in the whole country participate. However, no research study has ever been conducted on the competition. Therefore, the aim of this study is to investigate aspects of *The Technology Eight,* through reflections of teachers in science and technology. We are also interested in how teachers implemented the use of the competition in their class-rooms. Since support from school organisations are of importance in teachers' work, reflections from principals are also of interest.

The research questions are:

(1) Why do teachers use school competitions like *The Technology Eight* as one of their instructional strategies in teaching science and technology?
(2) How do teachers work with the school competition as part of teaching in science and technology?
(3) What is the role of the principals when classes participate in the competition?

Method

The research context

Already in 1993, a competition for school classes (grade eight, students aged 14) was introduced (Teknikåttan 2015). Teachers from a university in Sweden organised the competition, which was only locally arranged. The competition, *The Technology Eight*, despite its name, included questions about science, technology and mathematics, with an emphasis science. The aim of the competition was, and still is, to stimulate student's interest in learning science and technology. Furthermore, the questions were constructed in order to stimulate problem-solving and creative thinking, as well as relating to students' everyday life. In 2000, the competition was further developed and became a national event organised by universities across Sweden. Technology has gained a more important part in the competition during the last few years. This is shown with the emphasis on a class challenge, based on technology issues now included as major part of the competition.

Since the competition covers all topics in STEM, and has been held for several years and involves numerous students (30,000 students participated in 2015), it is interesting to study different aspects of *The Technology Eight*. The competition consists of three different levels: the selection round (which takes place in the schools), regional finals (which take place at the university in the region where the schools belong) and finally, a national final (which takes place at a university based on an itinerant schedule). In the selection round, students individually answer 15 multiple-choice questions. The results from the first round are then used as a device to select classes to proceed to round two. Two months before the second round, the classes are given a challenge, focused on technical solutions and creativity, design and problem-solving. The challenge also requires students to cooperate and work as a team. In the final round, the challenge is developed and once again presented. During the second and third rounds, there are also questions and practical tasks given to a smaller group of students from each of the classes. Examples of questions from each of the rounds are presented on the website of the competition (only in Swedish). However, this website is only presented in Swedish. See translated examples in Appendix 1 and 2.

Participants

Secondary school teachers teaching in science and/or technology, who had participated with school classes in the competition *The Technology Eight*, were invited to participate in the study. A prerequisite was that the classes had reached at least the regional finals in the competition in 2015. In fact, when classes had been selected, it turned out that two of the classes had also reached the national final. All invited teachers accepted to participate, representing seven different schools located in seven small town districts in south-western Sweden. The decision to invite these teachers was based on the fact that a great deal of work is needed to reach the regional and national finals. This work also encompassed solving a class challenge, given to the classes before the regional and national finals. In total, 17 teachers and three principals participated in the study. The teachers are presented as T1 – T17 and the principals as P1 – P3.

Data collection

Semi-structured interviews were performed with teachers and principals at their schools. If more than one teacher at the school had participated in the competition, the teachers were interviewed together. At those schools where the principals also agreed to be interviewed, she/he attended the same interview as the teachers. However, the question of how the teachers were supported by their principals was posed to the teachers without the presence of the principals. The interviews were audio recorded and transcribed verbatim. Each interview lasted 40 to 60 min. Altogether, seven interviews were carried out. The first author performed the interviews. Interview questions are found in Appendix 3.

Data analysis

Data were analysed using three different approaches. First, the transcribed interviews were analysed based on the research questions, using content analysis as described by Cohen, Manion, and Morrison (2011). The transcripts were read repeatedly by each of the authors independently. During the reading, the research questions were in focus, and the authors searched for emerging themes in the transcripts. The themes ended up in different categories depending on the research question. After identifying categories, the authors compared their categories and reached consensus after discussions.

In the second approach, data were analysed with parts of the TPS&S model presented by Gess-Newsome (2015) as an analytical framework. The parts of the model included in our analysis were: knowledge about curriculum, instructional strategy, teachers' implementation in the classroom, the context and students' behaviours and outcomes. Using the TPK&S model for data analysis, some rationale is necessary. Gess-Newsome (2015) argued that the model could 'predict a way to think about teacher knowledge and action, and allow for extant research to be situated within the model or reconceptualised based on relationships and definitions presented' (30).

The model has a foundation in teacher knowledge bases such as pedagogical, content, assessment and curricular-knowledge, as well as knowledge about students. Furthermore, it includes aspects such as instructional strategies, context, classroom practice, enactment, curriculum and student behaviours and outcomes. In our study, the use of a competition as

an instructional strategy was in focus. The competition covers many topics and even many subjects. The teachers do not know the topics that will be included before the competition. Some questions and tasks are topic specific, but the focus in the competition is more on development of twenty-first-century skills, such as cooperation, communication and problem-solving. Still, we found the model useful. It includes knowledge of instructional strategies, hence, this should include knowledge of the purposes of using a certain strategy.

Finally, in a third approach, data in the transcripts were compared with the list of findings from earlier research. The list mainly showed findings that connected to our first research question; hence, the approach served as a complement when the question about why teachers use competitions as an instructional strategy was investigated.

Limitations

Confirmability was guaranteed by the many citations presented, follow-up questions posed to the informants, if needed, and having two authors independently and repeatedly read the transcripts, categorising the data and following consensus discussion deciding which categories to use. Concerning credibility, the choice of the interview method was deemed to give the most relevant information. The informants were interviewed in groups, which could result in both advantages and disadvantages. However, it was regarded that the advantages outweighed the disadvantages, for example, the answers probably were richer and explained more clearly, as two or more informants could view a question from different perspectives (Cohen, Manion, and Morrison 2011). As the results are based on interviews with only 17 teachers and three principals, it must be stressed that this is a restricted study; however, it still gives a glimpse of how some teachers and principals experienced the competition *The Technology Eight*.

Results and discussion

Data answering the three research questions were analysed using the three different analytic approaches (content analysis, the results in relation to the TPK&S model and in relation to earlier findings).

Reasons to participate in the competition

Answers to the first research question of why teachers chose to participate in the competitions were several. Content analysis revealed two overarching categories in this section: *Effects on students* and *Aspects for teachers* (Figure 1).

Taking *Effects on students,* three sub-categories were identified as reasons why teachers perceived they participated in the competition, namely:

- social aspects
- stimulate interest for science and technology careers
- stimulate learning in science and technology

First, social aspects with students' participation in the competition, such as how to unite the class and encourage students to cooperate, were brought up by teachers as well as by two of the principals.

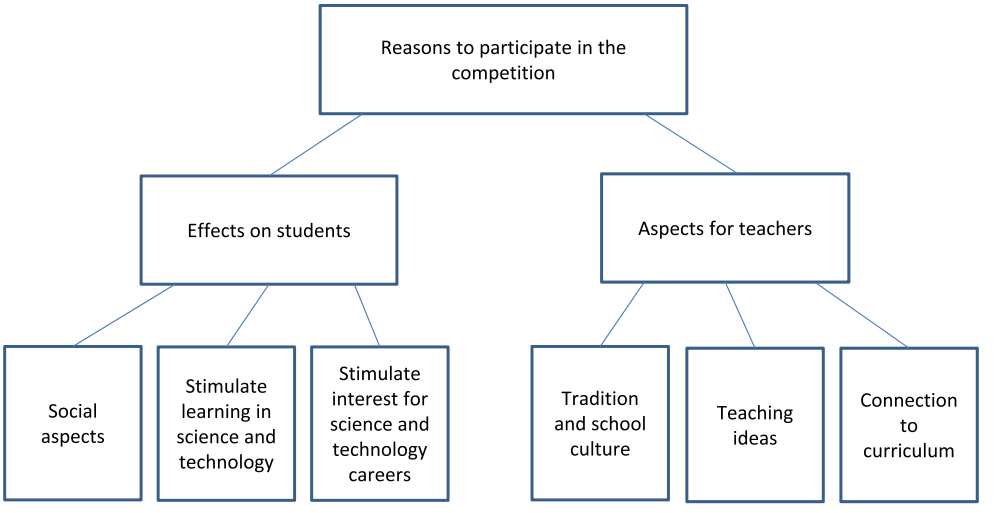

Figure 1. Categories and sub-categories analysed to answer the first research question, *Why do teachers in science and technology attend school competitions like* The Technology Eight *with their school classes*? The answer is divided into the categories *Effects on students* and *Aspects for teachers*, which are further divided into six sub-categories.

T2: They cooperated and became united.

P1: Yes, they were more united as a school class.

T1: Everyone had a role.

Other teachers and a principal argued:

> We would not continue to participate if we did not notice the positive effects on the students. We notice how they get engaged … the increased interest, but also how they get closer to each other, they are part of a context; this is important for us as human beings. [T11]

> To have a good team, different qualifications are necessary. It is not only about theoretical knowledge. It is also important with cooperation, being able to listen to others, to have some creativity; several pieces are needed. [T6]

> The most important is not to win, but having fun together during the process; we do things together which are stimulating. [P3]

The social aspects of participating in the competition relate to one of the twenty-first-century skills (sometimes called cooperation, or collaboration, e.g. Jerald 2009; Bell 2010). This aspect was one of the most emphasised behaviours of students reported in our study. Student behaviours are argued as a factor influencing teachers' choice of instructional strategy (Gess-Newsome 2015).

Secondly, in terms of stimulating the interest of students for science and technology careers, the teachers argued that participation stimulated their students' interest, motivation and engagement in science and technology. They mentioned how students wanted to work with the class challenge even though school had ended for the day.

> I must tell you, last year, when it was time to go to the competition … we had students who came to school in the afternoon, after school, to be able to work with the class challenge. That is cool, it really engages them. [T9]

One teacher mentioned how positive it was to actually be able to compete in science and technology, not only in sports. She argued that this was a motivation for the students. Other teachers also mentioned how their students appreciated the competition.

> It is great that it is possible to compete in our subjects and not only in sports. It can serve as motivation for students who like science and technology. [T10]

> Many students enjoy competing; they want to learn because of the competition. I do not need to tell them, they want it all by themselves. [T16]

> Well, they [the students] make an extra effort just because it is a competition. [T7]

One of the principals explicitly argued that the competition helped students to gain more knowledge about future careers in science and technology.

> I believe that through this competition, the students can realise what science and technology really are, things they cannot learn in a traditional school environment. They can gain some insights into what it means to have a future career as a scientist, what kind of problems they can solve in the future, and if they want to continue studies in this field. [P2]

Stimulating students' interest in science and technology, in general, was supported in the data and in line with the findings of Fisanick (2010) swoving that participation in a STEM competition had this impact on students. Earlier findings (Abernathy and Vineyard 2001; Sahin, Gulacar, and Stuessy 2015) on how participation in competitions supports career decisions was also confirmed as one of the effects on students in our study.

Thirdly, teachers argued that the competition was particularly good for students who were low-achieving and how other competencies than the usual ones shown in a classroom became important. This also affected students' choice of future studies. Hence, in this argument, there is an overlap between the category of stimulated interest in science and technology careers and stimulated learning in science and technology. For example:

> T13: In the class I had two years ago, which managed to go all the way to the national final, there were other students who had never shown any particular interest in science earlier. Then, all of a sudden, in this competition, they 'exploded' and started to 'take place', they were taking over, driving the project forward … and it continued … They have developed a lot in all science subjects after *The Technology Eight*.

> Interviewer: Still, in grade 9?

> T13: Yes, they have changed their minds about the programmes they wanted to study at higher secondary school. Before they wanted to study social subjects, and now they are interested in science and technology programmes … When you work this way, there are other students who get the possibility to show what they can do. They are able to show other competencies in technology compared to those shown in traditional school subjects.

The finding of stimulated learning in science and technology, in general, was previously mentioned by Fisanick (2010), but we have not found any earlier studies reporting that participation in STEM competitions has been particularly positive for low-achieving students.

The teachers perceived all three of the sub-categories presented relating to the effects on students positively. Hence, this probably had an impact on the teachers and motivated them to use participation in the competition as one of their instructional strategies when teaching science and technology. We argue that this is supported by the model of Gess-Newsome (2015) in which the students are included as amplifiers and filters affecting the teachers' choice of instructional strategy.

The only aspect relating to effects on students that was reported in earlier findings (Fisanick 2010), but not found in our data, was that students learned how research is conducted. This was not a surprise as this is not an aspect included in *The Technology Eight* competition. On the other hand, the findings from our study emphasise the impact of the competition on the social benefits for the students which have not been highlighted in earlier research, as well as the competition being positive for low-achieving students.

The second main reason for the teachers participating in the competition was its importance to the teachers themselves, categorised as *Aspects for teachers* (Figure 1), for which three sub-categories were identified:

- tradition and school culture
- teaching ideas
- connection to curriculum

First, the sub-category tradition and school culture was argued as one of the reasons for participating in the competition. This was an argument both from a teacher and principal perspective.

> We participate because it is a tradition. [T1]

> We participate in many things, not only in *The Technology Eight*. It is part of our school culture. I like it too and I'm interested even if I do not have an education in science … it is just part of the culture. [P2]

However, one teacher had not reflected so much on the reason for participating.

> We have always participated in the competition. It is a good contribution in our teaching. We do not reflect so much; we just go for it. [T13]

The connection to tradition and school culture as a factor having an influence on the reason for participating in the competition is supported by the TPK&S model by Gess-Newsome (2015). The model discusses the classroom context as a factor having an influence on the teaching, including school culture and tradition. Fisanick (2010) mentioned that participation in competitions was something that was expected from the school administration, hence, maybe a matter of school culture and tradition.

Secondly, in the sub-category about teaching ideas, the teachers argued that the competition provided them with ideas to use in their teaching, and pointed out how the competition related to life outside school.

> Well, there are good questions and tasks to use in discussions, a lot of connections to everyday life … and when they work with the class challenge, it is something they do, not just for our sake, but it is more for real, it counts … [T6]

> I think this is good teaching. Something that lasts. There is life after school; these things they learn are good knowledge … They are good questions and tasks to use in the teaching. Technology in school, there is a risk that it does not have any purpose. The purpose is not that it should be a subject only for fun, but that they can have some use for it outside school, and in a future working life, to solve problems, to be able to construct things, I think that is important. [T16]

Arguments about the teaching ideas and how the tasks in the competition were good from the teachers' perspective relate to the part of the TPK&S model (Gess-Newsome 2015) which is discussed as topic-specific professional knowledge and thus, of importance for the teachers. Gess-Newsome (2015) provided an example of this as knowing how to integrate science and engineering practices.

We have not found any arguments in earlier research suggesting that the reasons for teachers to participate in school STEM competitions are related to gaining teaching ideas. Hence, this is a new finding in our study, adding a reason to use competitions as an instructional strategy.

Thirdly, in the sub-category connection to curriculum, the teachers and principals found support to participate in the competition. They noticed that the questions and the class challenge were connected to learning objectives in the curriculum, thus, being a natural part of their teaching. According to the teachers, this was particularly obvious in the class challenge relating to learning objectives in technology.

> The tasks are very good; they develop the students, and us as well. [T12]

> What the students do in the competition, especially in the class challenge, is part of the assessment of how they reach the learning objectives, but not everything is covered in the task, of course. Some things in technology are included like making sketches of constructions; it depends on the challenge … [T6]

Arguments for support in the curriculum were also used by one of the principals:

> Yes, that is why I think it is important that the competition is part of ordinary teaching … because it goes well with the learning objectives in the curriculum. [P3]

Teachers in our study found support in the curriculum; this was supported by findings from Fisanick (2010). Knowledge about curriculum is also part of the TPK&S model and related to knowledge about instructional strategies (Gess-Newsome 2015).

Summarising the analysis of data providing answers to the first research question, we argue that the reasons for teachers to participate in *The Technology Eight* competition were similar to earlier findings in terms of having effects on students' interest in learning science and stimulating the learning of twenty-first-century skills (e.g. Fisanick 2010; Karp and Maloney 2013). The teachers in our study argued that their students developed similar skills and emphasised that other competencies than those usually shown in the classroom became important. Of special interest were arguments on how the competition stimulated the social aspects among the students, but also how it stimulated learning for low-achieving students. It was also particularly emphasised that the students appreciated taking part in a STEM competition, as most often competitions are related to sports. To our knowledge, these arguments have not been reported before as explicit arguments for participation in STEM competitions.

The effect on students also affected the teachers and their use of instructional strategy since there are interactions between students' responses and teachers' PCK as shown in the TPK&S model (Gess-Newsome 2015). The arguments from our teachers showing that participation in the competition also had positive effects on them, were from our point of view even more emphasised compared to findings in earlier studies.

The competition as part of teaching in science and technology

Content analysis of the answers to the second research question of how teachers used the competition as part of their teaching in science and technology resulted in two main categories: *As part of ordinary teaching* and *Practical arrangements.*

All teachers argued that they integrated the competition as part of their ordinary teaching in science and technology. None of the teachers used the competition only as an add-on.

Digging deeper into the question of how the teachers used the competition as part of their ordinary teaching, three sub-categories were revealed:

- using earlier competitions
- teachers working alone or in a team
- in cooperation with other subjects

First, the sub-category using earlier competitions showed how questions from previous competitions were often used in teaching. They could be used in lessons as preparation for the upcoming competition, or before national tests, as well as whenever appropriate.

> They [the questions in the competition] serve as good foundation for discussions, which we can use during the lessons. They are also possible to use as preparation for the competition, but we have not done that to a great extent. We have rather used them in everyday situations, and when we work with some fields it's possible to pick things from *The Technology Eight* … it is simply a natural part of the daily work. [T10]

> The students have used questions from earlier years as preparation for the competition. They have studied old questions. [T13]

> I have used questions from the competition as preparation for national tests. [T11]

Secondly, the sub-category of how teachers work with competitions related to whether they worked alone or in teams. It was reported that most of the teachers worked together in preparation for the competition, and that this was a winning concept.

> … it is about having a team of teachers with a permissing working climate. We are pleased with everyone who is successful; we try to cultivate the sense of being important, popular and competent. And this can also include failing, but you should nevertheless be wanted in the team … all share their good examples, that's also a success. [P3]

> No, we have no special enthusiast; it's more the whole working team. [L11]

In one of the schools, three teachers discussed their cooperation in the science team and reflected on how their positive cooperation seemed to pass on to the students:

> T3: I think we are rather humble …

> T1: There's no one thinking she/he is better than the others.

> T2: We have incredible fun together and the students could see this. Thanks to this, it's a little bit easier to get the students' attention.

However, two of the teachers in our study worked all by themselves and had no problems in participating in the competition with their students without support from colleagues, working together in a team. An example:

> Interviewer: So, you had to work with the competition all by yourself. You did not have any support from colleagues; you did not work in a team?

> T17: No

> Interviewer: How did you feel about that situation? Would it not have been good to have some colleagues working together with you? It must have been a lot of hard work for you?

> T17: No, it worked just fine. It was not any hard work. Not at all.

Thirdly, the sub-category of how teachers worked with the competition presented how the teachers in some schools also worked in cooperation with teachers in other subjects. In these

schools, teachers of subjects such as Swedish, English, mathematics and handicraft collaborated

> As in the last competition when we had Swedish, English and mathematics, it was great benefit to integrate several subjects, to get more resources, more teachers to participate, more and bigger responsibility tasks, which we could deliver to the students. Then, it's not only the traditional classroom tasks … but also language and esthetical parts. They [the students] write this log-book in the form of a blog, so we could put in some films and pictures, and so we also made some reports both in Swedish and English. This is good for the result and the good spirit in the class. [T11]

> Several teachers have been involved, and we have been like a team working together. The teachers in handicraft were also very active in this. There have been many to discuss things with, not just a one person task. [T10]

As mentioned, the only study we have found discussing how teachers work with competitions presented that teachers used it either as integrated part of their ordinary teaching or as an add-on (Verhoeff 1997). Hence, our findings reporting how the teachers used the competition as part of their ordinary teaching, using ideas from the competition in their teaching, are new.

Returning to the main categories of how teachers worked with the competition, the second main part *Practical arrangements* (Figure 2), contained several practical aspects divided into three sub-categories:

- more time or ordinary schedule
- more group work
- to involve other students

First, in the sub-category more time or ordinary schedule, teachers discussed how much time they used for the competition. Some of the teachers only used the scheduled lesson

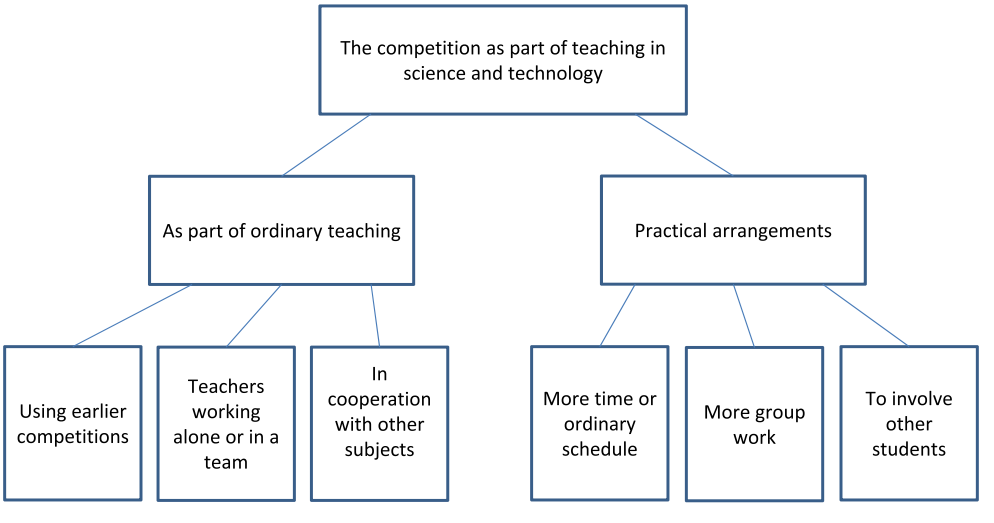

Figure 2. Categories and sub-categories analysed to answer the second research question, *How do teachers work with the school competition as part of their teaching in science and technology*? The answer is divided into the categories *As part of ordinary teaching* and *Practical arrangements*, which are further divided into six sub-categories.

time to prepare for the competition, while others reported how they needed more time, especially with the class challenge task.

> Interviewer: How did you handle the situation with being selected to the second round, did you need extra time for preparations?
>
> T17: No, we just used the ordinary lessons in science during a couple of weeks.
>
> T3: We had planned three to four weeks [for the class challenge]. That is the time we usually have for technology, but it was not enough, we needed more time.
>
> Interviewer: So, as a teacher, is that something you are worried about, not having enough time?
>
> T1: Well, yes. But, if we take a look at this class, the benefit from it, the cooperation and the unity that was created, maybe, the next subject we are going to teach will take less time, it's difficult to know and measure …

Issues of using more time than the ordinary scheduled lessons having an impact on the choice of participating could also relate to the classroom practice section in the TPK&S model (Gess-Newsome 2015). However, in our study, there were examples of both, where the teacher only used the ordinary time, as well as used more time.

Secondly, for the sub-category of practical arrangements, there were teachers who reported how their teaching style changed when they were participating in the competition, how the students worked more in groups instead of alone, and how this stimulated students' learning, thanks to their discussions.

> The competition stimulates their learning because they have an effect on each other, the students. When they sit and discuss, they start to think, well this is fun; I think I want to learn more about this … They create their own learning situations when they sit in the groups. [T16]
>
> This class challenge, you see, how they work, it's like a project. They work in another way, it creates companionship, where everybody feels as if they are worth something; they solve a problem together … They learn to think in new ways, together. I like that. [T16]

Once again we relate to the TPK&S model (Gess-Newsome 2015;) arguing that the choice of participating in the competition changed the classroom practice using more group work. Hence, development of collaboration using the twenty-first-century skills (e.g. Jerald 2009; Bell 2010) was enhanced.

Thirdly, the sub-category of practical arrangements showed how other students were involved, besides the ones participating in the competition. Teachers reported that students from other classes were curious about what was going on. This spin-off effect on other students than those participating in the competition has not been found in earlier studies.

> … other classes saw that they [students in grade eight] did a lot of mysterious things so they were a bit curious … [T17]
>
> … we have students here when they [students in grade eight] have worked with their class task; then students come from other classes and are curious and want to take part too, so it has a spreading out effect. [T6]

Summarising the analysis of data providing answers to the second research question, of how teachers work with the school competition as part of their teaching, we found that they all included the competition as part of their ordinary teaching, not as an add-on. Analysing our data with the TPK&S model (Gess-Newsome 2015), we find several reports from the teachers on how their enacted teaching style changed when they used the competition as

an instructional strategy. It had an effect both on their teaching in relation to the students, but also in their relation between the teachers. The interaction between teachers and students is clear in the TPK&S model (Gess-Newsome 2015); however, it is not as obvious to find the interactions between different teachers in the model. Nevertheless, the changed enactment of using more group work is supported by the intentions from the European Commission (EC 2007) of not using transmissive instructional strategies.

The role of principals

Content analysis of data answering the third research question of what role principals have when classes participate in the competition revealed two main categories: *Organisation support* and *Social support* (Figure 3). Teachers reported how their principals supported their participation in the competition in various ways. All of the teachers claimed that their principals were positive to entering the competition.

In the first main category *Organisation support,* there were two sub-categories: temporary schedule changes and permanent schedule changes.

First, the sub-category about temporary schedule changes included reports from the teachers such as:

> Yes, it has been very positive [to re-organise the schedule] and therefore everything was easy to solve. We got several full days to work, free from other subjects. [T2]

> Our principal was really listening to us, so at least once a week we only had half the class during lessons in science. We find this to be a better solution, working with fewer students at the same time. [T12]

> Well, it's the teachers who decide if we are going to participate in the competition, but we have support [from the principal] if a class manages to reach the regional final; maybe we sometimes need a substitute teacher and it has never been a problem. [T6]

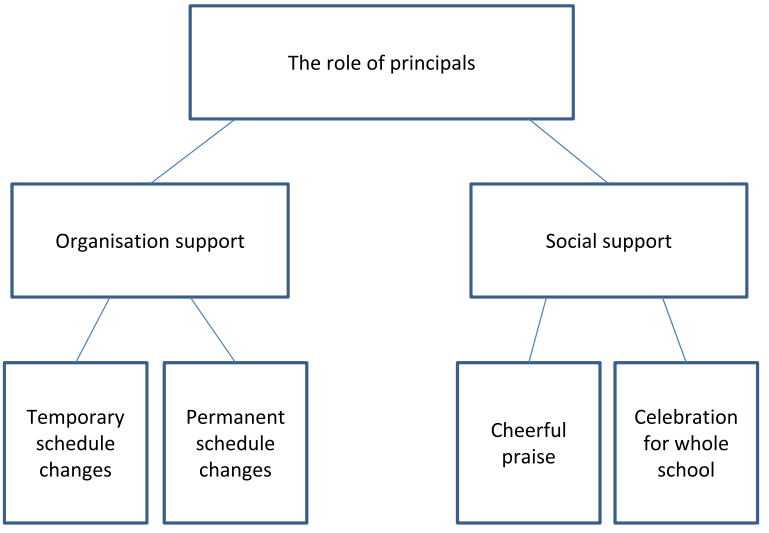

Figure 3. Categories and sub-categories analysed to answer the third research question, *What role do principals have when classes participate in the competition*? The answer is divided into the categories *Social support* and *Organisation support*, which are further divided into four sub-categories.

Secondly, the sub-category about permanent schedule changes revealed how the principals or teachers had reorganised the schedule for different grades to adapt to the competition. It could be, for example, rescheduling the teaching of the human body during a special period before the competition because there are usually questions about it in the competition.

> We have organised our teaching, adapting to the competition, because we know that there are always some questions about the human body, so we have moved the teaching in biology to the autumn instead, so they will have the knowledge … [T14]

Teaching in technology is often conducted two out of three years at lower secondary school. Principals changed the school years in which the technology lessons were studied to fit with the competition (in grade eight).

> We have changed the planning permanently, so now we have some of the teaching in technology in grade eight. Otherwise, it can be difficult to participate and be able to find time for it, but now it is an ordinary part of our teaching. [T10]

Fulton and Britton (2011) argued that teachers need practical support from principals and administrators. In our study, it was explicit how the principals' support was enacted in practice. From the TPK&S model perspective (Gess-Newsome 2015), we can once again refer to the section of classroom practice and teachers not being able to make changes to the schedules themselves.

In the second main category, *Social support,* there were two sub-categories: cheerful praise and celebration for the whole school (Figure 3).

First, the sub-category about cheerful praise presented how the principals supported teachers by just encouraging them to participate, even though the teachers had to perform all competition components themselves.

> Well, I have a principal, and I go to her and tell her, and she says just 'go for it'. I don't meet any resistance when I want to do things like this. [T16]

> The practical work is done by us as teachers, but decisions need to be made by our principal that it is OK for us to participate, because maybe we need to let go of some domains in science and make priorities to do this instead. So, it is a matter of school administration, but there have not been any problems, they also think it is good that we participate. [T13]

Earlier studies do not address if principals offer cheerful praise to support teachers' choice to participate in STEM competitions. This does not necessarily mean that this kind of support is non-existent in schools. However, we argue that even if this support in itself does not have the greatest impact on teachers, it could be considered as part of the classroom context in the TPK&S model (Gess-Newsome 2015).

Secondly, the second sub-category presents how the social support from the principals was in the form of concrete action, celebration for the whole school. Teachers reported how their principal organised a celebration for the whole school when a class reached the regional final.

> A party with cake for the whole school was organised to celebrate … [T2]

> The idea was that the whole school would feel involved. [T1]

To our knowledge, concrete action by principals', e.g. arranging celebration for the whole school, is not reflected in earlier research on how teachers are supported in their choice of instructional strategy. We use the same arguments as presented for cheerful praise, that is, this kind of support could be of importance, but maybe not the most important.

Summarising the results of the third research question of what role principals have when classes participate in the competition, we have presented specific new findings. The principals in our study supported their teachers both practically and socially when they participated in *The Technology Eight* competition even though they did not have a science background themselves. According to Holdren, Lander, and Varmus (2010), principals often lack understanding of how to stimulate education in STEM. Even though the principals in our study did not have an education in science and/or technology, they were positive and supportive, thus, diverging from the findings of Holdren and colleagues (2010).

Conclusions and implications

This is an important study, as it points to an example of using one instructional strategy, which is in line with what the European Union highlights in its discussions about teaching strategies and necessary competences for the twenty-first century (EC 2007). The European Union encourage use of renewed pedagogy instead of the transmissive pedagogies often used in schools. In Sweden, the national competition in science and technology for grade eight, *The Technology Eight*, provides an opportunity for teachers to work in line with the suggested instructional strategies.

The aim of our study was to investigate the reasons why teachers chose to participate in a STEM competition as one of their instructional strategies. Furthermore, we wanted to know how they used this strategy in their teaching practice and how their principals supported them. One reason for participation was positive effects on students in terms of development of twenty-first-century skills, as reported in earlier studies (e.g. Fisanick 2010). However, in our study the emphasis was on the development of cooperation between the students, which we reported as positive social aspects for the students.

We also highlight the fact that participation in the competition was positive for the teachers too. This was, for instance, reported as gaining new teaching ideas and new teaching style, such as having the students work more in groups. This allowed students to develop twenty-first-century skills, especially cooperation. The findings can be supported using the theoretical framework of the TPK&S model (Gess-Newsome 2015) from both the impact of the students acting as amplifiers and filters, knowledge about curriculum and issues of classroom practice.

The results in this study were specific in presenting how teachers used participation in the competition in their teaching. We have not found any earlier findings presenting how competitions are implemented in teaching of STEM. Hence, our study is an important contribution in terms of research, and can also serve as inspiration for teachers on how they could use participation in STEM competitions as an instructional strategy.

The findings regarding the importance of support from principals were explicit in showing how the support was given. In our study, we did not find any problems with principals having the lack of STEM education, which has previously been found as problematic (Holdren, Lander, and Varmus 2010). Hence, the results from this study can serve as a contribution for principals as well, showing them how they can support their teachers if they want to implement participation in STEM competitions as part of in their teaching.

Disclosure statement

No potential conflict of interest was reported by the authors.

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Appendix 1. Example of a multiple choice question from the selection round and tasks from the second and third rounds

Level of the competition	Question/task
Selection round, first round	What is dead or alive is not always obvious. There are many different definitions of what constitutes life. One definition refers to whether the object being studied has a metabolic rate (i.e. the energy needed for the processes in the cells). In most terrestrial organisms around us, this can be seen or measured. Usually they consume oxygen. This function ceases when they die Last spring, we planted carrot seeds. These have grown in the summer because they utilised the energy from the sun. This fall, therefore, we can dig up crispy and beautiful orange carrots out of the ground. We cut off the green tops and store the orange roots for various dishes in autumn and winter. Finally, we store them in the basement or refrigerator until we use them **Question: When do carrots die? Mark the correct choice** A. A carrot is not alive B. When we took them out of farming land and cut off the tops C. When they are placed in the refrigerator D. When we boil them
Regional final, second round	The problem of lighting a fire for warmth or light has employed man at all times. In the early 1800s, the first chemical method, wooden sticks dipped in a mixture of sulphur and yellow phosphorus, was developed. They were flammable but also very toxic. In addition, they were able to light up almost anything The safety match was invented by the Swede Gustaf Erik Pasch in 1844. Pasch created a division with a primer on the stick and the red (non-toxic) phosphorus on a plane. The safety match was born Matches can be used in many more situations than for lightening candles or a fire. Surely, you've met different matchstick problems. However, now you have a task to use safety matches in a completely different context: In front of you there are two boxes of long matches and a hot glue gun **Task:** Build a tower as high as possible with the help of matches and glue. The tower must be able to stand by itself Construction time: 3 min Materials: 1 glue gun and two boxes of matches for each team Points: The team that builds the highest tower receives 3 points, the next will receive 2 points and the team with the lowest tower gets 1 point
National final, third round	There are many dangers from space, both from the sun and other celestial bodies. The earth and its environment protect us against these. Below, you will find a list of various dangers that threaten us, and a list of suggestions on ways that the earth can protect us from them **Task:** Select any threat and connect it with a protection mechanism Some mechanisms may protect against more than one threat, others may not protect against any of the threats listed Protection Mechanism A. X-ray radiation B. UV radiation C. Charged particles D. Meteors E. Thinning of the atmosphere 1. The magnetic field 2. Gravity 3. Lower atmosphere 4. Ozone layer 5. The tide

Appendix 2. Example of a class challenge for the region final – Construction of a self-playing instrument

Policy

1. The instrument should be able to play the first four bars of 'The Bear Sleeping' (same melody as 'Old Man Noah').
2. The music must be programmed into the instrument so that the instrument plays itself, once it has started.
3. The energy that drives the instrument should be 'non-electric'. The instrument is not allowed to be played by a person operating during the play, for instance, by cranking the hand.
4. The sound may be produced by the mechanical method, the air in motion, strings, percussion, etc. The sound may not be enlarged using electronics.
5. The instrument may be constructed of any material except with tuned parts from already existing instruments (e.g. Xylophone bars). However, it is permitted to use parts that need to be reconciled, such as a guitar or violin strings.
6. In operating mode, the instrument must occupy an area of 1 m^2.
7. The instrument must be clearly labelled with the class and school name.
8. Substances, materials or equipment that could cause a hazard to students, spectators or judges and that may not be used in Swedish schools are not allowed. Otherwise, the choice of material is free.
9. During the design and construction period, the class should keep a logbook (max 1 A4) and take at least one photo (max 1 A4).

Time instructions

During performance in the competition, 30 s can be used for preparation and maximum 3 min as shooting time.

Appendix 3. Questions posed to the teachers and principals, respectively

Interview questions posed to the teachers

1. What are your motives for attending the competition *The Technology Eight*?
2. How many years have you participated in the competition?
3. How do you work with the competition? Is it a natural part of your teaching or something you add to give students a 'break' from traditional teaching?
4. Do you work alone as a teacher when you participate in the competition or do you cooperate with colleagues? If you cooperate with others, how does this work? Is the cooperation multidisciplinary?
5. How do you work with and use the class task from the competition?
6. Can you find any connection between the questions and tasks in the competition to the curriculum?
7. Can you notice any effects on the students from participation in the competition? If so, what do you notice?
8. What role does the school administration and the principal have when you choose to participate?

Interview questions posed to the principals

9. What role do you think you have as a principal for the schools' participation in the competition *The Technology Eight*?
10. What are the effects you notice on teachers and students when participating in the competition?

Table A3. The relation between the questions posed in the interviews and the research questions.

	Research question 1	Research question 2	Research question 3
Interview question	1, 6, 7, 10	3, 4, 5, 10	8, 9