Teachers' Attitudes to Teaching Introductory Solid Mechanics in Upper Secondary School

Caroline Forsell, Susanne Engström and Per Norström

In upper secondary school in Sweden, the students in the technology programme take an introductory course that aims at providing a broad introduction to the engineering field. The course's curriculum is open to various interpretations and solid mechanics is not included explicitly, but it is taught within the course by many teachers. Previous studies of teachers' attitudes towards other subjects showed that confidence is commonly influenced by subject knowledge. Thereby teachers' knowledge affects their teaching and their students' learning opportunities. The present study was based on interviews with 13 technology teachers, teaching in upper secondary school. The interviews concerned their attitudes towards teaching introductory solid mechanics and included those who taught solid mechanics, and those who did not. Those who taught solid mechanics did so through personal choice, because of influence from colleagues and local traditions, or because they took it for granted. Many among them expressed interest in solid mechanics and thought it to be of importance for future engineers. They had high self-efficacy and low anxiety regarding the subject. Those who did not teach solid mechanics omitted it mainly because of an experienced lack of knowledge. They let their students develop problem-solving and calculation abilities within other areas, which the teachers themselves felt more confident in. They ranked the importance of solid mechanics for future engineers as medium or low. The study indicates that technology teachers' attitudes towards various engineering disciplines may affect their teaching and that studying those attitudes is important to understand the enacted school subjects.

Keywords: *Technology education, Engineering education, Upper secondary school, Solid mechanics*

Introduction

In Sweden, the study of solid mechanics used to be mandatory for all upper secondary school engineering students (Skolöverstyrelsen, 1970). Solid mechanics is about mechanical properties of materials and their construction and it is a classical engineering subject. Since the 1990's, it is not mandatory , but it still has a high status and is commonly taught. This article describes and discusses teachers' attitudes towards teaching solid mechanics in the introductory engineering course for the technology programme in Swedish upper secondary school, where solid mechanics is one of many themes that can be included.

Through all nine years of compulsory schooling (age 7–16 years), technology is a mandatory subject for all pupils. The content is broad, and includes introductory engineering, as well as an understanding of everyday technologies, and the history and sociology of technology (Skolverket, 2017, 2019). Pupils should learn about materials (common as well as modern ones) and about stable constructions – two themes that could provide a foundation for future studies in solid mechanics and engineering.

After compulsory school follows three years of upper secondary school (age 16–19 years). Approximately 15% of the pupils (with huge variations between regions) choose the Technology programme (Skolverket, 2018), which should prepare them for future careers and/or studies in engineering, mathematics and the natural sciences. All students in the Technology programme have to take an introductory engineering course, called Technology 1 (*Teknik 1*). The course has a broad scope, and includes material science, technical drawing, teamwork, and gender issues in technology. The curriculum states that pupils should practice the ability to 'use the methods, concepts and theories of

technology' and practice solving engineering problems using mathematical models and methods (Skolverket, 2017, 2019). The curriculum provides a framework for the teaching, but the detailed content is largely decided by the individual teacher; his/her personal interests, knowledge, attitudes, and available equipment and other resources have a profound impact on what pupils will have the opportunity to learn. Solid mechanics is not explicitly mentioned among the core contents of Technology 1. Nevertheless, many teachers find that it is a suitable theme to fulfil the course's objectives. The grading criteria state that for grade E (the lowest 'pass' grade), pupils need to be able to 'give an account in basic terms of the technical properties of different materials and also of how and when they can be used […] solve simple technical problems, […] in consultation with the supervisor [chose] appropriate working methods, and document their work and results' (Skolverket, 2019).

Which textbook to use – if any at all – is chosen by the school or the teacher. There is no national or state-controlled body that evaluates or approve of individual books. At the time of writing this paper, only two textbooks intended to be used in the course Technology 1 were in print: *Teknik 1* by Johnny Frid (2011) and *Teknik* by Yngve Nyberg (2011). They are published by two of the largest publishers of textbooks in Sweden. Chapters on introductory solid mechanics are included in both books.

Books and syllabi influence teaching, as do teachers' self-efficacy and subject knowledge. Harlen and Holroyd (1997) claim that teachers' confidence affects their choice of content, as they tend to avoid themes that they are not comfortable with. Teachers' knowledge and understanding of their own knowledge thereby affect the teaching and the pupils' learning opportunities (Bell, 2016).

Previous studyhave shown that many technology teachers regard the subject technology as an important one. They are also commonly frustrated by the lack of teaching resources, such as time and equipment. Furthermore, they claimed that they were aware of the curriculum content and were able to follow it (Nordlöf, Höst, & Hallström, 2017).

In compulsory school, the technology subject is for all. In upper secondary school, it is only for those who have chosen a certain programme. They are inherently different in purpose. Despite the far-reaching content lists in the curriculum, technology in compulsory school is in practice largely a design-and-make subject (Skolinspektionen, 2014). Technology education in upper secondary school starts with a broad introductory course (Technology 1) which is followed by more specialised courses in programming, design, manufacturing, architecture, etc., chosen by the students.

Purpose and aim

The purpose of this study is to shed light on teachers' attitudes to teaching introductory solid mechanics in Technology 1 in upper secondary school: a theme that is not mandatory according to the curriculum yet is often taken for granted and also included in all available textbooks. The research question is:

- Why do teachers choose to include or exclude solid mechanics from the Technology 1 course?

Method

The respondents were found through social media platforms, where they were active members of groups for teachers.

The interviews were semi-structured (Bryman, 2012), based on four question clusters:

1. Do you teach solid mechanics in Technology 1? Why (not)?
2. Do you use a textbook? Does it include solid mechanics?
3. Is there anything special about solid mechanics as subject content? What do your students think? Difficulties and opportunities?
4. Is there anything special with teaching solid mechanics? What do your students think? Your colleagues? Difficulties and opportunities?

Before the interviews started, the respondents were informed of the voluntary nature of the participation, that they would remain anonymous in research publications based on the interviews, and that they were free to leave at any time. The rules and ethical advice formulated by the Swedish research council (Vetenskapsrådet, 2017) were followed.

Some interviews were conducted over the phone, while others were done face to face. Each interview took between 15 and 30 minutes. They were recorded and transcribed verbatim.

The interviews were analysed, using a deductive thematic approach (Braun & Clarke, 2006). Themes were identified and analysed further using a framework for teachers' attitudes and understanding presented by Van Aalderen-Smeets, Van der Molen, and Asma (2012). The framework is based on three main categories: *Cognitive beliefs* (thoughts about and evaluation of the subject, including perceived difficulties), *Affective states* (enjoyment, anxiety, etc.), and *Perceived control* (self-efficacy and context dependence). All these three factors influence the behavioural intentions and actual behaviour of the teacher.

Results

Thirteen (13) teachers who were teaching Technology 1 at the time or had done so in the past were interviewed. The respondents were of different age, came from different parts of Sweden and had (somewhat) different educational backgrounds. See table 1. Based on their replies, the respondents could be divided into four groups:

Enthusiasts (4 respondents)	Taught solid mechanics in Technology 1, and were confident in their knowledge of the area and found it to be important.
Reluctant teachers (2 respondents)	Taught solid mechanics in Technology 1, and were less confident in solid mechanics and found it not really necessary to fulfil the course's objectives, but still taught solid mechanics.
Sticklers (2 respondents)	Taught solid mechanics in Technology 1, and were confident in the area. They believed that teaching solid mechanics is compulsory.
Avoiders (5 respondents)	Did not teach solid mechanics in Technology 1, and found solid mechanics difficult and of low relevance to fulfil the course's objectives.

There were no easily discernible correlations between the respondents' backgrounds and their attitudes towards teaching solid mechanics. Those who attended the four-year technology programme when they themselves were upper secondary school students were exposed to the mandatory solid mechanics teaching. Even they were divided among the groups.

Across the groups, low interest in and insufficient knowledge of mathematics were mentioned as the most important problem for students' learning in solid mechanics. Another was terminology, words such as 'safety factor', 'stress', and 'tensile strength' were new to most students and refered to abstract concepts.

Enthusiasts

Solid mechanics enthusiasts were characterised by their fondness of solid mechanics. they found it important and were confident about their competence in the area.

> Yes, I include some solid mechanics in Technology 1. I teach relations and formulas … mechanics in tandem with materials science … and yes, that is my interpretation of the core contents: technical phenomena, theories and models, including calculations. (Teacher E)

Most enthusiasts stated that they enjoyed teaching technology and solid mechanics. Their worries concerned lack of time and some students' difficulties in understanding.

The enthusiasts described preparation for further studies as an important reason for studying solid mechanics; it is a good way to cover Technology 1's core content while also gaining a general technical understanding. It was also mentioned that solid mechanics is a suitable way of introducing calculations as a means of technical problem solving and to provide a context for the learning of elementary material science.

> It is like something that you can hold on to when describing the properties of different materials. Right now, I cannot remember the exact words, but it is something like that … about materials. (Teacher B)

Most enthusiasts used textbooks when teaching Technology 1.

Reluctant teachers

The reluctant solid mechanics teachers expressed a higher level of anxiety connected to teaching solid mechanics. They also rated the relevance of the content lower than the enthusiasts. Their main reasons for teaching solid mechanics in Technology 1 were influences from colleagues or local school traditions.

> I have taught this course [Technology 1], and there is a strong … how shall I put it? There is a strong tradition concerning technology, being largely about engineering mechanics, solid mechanics, and so on. (Teacher J)

Sticklers

The sticklers resembled the enthusiasts when it comes to anxiety. The main difference was that the sticklers believed that solid mechanics is a mandatory theme in Technology 1. This seems to be mainly because of very strong local traditions and well-established unwritten rules.

Avoiders

The avoiders did not teach solid mechanics. They were characterised by their negative attitudes and feelings of awkwardness towards the subject. They did not find solid mechanics important, and also found it difficult for themselves and/or their students as well as time-consuming.

> It feels like you have to … have to put a lot of time and effort into it if they are to understand enough. I do not really know how to do it. (Teacher A)

> I haven't really included solid mechanics in the course, because I can't do it too well myself. (Teacher H)

The avoiders used alternative strategies to fulfil the learning objectives of Technology 1.

> I choose not to do it, because I feel that I am not very skilled in the area. I have not studied it during my education. I include other stuff instead; I can fulfil the course's objectives without solid mechanics. (Teacher F)

> … and then we do some other engineering-related calculations. I am trained as a chemical engineer, so it's more of that. (Teacher H)

Half of the avoiders claimed that they did not use a textbook for Technology 1. A few members of this group mentioned that solid mechanics was included in other courses, later in the programme. :

Discussion

What is actually taught in classrooms, the so-called *enacted curriculum* (McKnight *et al.*, 1987), depends on a multitude of aspects. Apart from the *intended curriculum*, factors which determine the enacted curriculum include teachers' interests, attitudes and competence, schools' material, monetary and temporal resources, etc. It can take a very long time for classroom practice to catch up with a change of the curriculum. In this study, 2 out of 13 respondents actually believed that solid mechanics was a

mandatory theme in the introductory engineering course of the technology programme in upper secondary school, which has not been the case since the 1990's. Of the remaining 6 who taught solid mechanics, most mentioned that traditions and habits affected their choice of subject content.

Teachers tend to more seldom teach subjects that they lack confidence in (Holroyd & Harlen, 1996). This means that the teachers' subject knowledge as well as their awareness of this knowledge might affect what they actually teach and what learning opportunities are provided for the students (*cf*. Bell 2016).. Previous research also showed a profound variation in teachers' self-confidence and evaluation of their own subject knowledge, which affected their educational choices (Nordlöf, Höst, & Hallström, 2017). Those who avoid teaching solid mechanics could therefore, based on previous research, in most cases be expected to do so. In alignment with Van Aalderen-Smeets *et al.* (2012), their *perceived control* is low, their *affective states* are negative, and according to their *cognitive beliefs*, solid mechanics is not a very important content in an introductory engineering course. On similar terms, it is not surprising that the enthusiasts chose to include it, as their *affective states* are positive and their *perceived control* is high.

From the collected data, it was not possible to discern any effects of textbook use on whether solid mechanics was included in Technology 1 or not. In the group of avoiders, who did not teach solid mechanics, half the respondents did not use textbooks. Instead, the teachers used material from a variety of sources: excerpts from books, web resources, and texts and examples created by themselves. Within the other groups, who thought solid mechanics, the use of textbooks was common. Most respondents did however state that they did not use the book all the time. Technology 1 seems to be less textbook-driven than for example mathematics (*cf*. Martin, Ina, Mullis, & Stanco, 2012a, b).

There are various reasons why the content for solid mechanics if a part of Technology 1 may vary and still provides a solid foundation for further studies.. A course or a subject is not fully described by a curriculum. It is a complex phenomenon that is very hard to grasp. It is shaped by present and previous curricula, teachers' knowledge, interests, prejudice, and self-confidence, as well as current trends and resources in the form of books, equipment, and available time. Curricula with multiple degrees of freedom have advantages as well as drawbacks. On the one hand, teachers can shape the content according to their interests and special competences, as well as the pupils' needs and wishes. It can also be adjusted to the needs of, or resources provided by, local industries. On the other hand, the freedom is likely to reduce the equality between teachers and schools; different instances of Technology 1 all have the same name, but is it really meaningful to think of it as the same course when the content varies strongly? This is true not only for Technology 1 but for other subjects as well since many subjects include a freedom of choices for the teacher. The Swedish educational act (Swedish law SFS 2010:800) demands that the value of education does not vary over the country, and this becomes even more difficult to guarantee with a great variation in content.

References

Bell, D. (2016). The reality of STEM education, design and technology teachers' perceptions: A phenomenographic study. *International Journal of Technology and Design Education, 26*(1), 61–79.

Braun, V. & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology, 3*(2), 77–101.

Bryman, A. (2012). *Social Research Methods*. Oxford University Press, Oxford.

Fahrman, B., Norström, P., Gumaelius, L., & Skogh, I.-B. (2019). Experienced technology teachers' teaching practices. *International Journal of Technology and Design Education*. Advance online publication. doi:10.1007/s10798-019-09494-9.

Frid, J. (2011). *Teknik 1*. Malmö, Sweden: Gleerups.

Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching. *International Journal of Science Education, 19*(1), 93–105.

Holroyd, C., & Harlen, W. (1996). Primary teachers' confidence about teaching science and technology. *Research Papers in Education, 11*(3), 323–335.

Martin, M. O., Ina V. S. Mullis, P. F., & Stanco, G. M. (2012a). *TIMSS 2011 International Results in Mathematics*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

Martin, M. O., Ina V. S. Mullis, P. F., & Stanco, G. M. (2012b). *TIMSS 2011 International Results in Science*. Chestnut Hill, MA: TIMSS & PIRLS International Study Center, Boston College.

McKnight, C. C., Crosswhite, F. J., Dossey, J. A., Kifer, E., Swafford, J. O., Travers, K. J., & Cooney, T. J. (1987). *The Underachieving Curriculum: Assessing U.S. Schools Mathematics from an International Perspective*. Champaign, IL: Stipes.

Nordlöf, C., Höst, G. E., & Hallström, J. (2017). Swedish technology teachers' attitudes to their subject and its teaching. *Research in Science & Technological Education*, *35*(2), 195–214

Nyberg, Y. (2011). *Teknik* [Technology]. Stockholm: Liber.

Skolöverstyrelsen (1970). Teknologi. In *Läroplan för gymnasieskolan Lgy 70: Supplement 3-årig E, H, N och S linje samt 4-årig T linje* (pp. 90–96). Stockholm: Skolöverstyrelsen.

Skolverket (2017). *Swedish grades*. Retrieved 10 January 2020 from: https://www.skolverket.se/download/18.47fb451e167211613ef398/1542791697007/swedishgrades_bilaga.pdf

Skolverket (2018). *Jämförelse mellan elevers gymnasieval och var de studerade 2017/2018* [A comparison between pupils' upper secondary school choices an where they studied, 2017–2018]. Report from the Swedish National Agency for Education, number 2018:00719. Stockholm: Skolverket.

Skolverket (2019). *Technology* [official English translation of the Swedish syllabus for *teknik* in upper secondary school]. Retrieved 20 January 2020 from https://www.skolverket.se/download/18.4fc05a3f164131a7418107e/1535372300598/Technology-swedish-school.pdf

Van Aalderen-Smeets, S. I., Walma van der Molen, J. H., & Asma, L. J. F. (2012). Primary teachers' attitudes toward science: A new theoretical framework. *Science Education*, *96*(1), 158–182.

Vetenskapsrådet [The Swedish Research Council] (2017). *Good Research Practice*. Stockholm: Vetenskapsrådet.

Caroline Forsell Teacher and has a Master of Engineering; she did her PhD in solid mechanics, biomechanics at KTH Royal institute of technology, Stockholm, Sweden. Her research after that has been in biomechanics mostly but, she is now concentrating on teaching and education in technology.

Susanne Engström Associate professor in technology education at KTH Royal Institute of Technology, Stockholm, Sweden. Main research interests: different perspectives on knowledge content within technology education.

Per Norström Associate professor (Sw: universitetslektor) in technology education at KTH Royal Institute of Technology, Stockholm, Sweden. Main research interests: analytical philosophy of technology and its application in technology education.

Table 1: The respondents

Id	Certified to teach technology?	Higher education in technology and engineering	Teaching experience (yrs, interval)	Programme in upper secondary school	Age (yrs, interval)	City or region	Textbook	Group
A	Yes	Bachelor of science in mechanical engineering	< 5	Technology	40–49	Västra Götaland	Frid (2011)	Avoider
B	Yes	Master of science in engineering	5–10	Technology (4 yrs)	50–59	Skåne	Frid (2011), uses solid mechanics chapter	Enthusiast
C	No	Studied CAD at university	10–20	Electronics	40–49	Dalarna	Frid (2011), seldom used	Sticklers
D	Yes	Master of science in engineering and in education	< 5	Natural science	20–29	Stockholm	Frid (2011), seldom used	Reluctant teachers
E	yes	Master of science in Engineering specialised mechanical engineering	< 5	Technology	>60	Stockholm	Frid (2011), Nyberg (2011)	Enthusiast
F	Yes	Master of science in engineering, specialised in media technology	5–10	Natural science	30–39	Stockholm	Frid (2011), seldom used	Avoider
G	No	Master of science in industrial engineering and management	< 5	Technology (4 yrs)	50–60	Småland	Frid (2011)	Enthusiast
H	Yes	Master of science in chemical engineering	10–20	Technology	40–49	Luleå	–	Avoider
I	Yes	Master of science in engineering	10–20	Electronics	50–59	Stockholm	Frid (2011)	Sticklers
J	Yes	Master of science in electrical engineering	< 5	Technology	30–39	Västerbotten	Excerpts from a book by Sture Lönnelid	Reluctant teachers
K	Yes	Master of science in engineering and in education	< 5	Natural science	20–29	Gothenburg	–	Enthusiast
L	Yes	None	> 30	Technology (4 yrs)	60+	Gästrikland	Frid (2011), seldom used	Enthusiast
M	Yes	Master of science in engineering and nanoscience	< 5	Natural science	30–39	Gothenburg	–	Avoider