CDIO IMPLEMENTATION IN SWEDISH UPPER SECONDARY EDUCATION

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ABSTRACT

In 2010, the Swedish agency of education was given the duty of introducing a new educational programme at upper secondary level in the Swedish school system. In autumn 2015, it became possible for Swedish upper secondary schools that offer the Technology programme (preparatory for higher education) to start up a one-year vocational educational programme. This engineering programme is an additional course for students who have a degree from the three-year Technology programme.
This additional fourth year gives them the opportunity to obtain *Qualified Graduate from Upper Secondary Engineering Course* status. After graduation, students are qualified to work as an upper-secondary engineer (Swedish National Agency for Education, 2015).

When introducing this new educational programme, the Swedish National Agency for Education also took the opportunity to introduce new, hopefully more modern, pedagogical concepts. CDIO, a concept of thinking when conducting engineering education, is one of the pedagogical tools introduced in this additional year of engineering education.

To facilitate this implementation, support material was handed out to teachers during conferences arranged by the Swedish National Agency for Education in autumn 2015.

In this study, we wish to explore how teachers have embraced the teaching material and how they use it in their daily tuition. This paper presents a pilot study, which analyses the perspectives of six selected informants.

A questionnaire was sent to all teachers who participated in the conferences and, based on their answers, six informants were selected for further interviews. The analysis was performed using the Repertory Grid Technique (RGT) along with semi-structured interviews. RGT derives from George Kelly's (1963) understanding of how we perceive the world around us. Utilising RGT, this study examines teachers' expectations on teaching material that supports students' development of engineering knowledge and skills.

The results reveal that teachers' views on CDIO are largely positive and that it is perceived as something that offers a new description of something they have always used. However, they have not used the material in any significant way, despite the fact that, to some extent, the material is consistent with what they believe to be good support materials for teachers.

KEYWORDS

CDIO, upper secondary school, technology education, engineering education, Educational development, standards 1-12

BACKGROUND

Sweden is a country with an extensive educational tradition and with many high-technology companies. Therefore, engineers are widely needed and this has long been a popular profession (Berner, 1999). In accordance with this, the way engineers are educated has also been an on going topic for discussion. The old tradition of engineering education in Sweden has been that it is possible to take a diploma degree in engineering, i.e. undergo a four-year upper secondary education (Sveriges Ingenjörer, 2011), or to take a Master's degree, i.e. a five-year programme at university level. This will provide a "civilingenjör" as the engineering degree at university level has been termed since 1915 (Sveriges Ingenjörer).

In the late 1980s, the Government submitted a bill to parliament concerning the reorganisation of the four-year engineering education at secondary level. The education seemed out of date, due to the rapid technology development and the design of equivalent educations in Europe. The engineering education on secondary level was proposed to be a two-year education within higher education and a one-year technician training would be organised by adult education (Sweden. Government of Sweden, 1988. Sweden. Government of Sweden, 1991).

This new organisation of engineering education was run for almost two decades, albeit without the success for which the government hoped. In 2008, former Minister of Education Jan Björklund declared that the abolishment of the upper-secondary engineer degree in 1992 was a mistake. He concluded that there was a need to reintroduce of this form of schooling (Vene, 2009, Nilsson, 2008). In April 2010, the Swedish National Agency for Education received an assignment by the Government to investigate and propose the design of one-year upper-secondary engineer education (Swedish National Agency for Education, 2010).
This new education was supposed to be a supplementary year to the Technology Programme and it began as a pilot project in autumn 2011 (Swedish National Agency for Education, 2011) and became permanent in autumn 2015 (Sweden. Government of Sweden, 2014a).

After graduation students obtain Qualified Graduate from Upper Secondary Engineering Course status. The Swedish National Agency for Education cites project manager, production engineer, designer and site engineer as examples of possible vocation for an upper-secondary engineer (in Swedish gymnasieingenjör) (Swedish National Agency for Education, 2015a).

As the period of education is short, only one year, upper-secondary engineers rapidly become available on the labour market. In the diploma's goals it is stated; "After graduating from the education, students should be well prepared for professional work as upper-secondary engineer in their technical area." (Swedish National Agency for Education, 2015b, p. 2).

From this, emerges the question: What does it mean to be well prepared for professional work as an upper-secondary engineer?

Education is realised through political initiatives. Organisers and stakeholders influence the education and therefore the characteristics of an upper-secondary engineer. Teachers and supervisors (in workplace-based learning) lay the foundation for students' views on what it means to be an upper-secondary engineer.

The Swedish Agency for Education decided to look at how engineering education at university level has evolved during the last decades and uncovered the CDIO concept – a concept of thinking regarding engineering education that sets strategies for both content and pedagogic methodology (CDIO Standards 2.0, Crawley et.al. 2011).

Accordingly, teachers now have the responsibility to prepare students to become upper-secondary engineers with support from CDIO. The Swedish National Agency for Education states that the student "[…] shall have the opportunity to develop engineering skills with help from the internationally recognised CDIO model (Conceive, Design, Implement, Operate)" (Swedish National Agency for Education, 2015a).
In addition, in descriptions of diploma projects in the three-year Technology Programme, CDIO is emphasised as a method to develop an engineering approach and an engineer´s way of working (Swedish National Agency for Education, 2012).

The Upper-Secondary Engineering Education has four profiles and studies are combined with workplace-based learning, the education is presented as an opportunity for students to gain employment immediately following graduation. The profiles are: Design and Product Development, Production Engineering, Information Technology and Urban Planning.
This can be compared with the five orientations that fall within the Technology Programme years 1 to 3: Design and Product Development, Information and Media Technology, Production Technology, Community Building and Environment and Technology Sciences. Students graduating from any of these orientations can apply to any of the four profiles on *The Upper-Secondary Engineering Education*. (Swedish National Agency for Education, 2015a, Sweden. Government of Sweden, 2014b).

The Swedish National Agency for Education organised in autumn 2015 conferences for teachers involved in *The Upper-Secondary Engineering Education*. CDIO was presented during the conferences through presentations, discussions, workshops and support material.

The *Support material* from the Swedish National Agency for Education is designed to help organisers and teachers to develop and implement a technology education inspired by the CDIO. The CDIO model is presented as a toolkit to develop an engineering education and engineering skills.

RESEARCH QUESTION

This study focuses teachers' views on how to support students' development to upper-secondary engineers. Since the students will be active engineers for decades, teachers' ideas about this knowledge field will affect society in the future hence it is of particular interest to study this field in light of further development of technology education on secondary level.

The overall questions posed in this paper are:

How do teachers use support material for their education and what teaching materials do teachers, in *The Upper-Secondary Engineering Education*; think would promote an engineering approach in the students?

Three questions, in line with the overall questions, are posed to the informants in the interviews.

- Have you used the *Support material* from the Swedish National Agency for Education?
- In the diploma goals for *The Upper-Secondary Engineering Education,* it is stated that, after graduating from education, students should be well prepared for professional work as upper-secondary engineer. What do you think characterises such a student?
- Describe a project - is the CDIO model used?

A complementary assignment is given to the informants where they are asked to grade different teaching materials.

METHOD

A mixed-method approach is undertaken in this study. This begins with a quantitative section, where all participants at the Swedish National Agency for Education conference are asked to fill in a questionnaire. This approach is followed by a more qualitative approach. A Repertory Grid Technique (RGT) is used along with semi-structured interviews. The method derives from George Kelly's work, and is based on his theory of personal constructs (Fransella, Bell & Bannister, 2004; Jankowicz, 2004; Kelly, 1963). Although it has a quantitative structure (Jankowicz, 2004), RGT is primarily a qualitative method, the main purpose of which is to understand other people.

The questions in the questionnaire are generated from experiences with similar questions in a previous study (Isaksson Persson, 2015) and in discussions with the Swedish National Agency for Education. It is produced and published with help from KTH.

Questionnaire

The purpose of the questionnaire is to obtain an overview of the conference participants' experiences and to obtain a sample of informants. The questions concern the participants' own education and experiences of teaching and other work.

The choice of informants is made based on their interest in participating along with whether they teach the course *Practical upper-secondary engineering*. Every student studying to upper-secondary engineer takes this course, and it is of central importance to her or his education. The aim of the course is for the students to develop an engineering approach.

Of the 98 participants at the Swedish National Agency for Education's conferences in autumn 2015, 89 received a questionnaire. This has resulted in 43 participant responses. Because the number of responses to each question varies, the aim of the presentation of data is provide an illustration of the participants, rather than to provide a statistical analysis.

All four profiles of *The Upper-Secondary Engineering Education* are represented among the respondents.

- 22.7% of the respondents are female, 75% male and 2.3% preferred to be gender neutral (Out of 43 participant responses).

- 36.6% have 0 to 9 years of experience in teaching. 41.5% between 10 – 19 years and 22% indicated 20 – 34 years of experience (Out of 40 participant responses).
- 56.8% hold an engineering degree and 43.3% do not (Out of 43 participant responses).
- 31.8% have taught at *The Upper-Secondary Engineering Education* pilot project and 68.2% have not (Out of 43 participant responses).
- 37.2% teach the course *Practical upper-secondary engineering* and 62.8% do not (Out of 42 participant responses).
- 50% supervise diploma projects at *The Upper-Secondary Engineering Education* and 50% do not (Out of 43 participant responses).
- 62.8% teach year 1– 3 at the Technology Programme and 37.2% do not (Out of 42 participant responses).
- 27.9% teach at other programmes at secondary level and 72.1% do not (Out of 42 participant responses).

In summary: a majority of the respondents are male, often between 10 to 19 years teaching experience and are a holder of an engineering degree. Moreover, 'he' not participate in the pilot project of *The Upper-Secondary Engineering Education* before autumn 2015, teaches at the Technology Programme year 1-3 but not in other programmes at secondary level. He does not teach the course *Practical Upper-secondary Engineering* but may supervise the diploma project in *The Upper-Secondary Engineering Education*.

Interviews

Of the 36 conference participants who were interested in participating as informants, seven were contacted by e-mail. They were chosen on the basis that they teach the course *Practical Upper-secondary Engineering*. All seven were initially interested, but later one declined due to heavy workload.

The informants consist of four men, one woman and one person who prefers to be gender neutral and their experiences as teachers ranging from 2 to 21 years. They work in different cities in central and southern Sweden.

- Five have an engineering degree and work experience as engineers.
- Three have taught at *The Upper-Secondary Engineering Education* pilot project before autumn 2015.
- Five supervise diploma projects at *The Upper-Secondary Engineering Education*.
- Four teach other courses in addition to *Practical Upper-secondary Engineering* at *The Upper-Secondary Engineering Education*. These courses are CAD, Computer-controlled production, Mechatronics, Production equipment, Production knowledge, Production philosophy and Technology-specialisation.
- Four teach year 1 – 3 at the Technology Programme. The courses are Automation technology, CAD, Construction, Entrepreneurship and Technology.
- Three teach at other programmes at secondary level - these programmes are Industrial Technology Programme, Natural Science Programme and Social Science Programme.

In comparison to the rest of the participants at the conference, the informants in this study are representative as male engineers that teach, in addition to *The Upper-Secondary Engineering Education*, years 1 – 3 at the Technology Programme. The woman is distinct

from the other informants and the other conference participants due to gender and that she is not an engineer.

All six interviews are conducted at the informants' workplaces and recorded. The informants are initially given the opportunity to check and change their answers from the questionnaire. Following this, three questions are posed to the informants.

- Have you used the *Support material* from the National Agency for Education?
- In the diploma goals for *The Upper-Secondary Engineering Education,* it is stated that students after graduating from the education should be well prepared for professional work as upper-secondary engineers. What do you think characterises such a student?
- Describe a project. Is the CDIO model used?

The interviewees discuss issues freely and later the answers are transcribed and analysed.

Procedure using RGT

The last part of the interview was performed using the Repertory Grid Technique (RGT). Principal components analyses and Cluster analysis generated with WebGrid Plus (WebGrid Plus) has been evaluated.
The procedure for the RGT results in a number of two-dimensional constructs. RGT derives from George Kelly's (1963) understanding of how we understand the world around us. Kelly claims that we base our worldview on the way in which we construe our experiences. When we interpret our world, we use multi-dimensional attributes, which Kelly calls constructs (Kelly, 1963). The construct depicts two things about how we define a certain topic: what we consider to be characteristics and what we think is opposed to, or contrasts with, this. This renders constructs bipolar. Fransella, Bell and Bannister (2004) summarise Kelly's view on how we construe the world as "[...] we never affirm anything without simultaneously denying something" (Fransella, Bell & Bannister, 2004, p. 7).

Constructs are elicited regarding a certain topic. The topic for this study is *Teaching materials that promote an engineering approach*.

In the part where RGT was used the informants were given the assignment to suggest, at most, eight different teaching materials. The researcher herself also supplied two forms of teaching material as the basis for the interview. The ones supplied by the researcher are the *Support material* from the National Agency for Education and a mental picture of good or ideal teaching material.

The teaching materials are noted on a grid sheet and are presented three at a time by the researcher. Not all are present in physical form, such as digital materials. The informant picks two of these that share characteristics. The shared characteristic is noted in the grid and is a construct's first pole. The opposing characteristics possessed by the third teaching material is the construct's second pole. The first pole has the value 1 and the second pole value 5. All other teaching materials are then rated according to the construct on a scale from 1 to 5. The procedure is repeated until ten constructs are elicited or the informant wants to stop.

FINDINGS

Questionnaire

Reflections have been made on some of the relevant questions for further analysis of the research questions.
On the open question “Other work experience you consider relevant to you as a teacher?” 29 answers were given. Of these, 22 respondents referred to work in industry, engineering or technician assignments or work with IT, support or electronics. Three respondents refer to school related assignments.
On the open question “Education you have undergone relevant to your work as a teacher?” 33 answers were given. Of which, 25 respondents refer to education concerning engineering, IT or courses concerning the technology area. A further 13 of these respondents also referred to teacher training or other pedagogical studies. Five referred to teacher training alone or other pedagogical studies and other kinds of education.

Interview
Before compiling this paper, six informants have been interviewed and the transcripts have been analysed. The answers are compiled and presented in summary and/or with quotations to demonstrate common traits.

In the diploma goals for The Upper-Secondary Engineering Education, it is stated that students, after graduating from education, should be well prepared for professional work as an upper-secondary engineer. What do you think characterises such a student?

An upper-secondary engineer should possess basic practical skills and be able to participate in projects. But above all see the production/technology process as a whole and have ability to acquire the knowledge needed to solve problems.

> Informant: Yes, it’s a student who is independent in the sense that he can, if he is facing a problem, knows how he will act to solve it. That’s the engineering approach. Not that one possesses all knowledge about a certain specific area, but that one can find out, turn against it and be open and see the possibilities, try in ones area of expertise.
> (Teacher Te402, 08.12.2015, p. 1)

> Informant: […] an engineer is the one who has a systems approach, sees the big picture, understands that what we have is a social construction.
> (Teacher Te403, 13.11.2015, p. 3)

Describe a project. Is the CDIO model used?

Summary: All teachers use projects as a pedagogical method and describe the projects’ different phases. These are in line with CDIO. The teacher works with integrated learning in the projects and the results, ranging from 3D models, prototypes to usable products.

Have you used the Support material from the National Agency for Education?

Summary: The informants did not use the *Support material* in teaching explicitly but recognised the CDIO concept. The following quotes illustrate this. They describe experiences from engineering and teaching that they consider similar to CDIO.

> Informant: It’s obvious that it comes from University [...] in practice, it goes much faster. [...] We try to show that these types of models are available, but in practice, you do not make it as comprehensive.
> (About the CDIO model. Teacher Te404, 14.12.2015, p. 3)

Informant: Yes, I did briefly [...] Nah, I have not read it but focused on the Agency's curricula and then on [...] what the companies here want.
(About the *Support material*. Teacher Te404, 14.12.2015, p. 1)

Informant: And then I have already read the materials available online. So I have not looked so much on the Agency's support material. I have, just quickly looked it through but cannot say that I've used it, and I want to state that I recognised a lot of the CDIO concept. […] I think this is, it's vocational didactics to the very highest degree.
(About the support material and the CDIO model. Teacher Te402, 08.12.2015, p. 1)

Informant: I have read it. I have discussed it in class. Very similar to the one I used when I worked at [...]. [...] but there are some other names and things like that. But [...], the concept is pretty much the same.
(About the *Support material* and the CDIO model. Teacher Te401, 18.11.2015, p. 1)

Findings from the RGT study

Ratings 1 and 5, and constructs linked to them, have been taken into account in order to get an overall picture of the informants' thoughts about the *Good teaching material* (the mental picture of good or ideal teaching material) and the *Support material*. According to RGT indicates similarities in ratings, either between constructs, or elements representing the topic of the interview (in this study teaching materials), similar meaning to the informant (Jankowicz, 2004). With this reasoning in mind we suggest that the elements presented in table 1 represent the teaching material that the informants believe promotes an engineering approach.

Table 1. Teaching materials with similar ratings as *Good teaching material*.

Teaching materials with similar ratings as Good teaching material
PDF booklet with mechatronics assignments (Informant Te401)
Internet (for example web pages about Agile methods) (Informant Te402)
Teaching materials produced by the teacher (Informant Te403)
PowerPoint about organisational theory (Informant Te404)
Web page about entrepreneurial learning (Informant Te406)

Informant Te404 is not represented in table 1 because there is no high similarity in the ratings between the teaching material and the *Good teaching material*. He rates good teaching materials mostly to the value 3. In his view, there is no good teaching materials, he creates his own from different sources, he comments on this with the following quote.

Interviewer: And then we have the Good teaching material.
Informant: Yes, it is. All of it together is good.
Interviewer: Then it is a 3?
Informant: Yes [...] this is proof of that we have no good teaching materials, alone. We have no course adapted teaching material, but we can knock it together with what we think is good from various books and own expertise, lab equipment that we have and so on.
(About the CDIO model. Teacher Te404, 01.03.2016, p. 9)

Table 2 shows examples of constructs describing informants' views on the nature of a good teaching material. The informants' constructs reveal different perspectives on a good

teaching material. It poses questions about why and how becoming an engineer rather than specific questions about engineering skills [1]. It has a pedagogical approach [2]; it promotes a dialogue between teachers and students and is adapted to students and situations. It facilitates teacher's work [3]; it is easy, accessible and ready to use, and does not require a great deal of preparation. It has an element of creativity [4]; it is diversified, has endless possibilities; it is flexible, easy to modify and/or use for various purposes.

Table 2 shows constructs describing the *Good teaching material* and the teaching materials shown in table 1

Constructs	
Pole describing *Good teaching material*	Opposed Pole
Easy to find level for the students.	Hard to find level for the students.
Have parts that are adapted to teaching, to students' level.	Reporting of research. The students do not see the use of the book.
Follows specific models. Clear plan, common thread.	Aimless
Up-to-date	Rapid development, books become outdated
Dynamic	Static
Diversity	Limited
Endless possibilities.	Specific in its function.
Educational idea.	Not good teaching materials. Good content, poor structure.
Linked to reality.	Overall support. Steering documents.
Useful knowledge for the upper-secondary engineer.	Frameworks and guidelines
How and why learning the profession.	Skills needed in the profession.
Dialogue, discussion teacher – student.	Hard to discuss.
Whole	Part
Comprehensive	Based on subject area

Informants' views on the Support material

Two informants do not know the *Support material* well enough to include them in the RGT study. The other informants associate the *Support material* as a contrast to engineering practice and the industry and more linked to science, theory, guidelines and steering documents. On the other hand, they give examples of teaching in line with the guiding principles promoted by the *Support material*.

Summary: The *Support material* is considered to be a model or a working method. It is characterised by being easy to adapt to the students' level. It gives an overall picture of engineering. It is associated with theory and steering documents.

DISCUSSION

Shaping an upper-secondary engineer

In the findings we see that the *Good teaching material* poses questions about why and how to become an engineer but, surprisingly to us they do not suggest that it includes specific questions about engineering skills or project work, which is often suggested in other advices on how to improve teaching in technology (Skolinspektionen, 2014).

The informants value a holistic view on the technology process and think it is important for an upper-secondary engineer to have this ability as well as skills to solve problems in an engineering way. We claim that the informants think the *Good teaching material* supports the possibility to achieve this.

The *Good teaching material* also reflects issues of teaching. Teaching materials should be dynamic with a pedagogical idea. They shall facilitate the teacher's interaction with students and the process of selecting and presenting subject knowledge.

The technological-profession knowledge in focus

The *Good teaching material* and the *Support material* have similarities; they are easy to customize and have broad rather than specific approaches towards engineering. One interesting reflection is that the informants do not use the *Support material* in their everyday teaching. Some have only read the material briefly. But they express appreciation for The Swedish National Agency for Education's conferences where CDIO was presented and they use the CDIO in their teaching.

However, the *Support material* is associated with steering documents in a way that the *Good teaching material* is not. To us it appears as though the teachers have a very strong professional identity and that it is somewhat difficult to reach them with new directives.

When the conference participants consider what work experiences and education they find relevant to them as teachers, the dominance of technological-profession knowledge is colossal. It appeared as though the conference participants value this knowledge more than teaching experiences and education. They may not specify their teacher training, as they take it for granted, but this still shows the conference participants' homogeneous approach to what counts as important in the teaching profession. This findings are in line with another study were it was shown that teachers with no teaching degree used steering document to lesser extent than teachers having a teacher degree (Hartell et.al. 2014). We can argue that The Swedish National Agency for Education's conferences are initiatives towards teachers' professional development. Clark and Hollingsworth (2002) have identified six perspectives on teacher change. The results of this study emphasise that teachers' change is best achieved through participation in learning communities rather than by change through imposed external initiatives.

Conclusion and further research

The conference participants and the interviewees were predominantly male. It seem like they regard their experiences from work and education within the technology field relevant to their assignments as teachers. They value and appreciate teaching materials that promote a broad rather than a specific approach to engineering.
Is it harder for the informants to mediate a holistic perspective on technology than specific technology knowledge? Isaksson

ersson (2015) has previously examined work active engineers' views on their vocational knowledge and experiences from technology education. These engineers regarded it as a deficiency in their education that they did not learn much about general skills such as leading teams, communication, collaboration and so on. Another perspective, which needs to be examined, is students' perspective. What are their experiences of The Upper-Secondary Engineering Education, what is engineering knowledge to them?

The informants do not seem to appreciate the *Support material* very much, even though it is about CDIO, with which they are familiar. Is there an issue of pride from the teachers/engineers when the authorities impose their view on how to educate upper-secondary engineers? In addition, it would be interesting to dig deeper in the question about if it is a disciplinary conflict between a strong identification with a knowledge/professional field and demands from the pedagogical field?

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BIOGRAPHICAL INFORMATION

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