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You just have to take a big leap! Authentic teaching and learning in the technology program at an upper secondary school

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Abstract
In literature, teaching for an authentic learning experience is seen as rewarding and interesting, promoting better understanding of for example sustainable development and fostering students' independence. Some upper secondary schools emphasise authentic teaching and learning on their websites, showcasing how students engage in authentic tasks. We are interested in examining how authentic teaching is implemented in practice and what enables it. Therefore, we investigate a specific practice where authentic teaching occurs, and we follow students and teachers. We want to understand what may be required to implement authentic teaching. The research questions were: What characterises authentic teaching and learning when students on the technology program work on their design projects and individual pieces of work? How is authentic teaching and learning facilitated? Students in Year 3 of the technology program engaged in a project where they studied residential apartments' resource use and climate impact using sensors. They visited the energy research team, learned about the technology and data collection, and completed own upper secondary school projects related to sensor technology, programming, and data analysis. These were meant to be characterised by authenticity according to the school's procedures. Data was collected through interviews, observations, and analysis of video material, sound recordings, and field notes. The analysis revealed that the teaching exhibited characteristics of authentic learning, facilitated by early exposure, teacher empowerment, and strong support from management and resources. The results thus show both the characteristics of how the teaching is organized and how teachers handle students' learning, as well as the organizational factors at the specific school that enable it.

Keywords Authentic learning · Authentic teaching · Technology program · Upper secondary school · Technology teaching · Technology education

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Introduction

The purpose of the study presented in the article is to investigate how authentic teaching can be conducted and what might enable such teaching. There are many studies describing authentic teaching, the advantages and disadvantages for students learning that emerge, and what characterizes that type of teaching. We are primarily interested in exploring what enables authentic teaching and how authentic teaching is implemented in practice. Therefore, we investigate a specific practice where authentic teaching occurs, and we follow students and teachers. We want to understand what may be required to implement authentic teaching. The result can be valuable for practicing teachers and student teachers.

This article outlines a case study (cf. Eisenhardt, 1989) undertaken in respect of the technology program at an upper secondary school in Sweden. The technology program comprises preparatory courses for university and lasts three years. Students at the school in question are pursuing a specialisation which focuses on engineering science, and they are expected to go on to higher education to study STEM subjects. The specific technology subject of the technology program involves a lot of work devoted to the engineering design process, and in Year 3 the students must also complete a specific individual piece of work which can include a design assignment.

The school in question has highlighted the fact that it focuses on authentic approaches. For instance, the school's website describes how students get to work on authentic assignments in cooperation with companies and universities with the aim of training relevant skills and developing knowledge that can prove of further interest. When students reach year three – their final year at the school – they are expected to work authentically both on an engineering design project and their own individual piece of work.

This study was conducted during the academic year 2021–2022. Participants were the leavers' class at the school in question, numbering around 20 students. The study examined the way in which the students work authentically and in what way "authenticity" was facilitated. The study also examined what might enable such teaching. Data was collected repeatedly over the course of a year via observations and interviews. The analysis was undertaken both deductively in relation to theories of authentic learning (Herrington & Oliver, 2000) and thematically in an inductive manner (Braun & Clarke, 2006). The research questions were twofold. What characterises authentic teaching and learning when students on the technology program work on their design projects and individual pieces of work? How is authentic teaching and learning facilitated?

In this paper authenticity can relate to involvement of agents outside the school context, such as university, companies, and other organisations. Authenticity in the study is also characterised by what is described in the theoretical background, as outlined below. Among others, Herrington and Oliver (2000) identify nine guiding elements that characterise authentic teaching. We use these nine elements both as a theoretical tool for analysing data and to describe what authentic teaching can be characterised by.

Theoretical background

Authentic teaching and learning

In this section, we delve into various perspectives on authentic teaching and learning, aiming to discern their defining characteristics and the experiences they afford students within such contexts. This compilation serves as a consolidated depiction and a quasi-definition of authentic teaching within the study.

Authentic learning entails students developing their comprehension through active engagement, peer interaction, direct experience, and the sharing of their findings (Cross & Congreve, 2021). Scholars have outlined how teaching should be structured to facilitate authentic learning experiences (e.g., Herrington & Oliver, 2000; Herrington et al., 2010; Rule, 2006; Hill & Smith, 2005; Svärd et al., 2022). Authentic teaching can also foster engagement with wicked problems, like climate change, thus aligning with the objectives of education for sustainable development, aimed at enhancing students' understanding of such complex issues (Cross & Congreve, 2021). Singer et al. (2020) demonstrate how teaching focused on authentic learning can significantly enhance students' development of their STEM identity compared to conventional methods. In their study, authentic tasks involved group work, joint presentations, and interactions with diverse individuals outside the school, serving as role models.

Authentic learning often involves students completing tasks within a real-world context, where they can apply their knowledge and reflect on their experiences (Rule, 2006; Resnick, 1987; Young, 1993; Harley, 1993). This situational and context-bound approach (Brown et al., 1989; Cobb & Bowers, 1999; Lave, 1988) necessitates tasks and methodologies that are genuine and open-ended, allowing students to formulate strategies collaboratively (Collins et al., 1989). Throughout the process, students should have access to teachers and experts for guidance and discussion (Collins et al., 1989), fostering a sense of ownership and contribution to their learning (Rule, 2006). Collaboration with peers or external stakeholders, preferably across disciplines, should be encouraged (Young, 1993), with tasks designed for group engagement (Lave & Wenger, 1991). Exposure to diverse perspectives on complex issues is crucial, as students navigate multifaceted challenges (Rule, 2006).

Assessment in authentic learning contexts should mirror real-world scenarios, requiring students to apply their knowledge collaboratively and tackle complex challenges (Herrington & Oliver, 2000). Rule (2006) underscores the importance of students encountering authentic challenges and reflecting on their learning processes to foster metacognition and knowledge evaluation. The learning environment, characterized by cooperation and rich language interactions (Vygotsky, 1978; Mercer et al., 2004), emphasizes collaborative problem-solving facilitated by computer-based tools (Rule, 2006).

How to motivate teachers to use authentic learning has been less studied. Dennis and O'Hair (2010) made an investigation about what factors that benefit authentic instruction. In a study by Cunningham (2021) the interplay of beliefs and practices of four high school teachers were investigated, and the results showed that the teachers saw their roles as facilitator, coach, guide and co-learner, placing their trust in different aspects of the teaching and learning process.

In summary, authentic teaching and learning emphasise active engagement, real-world contexts, collaboration, and reflective practice, fostering deeper understanding and meaningful learning experiences for students. There are many studies on how teachers work with authentic teaching and learning, but less of what motivates the teachers to work.

Authentic learning linked to the engineering design process in technology teaching

In the realm of technology education, the integration of engineering design processes within real-life contexts presents significant advantages for fostering authentic learning experiences. Hill (1998) advocates for interactive engineering design work in schools, emphasizing students' ability to apply their knowledge and skills while connecting them to available materials and equipment. Hill (1999) further underscores the importance of community-based projects, were external demands drive assignments, enhancing authenticity.

Hill and Smith (2005) elucidate how authentic learning in technology education aligns with activity theory, drawing connections to Vygotsky's theories of learning (Martin, 1995). Activity theory, as described by Hill and Smith (2005), emphasizes learning through tool use in relevant societal contexts, collaboration, and consideration of historical and material aspects to create technical solutions and solve problems. Physical engagement in problem-solving is emphasized, as Hill and Smith (2005) assert that embodied experiences aid in understanding and creating technical solutions.

Building on Clark's (1998) insights, Hill and Smith (2005) emphasize the symbiotic relationship between learning, tools, and interpersonal interactions in the technology classroom. They advocate for collaborative group work, where individual expertise and collective memory converge to develop artifacts and solutions. Situational and context-based assignments are deemed essential for authenticity in technology education, as knowledge is often context-specific, with limited transferability between contexts (Hill & Smith, 2005).

Hill (1998) proposes an alternative perspective on technology education, advocating for problem- solving in real-life contexts using iterative design processes as tools for creation and investigation. Viewing design processes as non-linear and iterative, Hill emphasizes creativity and problem-solving skills over rigid, prescribed methodologies. Central to technology education, according to Hill (1998), is the integration of conceptual and procedural knowledge through the design process, moving away from teacher-formulated, linear assignments toward more authentic learning experiences.

In essence, integrating engineering design processes within authentic contexts enriches technology education, fostering creativity, problem-solving skills, and meaningful engagement with real-world challenges.

Relevant societal problems linked to the design process in technology education

The design process is described by many academic researchers, but differently. Some point out that the process is always carried out with human decision-making, that the process does not always have to be formal, and that it sometimes succeeds and sometimes does not. In the process, the designer needs not only to choose solutions and materials, but also to assess and consider risks, as well as take into account sociopolitical aspects, laws, economics and other things (Pleasants et al., 2019).

Such aspects affect not only how technology is designed but which individuals are involved in the engineering design process (Feenberg, 2010; Kroes, 2012; Mitcham, 1994).

Pleasants et al. (2019) have conducted a comprehensive analysis of previous research on NOT (the nature of technology),

and they describe how researchers take different positions as to how they view, inter alia, engineering design processes. One view is that social values impact on the process, because social processes occur when technology is designed, when, for example, the goals of the technical solutions are determined. The values and needs of society thus become involved in the technology that is created. This is relevant and worthy of consideration when students are due to work on engineering design processes for authentic learning. Society's problems must also be prominent in the technology that students design when they work authentically.

Teaching for authentic learning in a technology subject with a focus on engineering design should give students an opportunity to encounter society's values and needs as well as different actors. Generally, authentic learning gives students an opportunity to develop an understanding of real-world challenges (Cross & Congreve, 2020). Many of society's problems can be described as "wicked" (coined in Rittel & Webber, 1973), such as poverty, unequal health care, climate change, and they can be linked to social, economic and environmental processes (Peters & Tarpey, 2019), as well as to technological processes (Lönngren, 2021). When students are taught using an authentic learning approach, they can encounter "wicked problems" and authentic ways of working, such as group work, debating/discussing, pitching ideas, developing scenarios, etc., in such a way that the complexity of tackling wicked problems is rendered visible (Herrington & Herrington, 2006; Pitchford et al., 2021). Many sustainability problems may be described as "wicked", and students need to learn about such problems in order to contribute to for example sustainable development (Lönngren, 2021). The problems may be regarded as belonging to a type of problem that is common in the context of engineering design. The problems are unique and complex, and those who work with problem-solving need to collaborate with others and explore and develop new methods. When this happens in an educational environment, it is advisable that students learn to carry out project work in collaboration with societal actors. Lönngren (2021) argues that the problems addressed in the teaching should also be described as "wicked". Lönngren (2021) presents, inter alia, a guide for constructing problem descriptions for teaching about and involving wicked problems: (1) choose problems that engage students; (2) select interest groups that create opportunities to discuss the problem from different perspectives; (3) formulate background information needed to discuss the problem; (4) highlight that there is a problem; (5) incorporate the perspectives of all interest groups into the problem description; (6) incorporate at least one argument for each interest group; (7) highlight conflicts of interest; (8) formulate context, goals and recipients. With this guidance, the teacher can help students work up a problem description, but the students can also formulate a problem description themselves. The design described and guided by Lönngren (2021) can be seen as a model that can contribute to authentic teaching.

Description of the upper secondary school activities – the scope of the project

This particular study is based on the theoretical background as described, in that the subject of the study – the teaching at the upper secondary school under investigation – is to a large extent characterised as authentic. The teams involved in the research are depicted in Fig. 1.

In the early autumn of 2021, the upper secondary school established contact with a team of energy researchers from a university in Sweden. The research team has developed a

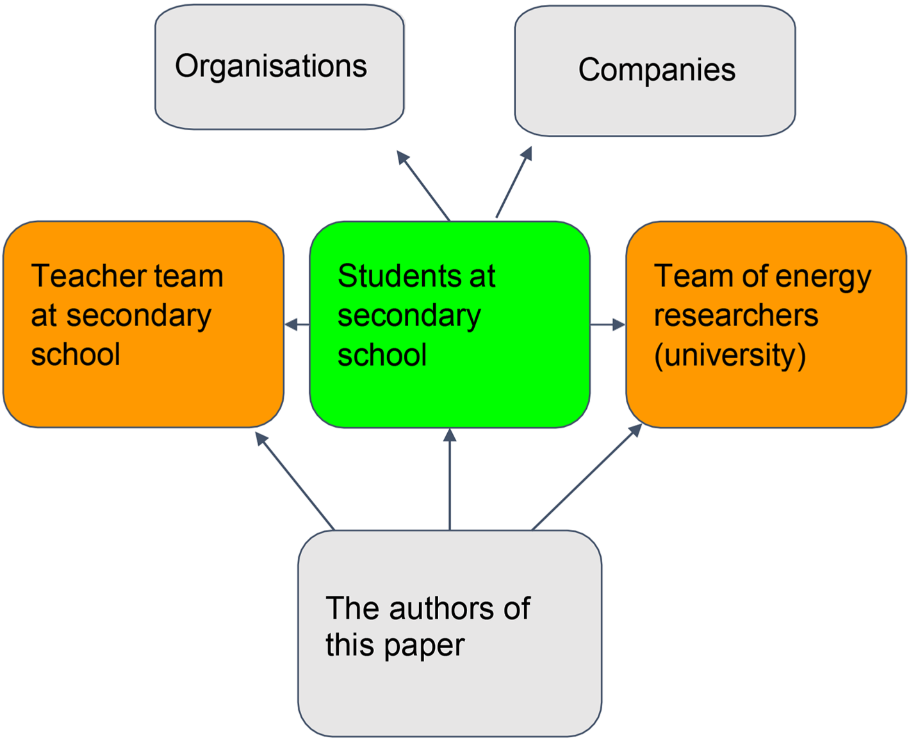

Fig. 1 The teams and parties involved in the study

laboratory in a residential building, allowing it to obtain data on a continuous basis from a number of "flexible" apartments. The flexibility in question means that the floor plans of the apartments allow of a degree of variation. The researchers have developed a sensor kit that is used to measure various parameters. Data collected from the apartments comprises: temperature, CO_2, water consumption, ventilation, air pressure, noise level, electricity consumption, air pressure, heat consumption, allergens, etc., in buildings. The energy researchers analyse the measured data, allow the residents to make limited changes to their floor plans and some parameters, and interview the residents to interpret how the living environment is perceived. The research project is an energy project that aims to further understanding of how households use resources (water, energy) and how various environmental parameters are generated and experienced. The research team's sensor kit (a box) can also be positioned in any room outside the laboratory. This has allowed data from different business premises, different types of households, etc., to be collected for analysis. The overall aim of the energy research project is to contribute to the development of sustainable construction.

The teachers and students on the technology program at the upper secondary school in question were initially visited by the energy research team, who described and provided information about their project. After that, the students were able to visit the researchers at the university, the laboratory, an apartment, etc., and discuss the project, its purpose and all the equipment with the researchers. Together, the energy researchers, teachers and students agreed that some sensor kits would be placed at their upper secondary school, and that the students would get to explore and develop the sensor kit (in a box). The students would also be allowed to take boxes with sensors into their own homes. The data generated by the sensor kits would be used by both the energy researchers and by the students, the students being given data by the researchers. The students and teachers from the upper secondary school devoted a great deal of attention to the different sensors, what could be measured and how this was done. They also looked closely at the data generated and how it could be analysed. Data processing was used in a mathematics course, and the study and development of sensors was used in a technology course.

After that, a start was made on the students' project work with subsequent individual pieces of work on the topic of programming, sensors, measurement, and control. The energy researchers who met with the students are experts in the field and offered to give advice while the students were working on their topic. The teacher team who teaches the students in the secondary school comprise a total of four technology/physics teachers. They have slightly different skill sets linked to mathematics, programming, control and regulation, mechatronics, and electronics.

The students thus set about describing and discussing what happens in our homes in terms of energy-related issues. The idea of the teachers was to create a sense of engagement with regard to resources and our way of living linked to housing. The energy research team contributed to problem descriptions and to highlighting the importance of carrying out various measurements of different parameters in order to then be able to analyse measured data. As previously stated, the students had opportunities to discuss complex problems and technology with the researchers as well as with their teachers.

Students were to begin working on a mini project including control, programming, and electronics. The project could then be developed into more extensive individual pieces of work. The students had to formulate their assignments after examining the needs of the local community, as well as after extensive discussions about energy issues linked to sustainable development. There was a requirement on the assignment that it should cover sensors, control/regulation, and programming. The assignments were created in different ways. Some students got in touch with a local energy company, for instance. A group of students found an international space competition for students, and they elected to take part in it. Another group found a private individual who needed a weather station, while others formulated design assignments in energy, and a couple of groups worked on various innovations.

The students worked in groups of two to five individuals. The lesson for the technology assignment was scheduled for one day a week, from 10 a.m. to 3 p.m. The students themselves were responsible for their lunch and any breaks. Premises at their disposal were a largish design- and technology (DT) workshop and a physics classroom, both rooms being very well equipped. At all times during the lessons, a technology teacher was present in the DT room. The other teachers assisted as and when necessary. Some lessons were teacher-led, involving reviews of certain elements, e.g. in programming and energy technology. The project work took place during the spring semester of 2022, and the teacher-led lessons/reviews occurred mostly during the autumn of 2021. During the autumn, the students got to visit and discuss aspects with the energy researchers, as well as design and build the sensor kit. They were able to analyse and evaluate the dataset from the researchers and relate their reflections and knowledge to energy facts and the UN's Global Goals.

The activities at the upper secondary school relate to objectives and abilities in syllabuses as well as more general goals and abilities in the field of engineering, for example as set out in the CDIO initiative (Crawley, Malmqvist, Lucas & Brodeur, 2011).

Theoretical approach for the deductive analysis in the study

This study aims to investigate what characterises authentic teaching and learning when students on the technology program work on their design projects and individual pieces of work and how a possible authentic learning approach can be facilitated. In more concrete terms, it involves studying teaching relating to sensor kits and associated data, specifically what emerges in the classroom and in students' and teachers' descriptions of the students' work on the material and, inter alia, their collaboration with energy researchers. This takes place in an educational approach that is closely linked to real-life contexts, and the intention is to develop what is termed authentic learning (Herrington & Oliver, 2000; Hill & Smith, 2005; Herrington et al., 2010).

In this study, we followed the authentic project in the upper secondary school while the students worked and interacted with the energy research team, teachers and other organisations, see Fig. 1. Throughout the duration of the project, we followed the students and teachers, filmed, conversed, and conducted interviews. Subsequently, when the deductive analysis was carried out, we looked back at the films, memos, and interviews. In our deductive analysis, we specifically chose to apply the principles of authentic learning that Herrington and Oliver (2000) and Herrington et al. (2010) have developed, presenting them as "nine guiding design elements":

1. Provide an authentic context that reflects the way the knowledge will be used in real life.
2. Provide authentic tasks and activities.
3. Provide access to expert performances.
4. Provide multiple roles and perspectives.
5. Support collaborative construction of knowledge.
6. Promote reflection to enable abstractions to be formed.
7. Promote articulation to enable tacit knowledge to be made explicit.
8. Provide coaching and scaffolding.
9. Provide for authentic assessment of learning.

When we interviewed the students in the study, we asked them e.g. to describe the following aspects, as stated in Herrington et al. (2014):

- Content: The content of the unit, the technologies you are using, the theory you are learning, your reading and the things you are exploring as you complete the tasks.
- Attitudes and feelings: your thoughts and feelings about the unit, your fears and reservations and your feelings of anticipation and achievement.
- Learning strategies: how you are learning and the strategies you use to help you learn new technologies and applications.
- Networks and communication: your communication with others in the class (in person and online), how you learn from others and how you help others.

– Connections and extensions: how you use your knowledge about technology in your everyday life, in your other units and how you anticipate using it in your classroom with students.

Method

Data collection method

Observations and interviews were conducted by the authors to collect data for analysis. On a total of seven occasions, the class was observed for the entire day. On two of the occasions, the students met the energy researchers, one day at their own school and one day at the researchers' university. On all seven days of observation, the activities in the classroom and, in one case, the energy researchers' premises at the university were filmed. Sometimes interviews were conducted with the students. The interviews were conducted when the students were actively working on their projects while being filmed. In these cases, the students had to describe their work, their experiences and thoughts. The conversations were guided by linking them to the theoretical approach (see above). On a couple of occasions, interviews were also conducted with the teachers, and on one occasion with a teacher and the principal of the school. In addition, more informal, unrecorded conversations were conducted, with both teachers and students during lunches and breaks. Overall, the dataset consisted of video clips, recorded interviews, field notes during lessons and memos from informal conversations, as well as teaching materials (presentations, student tasks, introductory material, etc.) and student reports. Video clips and recorded conversations were watched and listened to several times, and extracts from them were transcribed.

Analytic method – both deductive and inductive

The analysis was undertaken in two different ways. The first analysis was based on the nine elements (Herrington & Oliver, 2000). Based on each element, what happened in the classroom, in project work, in meetings with energy researchers, etc., was interpreted. The nine elements were seen as representing nine themes, and for each theme there was a description of what was relevant in the teaching in question. As we wrote earlier, the deductive analysis was conducted by looking back at films, notes, and interview transcripts to see how the nine elements emerge. The purpose was to search for and describe what emerged in the specific educational practice linked to each theme and what was therefore a characteristic feature of the teaching.

The second analysis aimed to search more inductively in the dataset for patterns characteristic of the educational practice. Above all, the characteristic features of educational practice that facilitates an authentic approach. For this analysis, an inductive thematic analysis was used (described in six stages by Braun & Clarke, 2006). For this, interview transcripts, recordings and video clips, field notes and other material from the teaching situations were used. Everything was carefully read and studied; the content was encoded and compiled into themes. This analysis was conducted in accordance with the steps outlined by Braun and Clarke. The purpose was to identify themes that characterize what enables authentic teaching.

Ethical aspects

Initially, on the first visit to the upper secondary school students and teachers were informed about the study by the authors of this paper. The students then had to fill out a consent form in which they agreed to be filmed, for instance. The teachers gave their verbal consent, which was recorded. Everyone was informed about the actual study and how the authors would participate and film, conduct interviews, etc.

They were informed that participation was voluntary and that their name, school and geographical location would not be published. However, there is still a risk that the identity of some of the participants can be deduced. No one has raised any objections. All data material, films, audio recordings, and transcripts were handled according to the procedures found within the actual university. For example, data has been stored in specific secure cabinets. Films, interviews, and textual materials have been stored on hard drives in the secure cabinet. Nothing has been stored on computers outside of it. These procedures are established by the university's data manager and research ethics contact person.

Results

The results chapter begins with a presentation of aspects, examples and perspectives that emerge in the educational practice studied which are linked to the various characteristics of teaching for authentic learning.

Initially, these themes are drawn directly from Herrington and Oliver (2000), correlating to the guiding principles outlined earlier. Due to the data being collected amidst genuine pedagogical contexts, direct citations tied to these guiding principles were not feasible; hence, comprehensive descriptions are provided instead. Subsequently, the chapter delves into themes that surfaced from the inductive thematic analysis, supplemented with relevant citations to support the analysis.

Themes related to the deductive thematic analysis

Provide an authentic context that reflects the way the knowledge will be used in real life

The teachers at the school in question contacted the energy researchers at an early stage. One of the energy researchers had presented their research project in several contexts where Swedish upper secondary schools with technology programs had been represented and had urged schools to contact them with a view to collaboration. The school in question got in touch, and a collaborative venture was established. One aim of the teachers was for the students to experience first-hand and actively how specific knowledge can be used in real life. In this case, in research into sustainable construction – real-world problems that need to be solved and how research can contribute. The students would experience how the researchers' knowledge and methods can lead to new technical solutions.

The students got to meet the energy researchers for two full days and hear from them how their research is conducted and what knowledge and methods are used. The researchers described what they did, asked the students questions, and the students asked the researchers questions, resulting in in-depth discussions. The energy researchers also described their measurement methods from a purely technical point of view, something that the students would then work on. Similarly, data analyses were discussed, which the students would also undertake further work on. The students engaged in extensive discussion, and some even questioned things in a critical way, to which the energy researchers provided answers and their own views.

When students worked at school on their tasks relating to data analysis and surveys of sensors, measurement methods, etc., they were able to relate to the conversations with the researchers. Some of them used the researchers' data and pondered the measurement parameters they had investigated.

Once the student projects started, many students were able to apply the knowledge initiated by the energy researchers. The students were also given a review on how to undertake project work by one of the teachers. That teacher has significant extra-school experience of project work in programming and energy technology. The teacher related examples from an industry that the students also know about, one to which they had already made study visits previously and had also received visits from engineers in that field. Project work as a process and the specific product development process with its various phases as such was thus given a real-life prerequisite by the teacher.

The teacher managed to create a physical environment and methodological approach that allowed students to see how the knowledge will ultimately be used. The set-up involving the school premises, the teacher's approach and the lesson time provides a design for creating complexity and situational opportunities. The approach allowed for many resources, also facilitating assessment from a number of different perspectives, a design that makes no attempt to fragment or simplify tasks. For instance, one student group developed a digital jukebox. They engineered a compact device allowing users to select from various melodies simply by placing a plastic badge nearby. The teacher team helped by supplying materials for the device and sensors, and by identifying suitable programming tools. Additionally, they facilitated student support through online chat groups.

Provide authentic tasks and activities

The meetings with the energy researchers gave the students a sense of how and why certain measurements are made and how data can be analysed so that conclusions can be drawn, and new technical solutions can be proposed. In addition, they showed that new technical solutions need to be created to solve problems with today's buildings and energy solutions. Once the students had attended the teachers' lectures and were given tasks, they could see the connection to issues that had been raised in the meetings with the researchers. The tasks became authentic and meaningful for them.

When the students worked on the assignments of their choice and when they worked in project form, they said that it felt "real" in some way. The assignments had a client who was interested, who needed the task to be completed or had at least set it for some specific reason. The students had to structure their projects, search for methods, search for ideas, discuss, read up on the subject, generate ideas, test, and retest, ask those who knew, etc.

The students had to take responsibility for their time and their planning. The lessons were scheduled for one day a week, when the week's planned activities were to be carried out, but they had to take responsibility for lunchtimes and how long each stage needed to last. Via short briefings, they were given the opportunity to describe to the teacher how the project work was progressing. The teacher constantly gave feedback on how project work is conducted in real life. The students seemed to be aware that they were being trained in such skills. In conversations with the students, statements often emerge to the effect that, e.g. by working "for real", they are being trained as engineers or for higher education and research. During lunchtimes, the teachers and students sat and eat together, discussing the projects as colleagues rather than as teachers and students. Examples of topics that might come up could include how to benchmark the students' projects and which university to apply to.

This approach facilitates activities that have real-life relevance, where the assignments and tasks are often poorly defined. There is only one complex task to be studied by the students, and the students can define the tasks and subtasks required to complete the main task. Throughout the entire time, they have an opportunity to discover both relevant and irrelevant information, the opportunity to collaborate, identify tasks that can be integrated across subject areas.

Provide access to expert performances

The teacher was present in the classroom and could guide students him/herself to some extent, but sometimes had to refer to someone else. It might be another teacher, the energy researchers, other contacts outside the school, a company, a website, etc. The teacher actively went round the class and gave good advice, discussed solutions with the students but, above all, gave tips on contacts who are experts in the specific problem. The teacher actively searched for solutions and to some extent helped the students find contacts. The classroom was not a limiting factor for the students: they felt that through the teacher they could connect with experts in various fields related to their project.

During lunchtimes, more teachers would join in and then there was an opportunity for specific discussions about issues that had arisen in any group. The environment resembled a company with ongoing projects where issues and examples of solutions could be discussed. The students asked questions or discussed their proposed solutions with a larger group of teachers, and there was potential for a sense of a unified expert group.

A group of students participated in a more extensive competition with their assignment: they were to develop a measuring box that would be launched like a rocket, before slowly falling to the ground, and carry out measurements in the air. The students competed abroad and made it to the finals in a completely different country. The assignment included, inter alia, advanced programming, for which the students needed some support, which is why one of the teachers who may be seen as an expert in the field, accompanied the students to the first competition country. The students gained access to expert thinking and modelling processes/real-life examples. They also had access to other students/teachers at different levels of expertise, and the environment gave them the opportunity to share their stories. They thus had access to the social context and, through meetings with, inter alia, the energy researchers, they could observe real-life situations where real-life activities occured.

Provide multiple roles and perspectives

In the students' work and in their meetings with e.g. the energy researchers, the students both took on various roles and encounter various roles. In the projects, a student was given the opportunity to play different roles. An example is where the same student first took on the role of the person who structured the project, drove the planning and schedule forward and showed interest in an overall project manager role. Then the same student ended up with a programming problem that caused the schedule to be relaxed, and the focus was entirely on a small task. By the students working independently in groups on their projects and feeling secure in the environment, they could take on different roles. The teacher also invited them to reflect repeatedly on the role they took on in the group.

Different perspectives were highlighted by the teacher. Through questions and advice about various contacts outside the school or via websites, teachers also provide new input on the assignments. This may relate to economic perspectives linked to material selection in the prototypes, ethical aspects linked to various parameters to be measured, various aspects of convenience/comfort associated with a solution to be used by individuals, external environmental aspects, etc. Students may have found it difficult to broaden perspectives without the teacher's guidance.

Through the approach and the environment, students acquire different perspectives on the topics/issues from different points of view. The teacher's prompts also give them an opportunity to express different points of view through cooperation. The teacher's contacts and willingness to go outside the school environment gave students the opportunity to encounter more than one resource fruitful enough to implement more variants.

Support collaborative construction of knowledge

Students were constantly encouraged to collaborate, and they themselves noticed that they could achieve more together. One student argued for the need to work alone, and the student was allowed to do so, but the teacher invited the student to constantly engage in discussion with another group which was working on similar content in their assignment. The lone student also described how contact was made with people and companies outside the school, where discussions took place. The teacher constantly asked about how ideas and knowledge were created; the purpose seemed to be to demonstrate to the students how important it is to collaborate.

The format of the teaching means that students were given tasks and develop assignments that were aimed at a group rather than at an individual. Then the teacher organised the classroom for pair work or small groups and created a suitable structure for whole-group presentations.

Promote reflection to enable abstractions to be formed

As previously described, students could encounter authentic contexts throughout the year through visits, conversations with energy researchers and others, and they were given an authentic task. It was also important that the students were given plenty of time, that they could return to the activities if desired and work further after a period of reflection. By having a whole day a week at their disposal that they themselves planned, they felt that they had time to think, reflect and reconsider if necessary. It was also important that students could compare themselves with experts. By being able to discuss with their teachers, whose intention is to act as colleagues rather than teachers, students believed that they learned to converse with "experts". Students also stated how they got the opportunity to compare themselves with other students at different stages of the project. The teacher also let the students stop working occasionally in a full class situation and allowed different groupings of students to present their solutions to facilitate further reflection.

Promote articulation to enable tacit knowledge to be made explicit

All students got the chance to work on a complex task that involves something real and ongoing, as opposed to a contrived task. They were also given the opportunity to develop the necessary knowledge within their projects. They had opportunities to speak out and collaborate in groups to facilitate social and individual understanding. In terms of the energy researchers, it become clear that the students both developed knowledge together with the researchers and developed the confidence to highlight their own opinions and positions. They expressed critical views and asked questions. In this connection, they were able to present arguments to express their views and argue their case.

Provide coaching and scaffolding

The teacher had planned for and facilitated a complex and open learning environment. He/she did this by scheduling the lessons for one day a week, by creating interesting classrooms that looked like creative project rooms with extensive equipment. Because collaborative learning was encouraged by constantly allowing students to evaluate it, the students got to experience how more capable partners can help. Similarly, the teacher and the entire teaching team enabled several people to assist the students with guidance. The students were left to control their own project, but the teacher implemented the task and was available for coaching while the project was ongoing. The students were never left to themselves.

Provide for authentic assessment of learning

When the students' work was finally to be assessed, this was done in a way similar to real-life project reports. The students got to be effective actors and apply their acquired knowledge to create performances and products that they could present. The teacher let the students spend a lot of time and effort on collaboration with others, and on the complex and unclearly structured challenges that required judgment and knowledge. The teacher, as mentioned earlier, had created a huge range of factual material and other resources. The assessment was also integrated into the activities: the teacher constantly went around and entered into discussion with the project groups. Several learning indicators could be made visible to the teacher and to the students themselves. They discussed how they wrote their programs, where they found facts or inspiration, what contacts they made and what they learned during specific conversations with others. Students submitted various written reports throughout the project period. They wrote weekly follow-ups and their final reports, and their own memos to remind them of how they thought and considered their options. The teaching team had set appropriate criteria for scoring different products, the project work itself and reports.

What facilitates an authentic teaching approach¸ themes related to the inductive thematic analysis

In the inductive thematic analysis, certain patterns emerged as to what seemed to facilitate an authentic teaching approach in the case under investigation.

The teachers described how they had tried their hand at it for six to seven years to come up with the right approach. Their starting point were always what they themselves have learned from industry. The collaboration with the energy researchers over the past year had changed and further facilitated their approach towards authenticity. There were more data to work on for the students and a clear link to tasks in control and regulation technology and mechatronics. Many projects with links to the energy researchers have been created. The school's profile has now been defined as focusing on energy calculations and measurements.

The environment as facilitator

The teachers described how they try to create a permissive environment. They have a low staff turnover, and they talk about "creating a special environment".

> *"We collaborate our way into the courses, deputise for each other, work together, collaborate between courses, there are several teachers on the same course". (Teacher)*

The teachers describe how they have incorporated various stages in the workflows and how it is always a teacher who is ultimately responsible, but that more lecturers come in from outside. They have tried to use guest teachers in various areas; they express the view that study visits are important. Blocks are created in the schedule to enable guest lecturers to present and run topics or to make study visits. A guest gets to present an area, and the students are given the opportunity to work on this e.g. between 8 a.m. and 4 p.m. for three days. An example would be the topic of hydromechanics that the students worked on during the autumn. The teachers describe how they want to showcase the university and companies – real-world work: they want to stimulate and motivate the students. They want to show that it is people who work, who have skills, that they are from real life and that they say the same thing as the teachers.

> *"We want to stimulate interest in life, in work." (Teacher).*

The teachers have built-up networks of contacts but want to develop more formal networks.

> *"Companies and universities should be interested in showcasing projects that they are currently engaged in and what things are important to learn." (Teacher).*

Process rather than product

The teachers describe how they want the students to work: work should be enjoyable and something positive.

> *"The students' curiosity should lead them somewhere." (Teacher).*

The teachers explain how they want the students to find a problem for themselves and find a method that helps them see how to tackle the problem.

> *"The students have to come up with something themselves. They shouldn't stop at asking how they're going to do it – that's not what happens in real life." (Teacher).*

The teachers also state that they are trying to get away from set grading patterns. Students can pass the course even though they are not creating a finished product; the important thing is the design process itself, that the students develop curiosity and creativity, that they learn how everything connects together, that they dare and fail.

> *"Students shouldn't just be accrediting tasks that they can already do. If they didn't finish, they should report why they didn't; they should reflect on why that was." (Teacher).*

Training to work independently

Already in the first year, the students need to start working on thinking for themselves. At the start of upper secondary school, they are still unsure and asking about what is right or about how to do it. The approach used at the school does not work right away, the students need to get used to it and train themselves. But once they are in the third year, they manage to work independently on their projects and understand how to work on projects.

How the teachers and the principal view their role

The most important ability of both the teachers and students is that "you just have to dare to take a big leap" (Principal). The teachers stress the importance of daring to make mistakes and not being immediately correct, both as a teacher and a student.

> *"We teachers are not omniscient, we have good skills and we can contribute with our breadth of knowledge. We have a common pool of experience, but we don't know everything." (Teacher).*

The teachers describe how they see the approach as an investigative activity, how they often must familiarise themselves with new things, all the time in fact. During this project four teachers who support each other and the students with the projects in the technology subject. According to the teachers, the students can sometimes be "sharper" and "you can take advantage of that". The teachers explain how the approach they use is beneficial in the subject of technology. They state how they do not subscribe to the view that "we are teachers and we should have the best level of knowledge".

The principal explains what is the most important thing for the approach to work:

> *"Dare to make that leap! Don't keep doing the same old thing! We can't do everything: the content is prescribed, but we develop the approach." (Principal).*

The specific approach plays a greater role in the technology courses than in other subjects. There is no textbook for the Technology 2 course in the technology subject on the program, and no assessment support has been developed centrally. The principal describes how they instead started from their own skills, the companies they know and can collaborate with. The principal describes a sense of insecurity, but above all freedom. The principal also states how important it is to provide support for business contacts, study visits, travel, etc. The principal further describes how this year the students have undertaken a CERN visit and studied solar power and pumping power in Seville, then nuclear power in the south of France. The principal provides support, the teachers have contacts they can cooperate with. The approach enables cross-curricular learning. In terms of content, the focus is on energy and on measuring various parameters, obtaining data, and using it. The principal sums it up: *"The students collaborate, we facilitate!" (Principal).*

Discussion

The questions raised within the study were twofold. What characterises authentic learning when students on the technology program work on their design projects and individual pieces of work? How is authentic teaching and learning facilitated?

To address the first question, we want to highlight the results from the deductive analysis that revealed the following aspects regarding the teaching. The teaching can be related to the nine elements and is thereby expected to provide authentic learning.

About the element *Provide an authentic context that reflects the way the knowledge will be used in real life (1)*, the students encounter a real-world context to a very large extent (Rule, 2006; Resnick, 1987; Young, 1993; Harley, 1993) when collaborating with energy researchers. This environment is designed to resemble a real-world workplace where engineering design work is conducted (Hill, 1998), meeting the demands of external clients (Hill, 1999). Regarding the element *Provide authentic tasks and activities (2)* students are engaged in assignments that offer authentic tasks and methodological approaches (Brown et al., 1989). They are allowed to formulate their own questions (Rule, 2006), assignments, and strategies (Collins et al., 1989), moving beyond simple, doctored tasks. Regarding the two elements *Provide access to expert performances (3)* and *multiple roles and perspectives (4)*, the learning environment allows students to consult with teachers and others (Collins et al., 1989) who have the time and interest to act as collaborators, guiding and discussing various aspects with the students. This setup supports the collaborative construction of knowledge. How the teaching is connected to the element *Support collaborative construction of knowledge* (5) we can see how the students' authentic approach is characterized by collaborations where they can share experiences and insights with one another and with more experienced individuals in the field (Cross & Congreve, 2021; Young, 1993; Hill & Smith, 2005). Regarding the elements *Promote reflection to enable abstractions to be formed (6)* and *articulation to enable tacit knowledge to be made explicit (7)*, the presence and commitment of the teachers, along with their overview of the work, enable students to constantly reflect and compare their thoughts with those who are more experienced (Herrington &

Oliver, 2000). This process is crucial for the students to communicate their results and suggestions, and reflect on their own knowledge, enabling them to evaluate and articulate their learning (Rule, 2006). That the teaching can *Provide coaching and scaffolding (8)*, is visible because we can see how teachers create an environment that supports the students' deep involvement in their assignments, fostering a sense of contribution with their knowledge and learning (Rule, 2006). Also regarding the element *Provide for authentic assessment of learning (9)* is demonstrated when students are assessed throughout the process based on various learning indicators (Herrington & Oliver, 2000), reflecting a comprehensive evaluation of their engagement and understanding in real-world challenges (Cross & Congreve, 2020). Through these elements, the case study illustrates a comprehensive approach to fostering an authentic learning environment that prepares students for real-world challenges and the practical application of their knowledge in professional contexts.

The result from the inductive analysis addresses how the authentic teaching and learning can be facilitated. The approach that emerges in the school in question is facilitated by the idea the teachers have of both their technology teaching and their own role as technology teachers. In their team, there is agreement on creating a learning environment that promotes authentic learning. They prepare the students for this from the first year of upper secondary school. The teachers feel confident in their teaching role and in their skills and knowledge, as well as in their way of looking at assessment (cf. Cunningham, 2021). They have contacts outside of school and they place great value on students being encouraged to learn about the outside world and deal with wicked problems. They want to act as the students' partners in the projects, they want the students to see opportunities and strategies so that they can dare to succeed and fail. The teachers think and plan outside the box, they dare to "take the big leap". Another very significant aspect that makes this approach possible is the school management's wholehearted support, contacts and supporting resources.

Conclusions

During the project about technology in the upper secondary school we have studied the process and we found that the teaching was classified as authentic according to the nine guarding elements (Herrington & Oliver, 2000).

The teachers view of how authentic teaching is facilitated is that they are mediators, working in projects together with the students and the energy research team, as well as collaborating with other actors. They search for knowledge together in a problem-solving way and when problems arise, they seek help from experts and companies as appropriate. The big leap is to let go of the limitations and search for solutions together. We find that certain organizational factors play a significant role in the possibilities for authentic teaching. Not only the didactic aspects. Having school leadership on one's side and able to provide concrete support appears to be an advantage. Feeling confident and engaged in the teaching form as a teacher is, of course, necessary.

Factor that enables teachers to work with authentic teaching and learning needs to be further studied. Wicked questions in teaching and learning could also be further used if teachers were more encouraged to work authentically.

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