# Authenticity in integrated STEM education – boon or fantasy? Observing upper secondary technology classroom practice

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## ABSTRACT

Engineering design and technological modelling have been argued as valid premises from which to increase authenticity, relevance and create bridges between the STEM disciplines while maintaining subject integrity. Previous research indicates that projects which emulate how engineers work has the potential of both integrating STEM disciplines and being authentic. At the same time, earlier research also cautions that few integrated STEM projects consider students' interests and their everyday contexts. The aim of this study is to investigate the implementation of an integrated STEM project in the Technology Programme at a Swedish upper secondary school. The studied STEM project involves students' designs for improving their physical school environment in terms of well-being, feasibility, and sustainability. Data collection consisted of participatory observations, as well as teacher and student interviews. The results are presented in terms of three themes, namely (1) cooperation and real-life application are fundamental for authentic learning; (2) using models and modelling for communicating design ideas are central to authentic technology and engineering; and (3) integration of STEM content and methods do not draw on all four disciplines. It is concluded that there might be easily accessible pathways to promote integrated STEM and authenticity, such as utilizing the school environment as a starting point. However, formally implementing authentic practices remain a challenge even though a majority of teachers are enthusiastic about real-world relevance in design projects. Integrated STEM in the design project mostly included technology and engineering content, and aspects of science and mathematics albeit to a lower degree, which made simultaneous integration of all STEM disciplines a challenging task.

*Key Words: Technology Education, Engineering Design, Integrated STEM Education, Upper Secondary School, Authentic Learning.*

# 1. INTRODUCTION

In recent years, engineering design and technological modelling have been argued as valid premises from which to increase authenticity, relevance and create bridges between the STEM disciplines while maintaining the integrity of each subject. Recent conceptual (Hallström & Ankiewicz, 2023) and empirical (English & King, 2015; Lin et al., 2021) studies indicate that projects which emulate how engineers work have the potential of both integrating STEM disciplines and being authentic. However, scholars such as McLure et al. (2022) caution that few integrated STEM projects consider the students' interests and their everyday contexts, which presents a challenge if integrated STEM education is intended to promote authenticity. In addition, authenticity is a contested phenomenon, not least when it comes to discerning *for whom* something should be deemed authentic (e.g., Anker-Hansen & Andrée, 2019).

The aim of this study is to investigate the actual implementation of an integrated STEM project in the Technology Programme at a Swedish upper secondary school. The studied STEM project involves students' designs for improving their school environment in terms of well-being, feasibility, and sustainability. We investigated the implementation of the project as well as how teachers perceived it.

# 2. THEORETICAL BACKGROUND

Authenticity in education is a popular, yet at the same time a very contested notion (Schriebl et al., 2022; Watson, 2008), as far as the term often induces the question, "authentic for whom?". Typical definitions of authenticity include that by Rule (2006) who describes authenticity as "learning in contexts that promote real-life applications of knowledge" (p. 1). Furthermore, Shaffer and Resnick (1999) have identified four inter-related types of authentic learning, namely: (i) learning that is personally meaningful, (ii) learning that relates to the real world outside of school, (iii) learning that relates to a particular discipline, and (iv) learning where assessment reflects the learning process. In focusing on *learning*, one centres the "for whom" question on the student recipient (Anker-Hansen & Andreé, 2019). Doing so also caters for students' own perceptions of authenticity, which in turn, might engage a further motivational component in their learning (Behizadeh & Engelhard, 2014; McLure et al., 2022). Since promoting authentic learning is regularly mooted as conducive to "real" settings and practice, technological praxis (e.g., technology and engineering) serves as a valid context from which to generate authentic learning activities (Turnbull, 2002). Hence, integrating authentic learning into upper secondary school technology programmes could serve as a meaningful point of departure (e.g., Svärd et al., 2022).

Contemporary literature views authentic learning as highly connected to STEM education and modelling. Authenticity in an engineering context is often embodied in design projects, which according to Pleasants (2020) could be based either on solving "pure STEM problems" or "STEM-relevant problems". According to Davies and Gilbert (2003), modelling activities spawn natural connections between, for example, the STEM disciplines, science, and design and technology due to overlapping modelling practices. Such a notion could even be extended to mathematics and engineering and thereby serve to forge further authentic connections.

In this study, we loosely adopt a definition of authenticity that emphasises students' participation in practices and activities of professional scientists, technologists, engineers or mathematicians, or activities appropriate for, or corresponding closely to such professional practices for solving real-world problems. Thus, authenticity comes in various forms and degrees that can be combined in a multitude of ways. Employing methods and instruments used in professional activities is one form of authenticity, whilst solving problems like those solved by professionals is another. Authenticity could also be forward-looking in terms of the design of products that could potentially be marketed, while authenticity could also lie in the methods of problem solving (see Murphy et al., 2006).

## 3. METHODS

Data collection was conducted at an upper secondary school in Sweden. The educational programmes that the school offers are included in the upper secondary curriculum, and the specific selection at this school is dominated by technology and introductory engineering programmes which collaborate closely with local industries.

An integrated STEM project involving the design of an indoor or outdoor environment was presented to 24 groups and 180 students altogether, within the programmes Technology; Health and Social Care; Electricity and Energy; and Industrial Technology. Three of the four authors collected data, during the full three weeks (18 April until 5 May, 2023) that the project lasted. Based on student consent, it was possible to collect data from 10 specific groups. In each of these, at least one student was enrolled in the Health and Social Care programme while the remainder were Technology programme students. The groups consisted of between 4 and 7 students. The project represented an integrated STEM (iSTEM) engineering design project that dealt with the design of an indoor or outdoor environment and artefacts that should promote good health. For the Technology programme students, the project took place during the final weeks of "Technology 1", an introductory technology course where the learning objectives include technical drawing, history of technology, and project management.

We carried out participant observation of the students and their solutions and designs as they engaged in the project, and solving the problem related to design of an environment that promoted healthy living. The school had worked with integrated STEM projects previously, but this one was larger and more organised. Furthermore, we observed the teachers and how they interacted with the students. We also interviewed teachers and students (see table 1). We collected the students' written documentation in the form of a logbook. The observation protocol was inductive, in the sense that we studied subject content, working methods, work environment, as well as degree of integration, model use, and authenticity. We asked related questions to both students and teachers, to garner their views on the degree of authenticity of the project, and related views of how the project transpired. The interviews were audio-recorded, and observations documented through field notes. All data were collected in Swedish and translated into English. Data collection and data storage were carried out according to Swedish and European law (General Data Protection Regulation, GDPR), and informed by the ethical research guidelines of All European Academies (ALLEA, 2017).

*Table 1*
*Project Activities and Data Collection Timeline Adopted in the Study*

| | ***Activities*** | **Data collection type** |
|---|---|---|
| 1st week | Introduction<br>Solution suggestions<br>Idea pitch | Teacher interviews (before commencing)<br>Observations |
| 2nd week | Physical modelling | Observations<br>Teacher interview |
| 3rd week | Preparation for final presentation<br>Final presentation | Observations<br>Student interviews |
| 4th week | Reporting | Teacher interviews (after completion) |

Inductive qualitative content analysis was performed on the data (Elo & Kyngäs, 2008). All authors participated in the analytical process. The analysis was informed by implicit and explicit references to aspects of authenticity and modelling, namely in activities and work organisation, in equipment, in problems, or contextual factors such as money, time, standards and security regulations.

## 4. RESULTS

Based on the observations and interviews with teachers and students that participated in the design project, the analysis yielded three themes:

### *4.1. Cooperation and real-life application are fundamental for authentic learning.*

The nature of authenticity in the design project, as perceived by teachers and students, is that it is the design/product that is to be authentic and useful. As such, the concept of authenticity is therefore forward looking and future oriented, and the product should therefore have the potential to be produced or to solve a present or future problem. In the introduction of this project, the teachers pointed out the opportunity to have one or more of the students' ideas implemented in real life at their school.

There is also authenticity in how the assignment was presented and in the working methods. The work was performed in smaller groups where students from different educational programmes were mixed. As represented in the quote below, from the teachers' perspective, this was one way to make the project authentic:

> You can really see it as a problem-solving process, a structured method for solving problems. For the Technology programme it could be roughly like how an engineer works, but for the others it can be problem solving in their own areas, organisational development in industry and similar (Interview, Technology teacher 1, 18 April 2023).

When introducing the task, another teacher encouraged the students to practice cooperating together and told them that "this is what it looks like in real life" (Field notes, English teacher, 18 April 2023). Also, the same teacher emphasised that in cooperating "everyone does not do the same thing" (Field notes, English teacher, 18 April 2023), it is about finding your strengths and contributing to the task. The connection to work life and mixing competencies is one of the main pillars of the project that contributes to authenticity (Nordlöf et al., 2022), which is something that the teachers maintained in the interviews, revealed in utterances such as:

> Different competences and knowledge are at least as important for carrying out the project successfully, for quality, and for efficiency – just as it functions in working life" (Interview, Technology teacher 2, 18 April 2023).

During the first week of the project, a presentation was given to introduce students to the design process. The teacher had experience in working as an engineer, which was explicit in the teacher's presentation. For example, she referred to companies familiar to the students and talked about the design process in terms of what the companies do, as per comments such as "they work with this process every day."

An example of a lack of authenticity was described by one student. He felt that the project was not authentic since they had no budget or economic framework to relate to, which would have been normal in a real-life project.

### *4.2. Using models and modelling for communicating design ideas are central to authentic technology and engineering.*

The teachers introduced the project by encouraging students to build their own cardboard models of their school environment designs. Such a model should be a means of displaying and explaining their idea to others, as part of their presentation of the product. For example, as one teacher said, "you do not bring a whole car to a meeting, but a model of a car could be presented" (Field notes, Technology teacher 1, 24 April 2023). A model could also be a way of showing the functions of a product, for example, in a physical model of a building (Norström & Hallström, 2023).

Many examples of modelling emerged from the observed activities. For example, the students generated pencil-and-paper sketches and simple CAD models to explain their ideas within the group. They also used photos, Google Maps, and other applications to convey ideas. One group had even obtained original blueprints of the school building to obtain exact measurements.

The modelling performed in the design project was mostly served to communicate design ideas within the project group, and to the teachers and members of the jury in the final innovation competition. Thus, while modelling is not performed to test design ideas, it plays a vital role in communication. Thus, while the models and modelling are authentic, there are essential elements of real modelling such as industrial enterprises that are lacking.

### *4.3. Integration of STEM content and methods do not draw on all four disciplines.*

Implementing the design project as an example of integrated STEM functioned in the sense that the activities included technology and engineering problem solving together with some mathematics, albeit at the lower-secondary level in the latter case. For example, mathematics was applied in measuring and converting scales and when building physical models. Students also performed simple geometrical calculations in relation to physical modelling and deducing scale. In Sweden, such calculations comprise lower-secondary mathematics education, and the mathematics integrated in the activities was not equivalent to the upper-secondary education Technology programme. Technology teacher 2 commented this in the following way:

> Well, about that, it's not really upper-secondary maths. […] As it was, the maths wasn't planned but was more brought in as an aid. […] Because the task in itself didn't require maths at a high level, but that doesn't mean that it wouldn't be possible to implement at a higher level (Interview, Technology teacher 2, 16 May 2023).

The same situation also arose when it came to integrating science education in the project. There was indeed content and methods that could be construed as science-related, in relation to health issues and well-being such as encouraging a healthy lifestyle, which are components of biology education. However, the students had already studied these perspectives at lower-secondary level, so these were not emphasised, or seen as explicit biological learning goals. Instead, science integration was related to the fact that students from the Health and Social Care programme participated in each group.

While the depth of exposed technology and engineering knowledge was not extensive, it is important to note that the participants were first year upper secondary students. Nevertheless, there was a great deal of focus on engineering working methods, such as project work, teamwork, and cooperation, which meant that technology and engineering content was still foregrounded (cf., Nordlöf et al., 2022).

## 5. CONCLUSIONS

At this point in the research programme, the overall conclusion from this project is that there might be easily accessible pathways to promote integrated STEM and authenticity, such as utilizing the school environment as a starting point. However, formally implementing authentic practices remain a challenge even though a majority of teachers are enthusiastic about real-world relevance in design projects. Integrated STEM in the design projects mostly included technology and engineering content, with some science and mathematics albeit at a lower level. The findings thus point to the difficulties involved in integrating all STEM disciplines simultaneously. Paradoxically, despite these observations, the Swedish curriculum encourages in-depth subject studies as well as interdisciplinary work. Frame factors also affect the possibility to work in a way that promotes the integration of STEM subjects, such as the structure of the schedule and how subjects and courses are executed. If increased STEM integration is sought, then introducing a curriculum that explicitly encourages subject integration would be beneficial.

Although the project did not expose extensive "depth" in knowledge, it did succeed in focusing on and unleashing cooperative and creative skills. The integrated subject knowledge was often at a lower level, as shown when mathematics was applied. If the purpose of integrated STEM is to also develop knowledge in separate disciplines such as mathematics or chemistry, the STEM project needs to be more closely related to contemporary upper secondary subject content, and the teachers need to plan problems with a clear subject focus.

The study highlights cooperation and teamwork as being key to achieving any true form of authentic learning – inferring that realising authenticity relies on cooperative dimensions. In turn, this also has implications for assessment. Much merit is to be found in "wonderful messy modelling" processes for communicating design ideas. Indeed, being part of a structured engineering design process is a learning objective in itself. Although challenging to achieve, the process also provides a framework for learning about technologies related to ergonomics, architecture, and construction. It is apparent that most groups learned about the process, but to what extent requires further exploration.

Finally, in reference to Shaffer and Resnick's (1999) definition (apart from considering assessment), the project can still be deemed an authentic enterprise. The project can also be construed as personally meaningful to the students since it relates to real world problems within their own direct school environment (McLure at al., 2021; Shaffer & Resnick, 1999). When it comes to STEM, the studied project deals with both a narrower as well as broader set of problems than what Pleasants (2020) terms "pure STEM problems". Focusing on solving technological and engineering problems with only a hint of mathematical and science problems might account it as narrower. But integrating economic and health problems in relation to Pleasants' (2020) "STEM-relevant problems" also render the project broader.

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