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Berit Bungum & Erik Mogstad

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Building and programming a weather station: Teachers' views on values and challenges in a comprehensive STEM project

Berit Bungum and Erik Mogstad

Department of Physics, the Norwegian University of Science and Technology, Trondheim, Norway

ABSTRACT

Background: Integrated STEM approaches are acknowledged as important for making school subjects relevant and engaging for students and are reinforced with the current emphasis on computational thinking. Still, such approaches are rarely realized in schools. This study investigates how the traditional 'grammar of schooling' may prevent realization of more holistic teaching in line with ideas from integrated STEM.

Purpose: A concrete teaching project where students design, program and build their own weather station is presented, and we investigate the values and challenges teachers see in the project and the obstacles that may prevent them from running it in class. This way it throws light on why STEM approaches may be difficult to realize in schools.

Sample: The sample consists of teachers involved in a collaborative project in which Project Weather Station was developed, including the teacher who was undertaking the project in his grade 9 class.

Design and methods: The study follows a case study design, with group interviews with teachers. Observation in class, video recording and interviews with students form a backdrop of the main interview data.

Results: Results show that teachers see value in the weather station project in line with the overarching aims of the curriculum and consistent with STEM ideas. Challenges they see are related to own competence, time use, risk of failure and logistics across subjects.

Conclusion: It is concluded that teachers' challenges reflect a tension between overarching aims in education and the more specific competence aims in the curriculum. On a systemic level there is therefore a need for an acceptance for the value of teaching that targets overarching aims of education. It is important to acknowledge teachers' challenges and fulfil their needs for support when undertaking extensive projects that have potential for realising the more holistic aims of education typical for STEM projects.

KEYWORDS
Integrated STEM; teachers; grammar of schooling; interdisciplinary teaching

CONTACT Berit Bungum berit.bungum@ntnu.no Department of Physics, the Norwegian University of Science and Technology, Trondheim, Norway

Introduction

Science and mathematics education is in constant need for approaches that make the subjects meaningful, relevant and engaging for students. In line with this, more holistic and practical approaches to the teaching of science, technology, engineering and mathematics have developed during the last decades, many under the label 'STEM' where the disciplines are combined with more or less integration (Wilson 2021). The inclusion of engineering in STEM reflects a wish to include aspects of engineering knowledge in the education for young people, acknowledging that it represents a distinct area of knowledge (Simarro and Couso 2021). Engineering is also included in the more recent description of engineering practices alongside science practices (Crawford 2014). Digitalization and the recent emphasis on computational thinking have further accentuated the relevance of STEM approaches in school (Li, Schoenfeld, et al. 2020), and the T in STEM is increasingly associated with digital technology (Tytler 2020).

There is, however, still little research on what integrated STEM approaches require from schools and teachers, and on the potential obstacles that may prevent teachers from running this kind of teaching. This paper contributes to the field by investigating how teachers perceive gains and challenges in an extensive teaching project called *Project Weather Station*, where lower secondary students design, build and program their own weather station by use of digital sensos and microcontrollers. The teaching project contains aspects of the ideas inherent in STEM, computational thinking and engineering practices, and is developed with the aim of fulfilling intentions in the new curriculum for compulsory education in Norway, where programming forms part of several subjects. Project Weather Station is one of several teaching projects developed by a group of teachers of science and mathematics in lower secondary school, in collaboration with science and mathematics educators as well as technology experts from a university in a joint project called KreTek (see Bungum and Sanne 2021). The teaching project is then undertaken by one of these teachers in his grade 9 class.

As described by Westbroek, Janssen, and Doyle (2017), curriculum ideals often get compromised as a curriculum moves through its various levels of representation. They show how teachers' goals to a high degree influence how ideas are realised in schools. It is therefore a need for a better understanding of the values as well as challenges teachers see in concrete educational innovations that are realizations of curricular aims. We therefore take a teacher perspective, and the research questions are therefore:

(1) What values do teachers see in Project Weather Station?
(2) What challenges do they see in realizing the project in class?

In the case of programming as a new curricular content in Swedish schools, Vinnervik (2020) has shown that teachers experience extrinsic as well as intrinsic challenges, and in particular call for pre-existing teaching materials and professional development. The present study, however, investigates teachers' challenges when these aspects are in place, since Project Weather Station arises from collaborative work in the KreTek project, where the teachers have received training in programming and collaborated in developing the teaching project.

The study is undertaken by means of interviews with teachers in the KreTek project, including some who were reluctant to running the Project Weather Station with their own students and therefore did not undertake it. Interviews with students and video recordings in the classroom were also conducted and are used in this paper mainly as a backdrop for teachers' views investigated through interviews. We discuss how teachers' views on values in the project compare to ideas inherent in STEM approaches and the new curriculum for compulsory education in Norway. Further, we investigate how challenges teachers see reflect the *'grammar of schooling'* (Tyack and Tobin 1994), that is, the implicit but still very fundamental structures that govern how instruction is organized and undertaken in schools. This approach reflects how we view teachers as professionals that make well-founded decisions in what they do, and that when curricula and other initiatives are not implemented as intended, explanations should be sought from other places than in teachers' lack of skills.

Perspectives on STEM education

This section reviews some main ideas and curricular approaches that will function as a theoretical lens for the empirical part of this paper. We briefly present what is meant by integrated STEM approaches to teaching, and ideas inherent in the more recent concepts of computational thinking and engineering practices. We point to commonalities in these ideas and approaches and how they challenge the 'siloed' nature of school subjects and the traditional 'grammar of schooling' as described by Tyack and Tobin (1994).

The acronym STEM (Science, Technology, Engineering, Mathematics) refers to a combination of disciplines for educational purposes, sometimes also including Arts under the label of 'STEAM' (White and Delaney 2021; Anderson and Li 2020; Li, Wang, et al. 2020). The attention to STEM and what it may achieve in general education has increased considerably during the last 20 years, but with a wide range of approaches and interpretations of what it actually involves (Yeping et al. 2020; Johnson et al. 2020). It may mean interdisciplinary or cross-disciplinary approaches, or simply combinations of the individual STEM disciplines but is mainly understood as amounting to more than the sum of its disciplinary parts (Tytler 2020). Wilson (2021) asserts that while STEM may be seen as an umbrella title for all education that falls under the tent of the broad disciplines science, technology, engineering and mathematics, these disciplines ought not exist in siloes, but instead be integrated in ways that reflect the multi-, cross-, inter-, and transdisciplinary work that integrates those separate disciplines.

Common to the various approaches to integrated STEM education is that they aim at giving students relevant and motivating experiences of the subjects and to better reflect how the different knowledge areas are related in the society (Tytler 2020). Reynante, Selbach-Allen, and Pimentel (2020) discuss, however, how this integration may compete with disciplinary practices and epistemologies and represent a risk that students are not taking up the more abstract ideas from e.g. mathematics. This relates to how Savage (2012) has argued that interdisciplinary approaches are challenging since school subjects are not necessarily compatible in terms of their epistemological, discursive or pedagogical approaches. In line with this, case studies of how teachers implement integrated STEM teaching indicate that the approach is often influenced by the teacher's subject background (Wang et al. 2011; Dare, Ellis, and Roehrig 2018).

It is also argued that STEM teaching may lead to a devaluation of basic scientific knowledge that does not have direct practical applications (see McComas and Burgin 2020). Reynante, Selbach-Allen, and Pimentel (2020) argue further that the nature of knowledge in any discipline is complex, contested and dynamic and that the boundaries between disciplines as professional practice are blurred. Since this complexity is typically neglected in how the subjects are taught in schools as fixed domains representing 'siloed' knowledge, integrated STEM approaches may reflect the nature of disciplines in more authentic ways.

In later years, several authors have pointed to a connection between STEM and *computational thinking* as a learning target, which has evolved in educational research, policy and curriculum development due to the rapid digitalization (e.g. Li et al. 2020; Grover and Pea 2013). It is associated with the representation of problems in ways that can be effectively carried out by means of computers, but also involves more general cognitive processes. These are made explicit for example in how Weintrop et al. (2016) have developed a taxonomy of skills that comprise computational thinking practices. This use of the term practices in the taxonomy for computational thinking by Weintrop et al. (2016) connects to how 'practices' has replaced 'scientific methods' in science education research and curriculum development (see e.g. Crawford 2014). The purpose is to avoid an instrumental recipelike view of how science is performed, and to present students with more authentic experiences of what scientists do as they engage in scientific inquiry (Lee, Quinn, and Valdés 2013).

In more concrete terms, the American curriculum framework *Next Generation Science Standards* (see Crawford 2014) has developed definitions of engineering practices alongside science practices in ways that in a broad sense capture the nature of science and engineering, including computational thinking. With a STEM perspective, Simarro and Couso (2021) propose a modified and more specific set of formulations, where *materializing the solution* is explicitly described as one of the engineering practices. The importance of materialization will be subject to discussion of results in the present study.

Challenging the 'grammar of schooling'

In sum, the ideas behind STEM education, computational thinking and engineering practices have much in common in that they transcend traditional disciplines and school subjects. This way, they also challenge what Reynante, Selbach-Allen, and Pimentel (2020) have described as *'settled and siloed knowledge'*. Knowledge being 'siloed' can be related to the organization of knowledge in schools, expressed by Tyack and Tobin (1994) as 'the splintering of knowledge into "subjects"' (p. 454). They argue that this is a key aspect of the grammar of schooling, which has kept education being organized in similar ways over centuries. Other aspects of the grammar of schooling they point to, are the taken-for-granted organizational practices in dividing time in specified units and space allocated to age-graded classrooms. They describe how the grammar of schooling has been remarkably resistant to change, and that it serves political purposes as well as being labour-saving:

> The familiar matrix of schooling persisted in part because it enabled teachers to discharge their duties in a predictable fashion and to cope with the everyday tasks that school boards, principals, and parents expected them to perform: controlling student behavior, instructing heterogeneous populations, or sorting people for future roles in school and later life. (Tyack and Tobin 1994, p. 476)

Failure to recognize the influence of organizational practices inherent in the grammar of schooling is likely to lead to a failure of educational reforms and curricular aims, or what Westbroek, Janssen, and Doyle (2017) point to as a slippage between innovation and practice. For STEM education, a review of research studies undertaken by Margot and Kettler (2019) has shown that secondary teachers see value in collaboration across disciplines, but may experience problems in communicating between subject area teachers, as well as in scheduling and adhering to content standards. Based on the review, they argue that teachers' efficacy beliefs and the value they place on STEM education influence their willingness to engage in and implement STEM teaching. Other research suggests that teachers who are used to teaching in a traditional silo approach may not be prepared for the holistic integrated approach that STEM represents (see White and Delaney 2021, p. 14). The case investigated in this paper will illustrate what a potential 'slippage' may represent in concrete terms in the view of teachers, in the case of an innovative teaching project that contains aspects of STEM as well as computational thinking and engineering practices in schools.

The case: designing and building a weather station

Meeting the aims of a new curriculum

Project Weather Station has been developed and tested within the combined research and development project KreTek, where science educators and technologist from a university collaborate with eight teachers from four lower secondary schools. The aim of KreTek is to support teachers in realizing intentions in the new curriculum for compulsory education in Norway where development of students' innovative skills is emphasized, and where programming forms part of several subjects (see NDET 2020).

The general part of the new curriculum presents six core values, whereof one states that

> School shall allow the pupils to experience the joy of creating, engagement and the urge to explore, and allow them to experience seeing opportunities and transforming ideas into practical actions.

These broad aims are reflected in the description of Science as a subject, which also includes technology as one of its core element. The science curriculum requires that students shall

> understand, develop and use technology, including programming and modelling, in their natural-science work. By using and creating technology, the pupils can combine experience and know-how with creative and innovative thinking.

In Project Weather Station, the core value and core element referred above are realised in the context of programming, which is also emphasized in several subjects, in particular Mathematics and Science. For Mathematics, a competence aim, that is, one of the more concrete aims that forms the basis for student assessment, states that students should be able to

> explore how algorithms may be created, tested and improved by means of programming, and to find and discuss measures of central tendency and measures of variability in real datasets.

A specific competence aim in Science states that students should be able to

> explore, understand and make technological systems that have a transmitter and receiver and to explore natural phenomena by means of programming.

The teaching project about weather stations presented in this paper is an innovative example of how this may be realised in concrete terms in classrooms.

Developing and running Project Weather Station in class

The planning of the weather station project was undertaken as part of the KreTek project, mainly by a sub-group of the pilot teachers, with assistance from university science and mathematics educators as well as the involved technology experts. The group of teachers, with varied backgrounds in science, mathematics, technology and arts & crafts, developed a supportive professional learning community as described in Bungum and Sanne (2021). The collaboration lasted for three years, and the present study was undertaken after two years of collaboration. The teaching project about weather station was seen as a joint product of this collaboration, but undertaken only by one teacher, in the following named Edwin, and his class. During the development, the group had regular meetings where the involved teachers received training in programming, tried out and discussed various ideas and equipment and together with the science educators and technology experts produced tested teaching material available to other teachers.[1] The teachers were not given specific training in integrated STEM pedagogy. The four schools they come from all value cross-curricular teaching and project work, but support the teachers in this work to a somewhat varying degree.

The technical core of Project Weather Station is the use of electronic sensors and microcontrollers (micro:bit) that collect and transmit weather data via radio signals to a computer where data sets may be treated numerically. As an introduction to the project, students are introduced to climate, weather measurements and requirements for the weather station to be designed. The requirements were that the weather station must contain a temperature sensor, a light sensor, a micro:bit (microcontroller) for data collection and a device for manual rain (/snow) measurement. The microcontroller must be protected from water, and it must be positioned within the range of the radio transmitter. With external requirements, freedom in finding solution and an iterative process in order to make the weather station work as intended, Project Weather Station gives the students an experience of key aspects of design thinking as described by Hennessey and Mueller (2020).

In separate sessions, students are taught how to program the micro:bit and transmit data from the sensors via the microcontroller to the computer. The students then work in groups of 2–3 students to first make sketches and discuss how the weather station can best be constructed and positioned. Before they start building, Edwin requires a detailed working drawing from the students, and for building the weather station, a range of tools and materials is available, also on students' requests.

The time use for the teaching project in class was extensive. Edwin, who ran the project in his class, is an experienced teacher of Science and Mathematics; he is used to developing and running larger projects with his students but not particularly skilled in programming and the use of microcontrollers. Edwin used all lessons in Science and Mathematics in his grade 9 class with 24 students for about 8 weeks on the project, corresponding to 36 hours. Many of these hours were used on the actual building of the weather station, where students were allowed to follow their own ideas with their own choice of materials.

Research methods

Data collection

Two researchers followed the weather station project in a grade 9 class with Edwin and the 24 students. This involved observation that served as giving a sense of the project, how it was approached by the teacher and how it was received by the students. More systematic data collection was undertaken by means of interviews with students and teachers, video-recordings by head-mounted cameras and recordings of student presentations.

An individual interview with Edwin was conducted after the class had finished the teaching project. It focused on the teacher's experience with Project Weather Station, what values he sees in it and the challenges he met, and how he did assessment of students' performance in the project. In addition, a group interview was conducted with Edwin together with five other pilot teachers in KreTek, in order to get as many views as possible of what values teachers see in the project, the challenges involved and the obstacles that may make teachers reluctant to running the project in their school.

The group interview had aspects of focus group interview, in the sense that the teachers discussed the topics under consideration, not only responding to interview questions.

During the conduct of the project in class, two student groups were wearing head-mounted cameras that recorded parts of the planning phase of the project. These two student groups were also interviewed after finishing the building of the weather station, and their presentations of their product for the teacher (which all student groups did) were recorded.

The main data source for this paper are the interviews with teachers, since we are here interested in their views. The classroom recordings and student interviews formed an important backdrop of the interviews and their interpretations, and some data from students are included in the presentation of results in order to consider teachers' views in the actual context of the classroom.

Analysis

The study was concerned with identifying the essence of the teachers' *lived experience* (van Manen 2016). The study thus has aspects of phenomenology, where one is concerned with the structures of experience as they are presented to consciousness without the filter of theory and deduction (Barnacle 2004, p. 66). The unit of analysis has been text segments from transcribed interviews, and not individual teachers. This means that we identify views that exist in the group rather than describing and comparing individual teachers.

Transcribed interviews were analysed in several steps in line with how Braun and Clarke (2006) have described thematic analysis. After familiarizing ourselves with the entire data set as a whole, sequences of interest were grouped in two main topics: *values* and *obstacles*. A more detailed coding system was used, and examples of subcodes for values were *learning, motivation* and *programming*, and for the obstacles some subcodes were *time, teacher competence* and *physical settings*. Codes are not presented as results in themselves but worked as a way of structuring the analysis and presentation of results.

Translation of interview data (in this case from Norwegian to English) involves interpretation and thus carries a risk of weakening the authenticity of data. Therefore, translation was done in three steps. After an initial quite direct translation of quotations used in the draft of this paper was undertaken by one author, the translation was refined and somewhat compressed for readability by the other author. Finally, the translations were compared to the originals, outside the context of the paper, by a colleague familiar with the project but not with the content of the actual paper. It was this way ensured that the translated data carries similar meaning and connotations, and some adjustments were made.

Notes on trustworthiness and ethics

The close collaboration between researchers and teachers in the KreTek project is a potential threat to validity of results in the study, since participants might hold back opinions to avoid criticising or disappointing collaborators. However, the fact that Project Weather Station was experienced as a joint product of the collaboration made it possible to discuss its values and disadvantages freely in the group. An indication of this being the case is found in the group interview when one teacher questions whether programming is at all essential to the teaching project. This was received as a valuable reflection rather than critique by the researchers as well as the teacher group.

Informed consent for participation in the study was collected from the participating teachers, students, and students' parents. Data handling has been approved by the Norwegian Centre for Research Data (approval number 953765).

Results

This section presents results of the analysis of teacher interviews, supplemented by classroom observations, video recordings of students' work and student presentation and interview. It is structured in two parts that reflect the two research questions: values teachers attribute to the project and what challenges they see in running it. The presentation contains citations from the teacher Edwin who ran Project Weather Station with his students as well as from the other teachers in the KreTek project, referred to as T1, T2, etc. This notation is chosen in order for the reader to easily distinguish between the teacher who ran the project and the others. Students are referred to as 'S', but this signifies different students.

Teachers' views of values in the weather station project

In describing the weather station as a teaching project, the teachers used words like 'deep learning' and 'holistic understanding'. They explain how this type of project can contribute to students' understanding of technological systems, measurements, and exploration of scientific concepts. One teacher states that he sees a lot of science in the project, and that it allows for students' creativity:

> T2: I think there is a lot of science in the weather station project. It's about weather, you measure, you collect data, and on top of that it is a creative process. That was my intension, that we should use technology, and there is creativity, and you are to design, shape, build something.

Students' data collection and interpretation are highlighted by one teacher, as the students not only have to collect and interpret data, but also design, test and develop the measuring instrument. The amount of attention students gave to the measurement accuracy while working on weather station is evident from one student's description of her main learning outcome from the project:

> S: At least I learned a lot about measurements and that sort of things, that many meteorologists use . . . if they know that there is a certain measurement error, then they just subtract or add so much they know is wrong. I did not know that before. For example, if you know that it will be two degrees warmer because of the specific location, then you can just subtract two from the temperature you measure.

Even if the student does not use the word 'calibration', her description shows a good understanding of what it means, why it is important and how it can be implemented in concrete terms in the coding.

The collection of weather data and interpretation of results form a basis for discussing methods for accurate and valid measurement. The actual designing and building the physical weather station provides even more problems and queries for the students to discuss. Examples are when a student group discusses what to do with the measurements from the rain gauge if it snows, or how to handle the temperature sensor that does not tolerate water:

> S: The temperature measurer, for example, we plan to place it under cover to protect it, right? But maybe the cover makes it a bit warmer than it is outside in the air. Then we would get a measurement error. So, we must try to make our sensors as good as possible and as correct as possible. So, we must also measure outside in the air to check whether we get the same temperature as with our micro:bit.

The opportunity for the students to immerse themselves and use knowledge from different content as well as a range of techniques seems to be valued by the teachers as well as the students. Edwin states that his students did not necessarily get as much benefit in terms of programming skills, but that they through immersing themselves got a more holistic and realistic picture of how programming is a part of a technological system. One of the other teachers underlines that the project could have been undertaken without making students program at all, because they could have been given a ready-made code. He also doubts the effectiveness of the project in teaching students programming, but points to how it rather demonstrates for students what programming can be used for:

> T1: I think this project can actually be done without programming, (. . .) it´s not sure the students have learned so much programming by doing this, I don´t actually think they have, so I wouldn´t say that this essentially is a programming project. But it is a way to show to the students that here you can program a chip to do something (. . .). But if the goal is that the children should learn programming, I would never recommend to teachers to choose this project.

This teacher also points to the value of collecting authentic data that students can work with in statistics as part of mathematics:

> T1: I also thought much about the mathematical component, the statistics, that this could be a nice introduction to the topic. When the statistical analysis you perform is based on something you have ownership to. You have built something to collect data about temperature or wind or similar that you can analyze afterwards.

One teacher highlights that the assignment given to the students does not come with a step-by-step guide. The project instead encourages students to come up with different ideas for solutions, and then to test them. In general, the teachers seem to value the openness of the assignment given in the weather station project. There were, however, some requirements the students had to adhere to in the way Edwin ran the project. These requirements were important as a starting point and framework. The freedom to make their own decisions regarding design, choice of material and even tools for the job, is highlighted as an important factor in fostering exploration, creation and creativity. This value of the project also appears in the student interview:

> S: Yes, if he [the teacher] in a way had said that it for example must be this tall and this long or similar, then it would be a bit harder to be creative, because it would have been more requirements. But now, when he in fact only tells us what has to be included and gives us some freedom to create it in our own way . . . Then, I think it is a bit easier.

The teachers also advocate the significance this type of project may have in terms of creating a sense of relevance and authenticity in students' schoolwork. Edwin states that the students' motivation and the positive impact the project had on student – teacher relationships perhaps were the greatest values of the project:

> Edwin: Perhaps the most important impression I am left with is the motivation the students got to work on it [the project], the engagement they showed, and the relationship we developed.

The project's impact on student motivation was evident when one student exclaimed *'this is a lot more fun than Science!'*. It is very positive that this student found the project to be fun and motivating. On the other hand, it might be seen as worrisome that the student does not see that what they are doing in the project is in line with the Science curriculum and in fact more related to scientific work than traditional learning activities such as reading in a textbook and answering questions. Since Edwin's teaching is normally varied and contains various student-active projects, the utterance from the student is a bit surprising. Rather than characterising Edwin's actual teaching, it may reflect how the student perceive a more general 'grammar of schooling' in the context of science teaching.

Challenges teachers see in the weather station project

The relatively large amount of time required to complete the weather station project is highlighted as a main challenge among the teachers. T2 describes it as a barrier:

> T2: Yes, I am a bit, I don't know whether afraid is the right word, but I think that the time consumption, if presented to all teachers, even if it is rational, might be a barrier for many to embark on this project, since one is not guaranteed to succeed. If you are two thirds out in the project, and you realize that this is a fiasco, then you have wasted four weeks, right. There is a certain anxiety related to starting such a big project.

The problem this teacher points to is, however, not necessarily the time used, but the *risk* involved since you are not guaranteed success. Spending 36 hours of teaching time may be worthwhile, but in case of failure there is a lot at play. This risk associated with the learning outcome might make other teachers apprehensive even if they see a potential value of the project.

In addition, running of ambitious teaching projects like Project Weather Station requires, as one of the teachers states: *'a lot of planning time for the teacher'*. However, the teachers do believe that the use of time can be justified. One teacher emphasizes that although the time usage is extensive, there is enough time during a school year to have a couple of large and time-consuming projects. Still, Edwin upholds that teachers may be unwilling to carry out such a project because the content and learning outcome are not specific enough, in relation to the competence aims in the curriculum:

> Edwin: It's not so clear [in the project] that 'now you learn about this, now we measure this competence aim'. Therefore, yes, I believe not many teachers would be willing to spend so much time on it.

The relationship between the number of competence aims covered by the project and the time it takes to complete it can thus be seen as a challenge. As a solution, the teachers discuss a more interdisciplinary approach. Edwin says that including a subject like Art and Crafts may be a way to shoulder the burden of such an extensive teaching project, in addition to lessen the use of teaching time from science and mathematics. However, this is not always easy according to Edwin. He says he tried to involve Art and Crafts when planning the project but that it became difficult, especially because Art and Crafts lessons were filled up with other projects. Science, Mathematics and Arts and Craft have different curricula and annual plans, and teachers do not necessarily share the same subjects. In the following interview sequence, one teacher who happens to teach both Mathematics and Arts & Craft, shares some of her thoughts on interdisciplinary cooperation:

T4: Not many teachers teach the combination of subjects that I have, it is not common to teach both Mathematics and Arts and Craft. Arts and Craft is often quite fixed. We do know what we are going to do next year as well, we have made the plan already. Of course, it can be adjusted, and we should have interdisciplinarity, but at the same time it is a subject that is typically fully planned early in the school year.

T1: So, if we are to plan to carry out a large interdisciplinary project, it should be decided already at the start of the school year?

Interviewer: Because of the equipment and the projects?

T4: Yes, we often have 4 – 5 groups of students that rotate between 5 teachers. Usually it adds up well, sometimes we have some days left that we can spend on a Christmas workshop, for example. However, you must be willing to do it [participate in an interdisciplinary project], and you must have Arts and Craft teachers who are willing to do it. So, it depends . . . how easy it is to sell.

It appears that interdisciplinary projects may be a challenge due to logistics within and across subjects. Rigid annual plans and the involvement of several teachers can make projects like the weather station difficult to carry out across subjects. In addition, it requires commitment from all teachers involved.

Uncertainty related to one's own competency in programming and other technical aspects is also highlighted as a potential challenge by the teachers. One teacher says:

T3: For me it´s related to the feeling that there is a lot at stake, I feel there are several things that I would be somewhat uncertain about. I tried to look at it yesterday, for example, you must connect quite many different things to the micro:bit, and, is there a manual that shows how the temperature sensor works, how the different sensors work? That part would make me a bit, kind of uncertain.

In addition to insecurity and worry about failure, another perspective is presented by one of the teachers, in explaining how his views have developed during participation in the KreTek project:

T2: At the same time, I recall the beginning of the KreTek project . . . During the project period we have got training in programming and micro:bit, but at the time we started to talk about [student] project proposals, all of that was still quite unknown to us. I had heard about Scratch before, I might even have seen it in use, but I had no knowledge about it. Micro:bit was something I learnt about during this project, through the workshops. So, at that time, the potential was perhaps still not evident to me, it was not clear to me what I could do with those tools.

He tells how his own growing competence has helped him to, in a greater degree, appreciate the value of projects like the weather station. As such, a lack of competence might not only be a challenge because one feels insecure. It might also prevent teachers from seeing the potential values of the project at the outset.

Technical assistance is also a need that emerges from the interview. Edwin explains that without the support from the other project teachers, whereof one very skilled in programming, he would never have taken on the project in class:

Edwin: I think that's exactly the barrier that is crucial, for whether they [teachers] are going to do it or not. Because if I hadn't got help from you [the project teachers], I wouldn't have done it. And, because it would have taken so much time for me to learn that on my own.

Again, time is a crucial factor as Edwin points to that it would have taken him too much time to learn all he needed on his own. Several of the teachers also state that they would have liked to have access to an expert or a skilled colleague in the classroom when working with comprehensive projects like the weather station, to help with programming and other technical parts.

Discussion

This study has investigated values teachers see in Project Weather Station and the challenges they see in running it in class. The values they see can be summarized as follows:

- Students' gain a deeper understanding of the science in the curriculum including technological systems and better understanding of measurement.
- The authenticity in the project gives the students ownership to measurement and data handling by designing and building their own data collection device.
- Students get opportunities to immerse themselves and to be creative, which in turn lead to increased motivation and improved student-teacher relationship.

These values resemble many of the ideas inherent in integrated STEM, engineering practices and computational thinking, in that they transcend disciplinary borders and 'siloed knowledge' and emphasize relevance and authenticity. The teachers value how students are given the opportunity to work with a project that they get an ownership to, immerse themselves and use their creativity. Also, the students value these aspects, in acknowledging the freedom they have to shape their own product and the ownership this creates. While Reynante, Selbach-Allen, and Pimentel (2020) have described how integration in STEM teaching may compete with disciplinary practices and epistemologies, evidence from the students show that they have focused on the importance of accurate measurements, a typical feature of science practices. This is, however, likely to be dependent of how the teacher frames the project. The focus Edwin put on the need for accurate measurement has strengthened the authenticity and links the project to explicit content in the science curriculum.

Originally, programming was meant to be a key part of the project in order to meet the curriculum's requirements in this regard. However, teachers admit that it is not the most effective way to teach e.g. programming in terms of coding; the value lies rather in how the project lets students experience what it can be used for. This is consistent with how the Norwegian curriculum describe that by using and creating technology, the students can combine experience and know-how with creative and innovative thinking. This means that meeting the ambitious aims of the curriculum's general parts may be directly in conflict with an emphasis in effective fulfilment of each of the specific competence aims, as these represent the curriculum in more settled and siloed ways as described by Reynante, Selbach-Allen, and Pimentel (2020). Teachers' concerns for uncertain learning outcome is likely to be due to the specific competence aims, rather than to the more holistic experience of the project.

Many of the values teachers describe can be attributed to *materialization* in how Simarro and Couso (2021) have described engineering practices. It is the materialization – the building of the weather station – that gives the students ownership and opportunities to be creative. Paradoxically, the materialization also represents a main challenge, as it is the main cause for the extensive time use. The actual materialization seems to be important in order to create a driving force in the students' design process and to give the student a sense of fulfilment that motivates their effort. However, time spent on materialization does not necessarily pay off by meeting specific competence aims in the curricula for subjects. This probably contributes to the teachers' feeling of *risk* involved in the project, since the time use puts a lot at stake for the teacher.

This dilemma of time use can be seen as a tension between different intentions in school more generally, also on formal level of the curriculum. Intentions described in the general part of the curriculum include terms such as innovation, creativity, and in-depth learning. These are consistent with current curricular trends such as integrated STEM, engineering practices and computational thinking. However, these intentions seem to be overruled by the more concrete competence aims, which in turn reflect the traditional 'grammar of schooling' (Tyack and Tobin 1994), with limited time slots, siloed knowledge and emphasis on assessable learning outcomes within specific subjects. Results of our study indicate that the value teachers see in Project Weather Station is not a sum of disciplinary content but lies in how this content is combined in a larger project that students have ownership to.

Other challenges teachers see are the considerable amount of planning time for the teacher and a potential lack of confidence, in particular in programming and other technical aspects, where many students may need supervision at the same time. Lack of support for the teachers is likely to prevent projects like the Weather station to be undertaken. Support could be in terms of guiding from more skilled teachers, as Edwin points to that he has benefited from in participating in the KreTek project, or it could be to have another skilled teacher participating in class.

Interestingly, none of the teachers pointed to lack of support from the school's management as an obstacle for running the project. Instead, they point to logistics with an interdisciplinary approach due to different curricula for different subjects as a challenge. An approach that includes the subject Arts & Crafts could allow for more time spent on the materialization of solutions in students' interdisciplinary projects. However, as these subjects also are governed by a curriculum and competence aims, and have their practices and epistemologies as described by e.g. Reynante, Selbach-Allen, and Pimentel (2020) and Savage (2012), larger teaching projects with use of workshops and teachers with different expertise, cross-curricular projects require an effort that may be overwhelming for teachers. It seems, however, that it is the practicalities involved, not the combination of subject content as such, that represent the major challenges for the teachers in this study.

Research studies tend to conclude that teachers need more knowledge in order to effectively implement STEM approaches (e.g. Fan, Yu, and Lin 2020), and that teachers' beliefs and own goals for teaching must be better aligned with the purpose of an educational innovation (DeCoito and Myszkal 2018; Westbroek, Janssen, and Doyle 2017). It is also shown that teachers call for pre-made teaching material and professional development when new content is introduced in the curriculum (Vinnervik 2020).

However, the present study illustrates that with these components in place, there are still genuine challenges that prevent teachers' realization of ideas of integrated STEM teaching. The pressure of effective time usage in teaching, lack of time for preparation and the risk of failure may explain teachers' reluctance towards running Project Weather Station even if they acknowledge its value. This may also be important factors in the teacher reluctance towards STEM approaches more generally that research has revealed (Margot and Kettler 2019; White and Delaney 2021).

Conclusion

The study has shown that the teachers see great values in the comprehensive project where students design, build and program a weather station, and that their views in this case are fully consistent with the holistic ideas of integrated STEM. The reason why teachers still are reluctant to make use of it in class seems to not be a lack of knowledge or professional development, but is rather due to a tension between the overarching goals of the formal curriculum and concrete competence aims for subjects. In the Norwegian curriculum, overarching goals adhere to a broad view of educational intentions consistent with STEM ideas, while the concrete competence aims that are supposed to support realization of the overarching aims, rather support education as 'siloed knowledge' and a more traditional 'grammar of schooling'. The double message that teachers receive may form part of the reason why teachers refrain running teaching projects like the weather station, even if they see value in them. The challenges they see regards time use in terms of teaching time as well as teacher preparation, risk of failure, potential shortcomings in own competence and obstacles due to the overall logistics in their school. In order to encourage holistic approaches that contribute to relevance, students' engagement and their creativity, it is important to see these as real challenges for teachers rather than a result of their mistaken beliefs or lack of knowledge. An important implication of the study is, therefore, that teachers should be given practical support in undertaking complex STEM projects. On systemic level, there is also a need for general acceptance for the value of teaching that targets overarching aims of education rather than effective fulfilment of competence aims within subjects in 'siloed' ways.

Note

1. Available in Norwegian from www.ntnu.no/skolelab/kretek/ressurser.

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ORCID

Berit Bungum http://orcid.org/0000-0003-1739-7887
Erik Mogstad http://orcid.org/0000-0001-6946-9585

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