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A qualitative study of teachers' and students' experiences with a context-based curriculum unit designed in collaboration with STEM professionals and science educators

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Abstract

Context-based science teaching aims to increase students' motivation for science learning by demonstrating the personal and societal relevance of science knowledge and practices. However, designing and implementing context-based science teaching can be challenging for teachers. Moreover, context-based learning can be challenging for students as well. The purpose of this study is to describe the experiences of two science teachers and their 16-year-old students after implementing a context-based curriculum unit designed in collaboration with STEM professionals and facilitated by us – science educators and researchers. The research approach is informed by participatory methods involving collaboration between teachers and us as science educators, with the intention of supporting teachers in developing new teaching practices. Data were collected through three focus group interviews with two teachers and two groups of students ($N=9$). The transcripts were analysed by inductive coding combined with a refined, literature-driven analysis. Besides positive influences on students' learning, we found that the context-based curriculum provided an opportunity for the students to contribute to society, which served as another purpose for learning science than traditional science teaching. However, we discuss some challenges that may have implications for this type of collaboration between teachers, science educators, and STEM professionals: the importance of authenticity, teacher involvement in field trip planning, and misalignment between the curriculum unit and assessment.

Keywords: Context-based teaching, Field trips, Collaboration with STEM professionals, Authentic context, Student outcome

Introduction

A recurring challenge in science education is that students often perceive science as boring and irrelevant to their lives, mainly because science is taught through authoritative teaching methods in which the scientific knowledge is presented as isolated facts with few links to students' personal life or local communities (Gilbert et al., 2011; Osborne & Dillon, 2008; Rennie et al., 2018). Therefore, approaches such as context-based teaching, project-based teaching, and socio-scientific issues have been proposed to demonstrate the personal and societal relevance of science knowledge and practices and hence foster students' motivation for science learning (Bennett, 2016; Hasni et al., 2014; Sevian et al., 2018; Sadler et al., 2017). Within context-based teaching, for example, a realistic problem taken from the world of science or from the students' everyday life outside of school is used as a starting point for meaningful learning of the scientific content (Gilbert, 2006). Examples from research include saving energy, assessing the necessity of bottled drinking

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water (Lupión-Cobos et al., 2017), designing sustainable travel (Overman et al., 2014), investigating the declining effects of antibiotics (Penuel et al., 2022), and assessing the health of local creeks (King & Henderson, 2018). Other research has exemplified how context-based teaching can be realised through partnerships between science teachers and external professionals within science, technology, engineering, and mathematics (henceforth: STEM). In these partnerships, STEM professionals provide the context for applying scientific knowledge and practices. (Hellgren & Lindberg, 2017; Houseal et al., 2014; Kostøl et al., 2021; Tytler et al., 2018).

Current research concludes that context-based approaches can have a positive influence on students' attitudes to science and that students learn the same amount of science in context-based teaching as in traditional science teaching (Bennett, 2016; Bennett et al., 2007). Studies have shown that context-based curriculums involving collaboration with external STEM professionals also inform students about the relevance of science outside school and possible careers (Houseal et al., 2014; Kostøl et al., 2021; Parker et al., 2020; Tsybulsky, 2019). However, studies have also identified challenges with context-based science education. For instance, students are unfamiliar with context-based problems and produce answers that they believe their teachers expect from them (Broman et al., 2018). From a teaching perspective, teachers find it challenging to design suitable contexts (Stolk et al., 2016), to reduce traditional science teaching, and to address the complexity of the context, such as linking scientific content to society, technology, and politics (e.g., Bossér et al., 2015; Lupión-Cobos et al., 2017). Consequently, science educators call for initiatives that support teachers in designing and implementing context-based teaching in science (Lupión-Cobos et al., 2017; Stolk et al., 2016), as well as initiatives that support teachers in collaborating with STEM professionals outside of school (Falloon, 2013). It is thus important to develop knowledge about how teachers and students actually experience context-based teaching developed through such initiatives. Accordingly, the present study is carried out within Lektor2 in Norway, where science educators support teachers in collaborating with STEM professionals to design and implement context-based teaching units for grades 8–13. The present study investigates how two science teachers and their 16-year-old students reflect on their experiences from a context-based curriculum unit, developed and implemented within Lektor2, which involved collaboration with a STEM professional and ourselves as science educators facilitating the process of designing a context-based curriculum unit. The following research question is investigated:

- How do two science teachers and nine students describe their experiences of implementing a context-based curriculum unit involving collaboration with a STEM professional and facilitators?

Before presenting further details about the methodology and findings, the theoretical perspectives informing the context-based curriculum designs are explained.

Context-based science teaching

Theoretically, context-based teaching – and similar ideas such as problem-based teaching, project-based teaching (Hasni et al., 2014; Penuel et al., 2022), and teaching about socio-scientific issues (Sadler et al., 2017) – is associated with constructivist theories and situated learning, which consider learning as construction of knowledge through active, collaborative engagement within authentic contexts of practice (Gilbert, 2006; Lave & Wenger, 1991; Taconis et al., 2016). Context-based approaches thus address the purpose of science education to more than acquiring scientific concepts; it is also about developing scientific literacy. Sevian et al. (2018) use the two visions of scientific literacy described by Roberts (2007) to illustrate context-based teaching. In Vision I, scientific literacy involves learning basic scientific content and skills that can later be applied to more complex scientific problems. By contrast, Vision II begins with confronting a complex societal problem that sets the scene for learning the scientific content and skills necessary to solve the problem. According to Sevian et al. (2018), context-based learning 'takes a solid stance as Vision II'. Hence, the context serves as a starting point – a knowledge need – that facilitates further student-driven inquiries and collaboration (Bennett et al., 2007; Stolk et al., 2016). This approach to learning requires that the teacher reduce their use of traditional teaching of science and rather support students in carrying out inquiries and developing the needed knowledge (Overman et al., 2016). More specifically, teachers can provide support by, for example, asking questions to elicit students' experiences and ideas, modelling what questions students need to ask, scaffolding student inquiries by asking the students to describe their observations, hypothesis, and experiment, directing students' attention to important learning goals, providing feedback, and discussing challenges that students encounter in their process of learning (Bjønness & Kolstø, 2015; Grossman et al., 2019; Hmelo-Silver et al., 2007).

In some cases, the context for the problem derives from the school's local community, also called society-based science teaching or community science (Adams, 2012; King, 2012). For example, the problem can be questions related to local food production, water quality of the local river, or a survey of available food choices in the community. As these contexts are more accessible outside the classroom, out-of-school activities – such as *field trips* – can often become natural components in context-based science teaching (Baran et al., 2019; King & Henderson, 2018).

Field trips as a component of context-based curriculum units

Field trips can be undertaken to several different settings, including science centres, museums, urban and natural environments, university laboratories, industrial sites, or STEM professionals workplaces. Activities in such settings can provide cognitive and social learning and promote interest and motivation for science (DeWitt & Storksdieck, 2008; Tal et al., 2014). However, the learning potential of field trips depends on the quality of planning and implementation, which are influenced by factors such as preparation and follow-up activities in the classroom, setting novelty, the quality of student activities, teacher involvement, and connection to school curriculum (DeWitt & Storksdieck, 2008; Jose et al., 2017; Lee et al., 2020; Tal et al., 2014). Accordingly, design principles and recommendations have been developed to support teachers in designing effective field trips in science education (e.g., Remmen & Frøyland, 2017; Tal et al., 2014). For example, with the aim of identifying key characteristics of good practice in outdoor teaching, Tal et al. (2014) analysed 40 field trips in Israel, which resulted in the following design principles (directly quoted):

- Field trips should be planned together by the teachers and the field guides who need to discuss their goals, means and collaboration pattern
- Field trips should be planned with knowledge of and connection to the school curriculum, in order to make ideas visual and concrete
- The teacher should be involved throughout the field trip, as a mediator in the cognitive and in the social domains
- The guide should make use of the environment in various ways, including building on students' discoveries and their attention
- Students should learn from interactions with objects in the environment and from interactions with each other
- Field trips should be based on student-centered learning activity, in which students explore and investigate the environment hands on, share findings and thoughts and discuss things
- Field trips should include "amplified" physical experience, adventure activities, and opportunities to directly experience the unique features of the outdoors

The design principles from Tal et al. (2014) informed the present study, as the context-based curriculum includes collaboration between teachers and STEM professionals and taking students on field trips to the STEM professional's workplace. Two principles were particularly important for the present study, namely the principles emphasising the importance of teacher involvement and collaboration between the teacher and field guide for succeeding with field trips. Students exposed to 'high teacher involvement' during field trips report higher learning outcomes, indicating a positive relationship between teacher involvement and self-reported student outcomes from field trips (Alon & Tal, 2017). However, lack of teacher involvement in planning and during field trips have been a common challenge in collaborations between teachers and external partners (Faria & Chagas, 2013; Morag & Tal, 2012).This in line with our own experience with Lektor2. Therefore, a crucial point in the present study was to ensure close collaboration between the teachers and the STEM professional on designing a context-based curriculum unit in science.

Methods

The study context and research approach

The context for the present study is Lektor2, a national partnership programme in Norway offering professional development for teachers and financial support for schools that aim to involve STEM professionals from the local community in their teaching. The teachers enrolled in the programme are required to collaborate in designing an authentic context-based task for students called a *commission*, in which the students are commissioned by STEM professionals to carry out a job requiring authentic, complex problem-solving (Kostøl et al., 2021).

Based on the need for more research on the support of teachers for designing context-based curriculum units (Falloon, 2013; Lupión-Cobos et al., 2017; Stolk et al., 2016), our approach is informed by participatory methods, involving collaboration between teachers and science education researchers. Participatory methods aim at supporting teachers to expand their perspectives on teaching and develop new practices (Postholm, 2020). Our study involves two science teachers and their students, a STEM partner, and ourselves as science educators, facilitating and researching the process. In the present project, collaboration between teachers, STEM professionals and us as science educators on a context-based curriculum unit was considered as 'new practice', as the teachers lacked prior experience with both context-based science teaching and collaboration with STEM professionals outside the school system. Teacher A (TA) was in her first year of teaching and taught two classes of Year 11 upper secondary students (aged 16 years) in an integrated science course, while Teacher B (TB) had more than five years of teaching experience and taught the same course in one class of Year 11 students. Approximately 90 students were involved.

The STEM professionals were employees from Ruter, a company operating public transport in the capital district in Norway. The head of a project called Fossil Free 2020 and one of the company's managers were directly involved in the collaboration with the teachers. Similar to the teachers, the STEM professionals also lacked experience with collaborating on context-based science curriculums.

Our role as science educators was to facilitate collaboration between the teachers and the STEM professional and support the teachers to develop the curriculum unit in collaboration with the STEM professional. Specifically, we as facilitators tried to discuss with the teachers to ensure that the curriculum unit was designed in line with Lektor2 requirements, the literature on context-based science teaching, and design principles for field trips described above. Even though we were familiar with Lektor2 and the literature, we felt that our involvement in putting theory into practice together with the teachers and the STEM professionals, required us to refine our own practices of supporting such collaboration processes in context-based science teaching. Hence, we consider our collaboration on developing a context-based

Table 1 Description of the development phases and implementation of the curriculum unit

Phases	Description of the phases and the participants	Connection to the literature
Connecting the teachers with a STEM professional	Based on the teachers' preferences, the facilitators contacted a company and initiated a meeting between the teachers and the STEM professionals. The goal of this meeting was to identify a commission for the students that provided the focal point for the curriculum unit.	Bennett et al. (2007) Fallon (2013) Tal et al. (2014)
Development of the commission	After the meeting (see above), the teachers drafted a commission letter. The draft was reviewed by the facilitators, and the teachers sent a revised version to the STEM professional. The STEM professional finalised the commission letter (Fig. 2). In essence, the students were commissioned by Ruter to evaluate best practice, available technology, and budget constraints to design solutions for fossil-free public transport that could be implemented within 4 years.	King (2012) Sadler et al. (2017) Sevian et al. (2018)
Establishing contact between the teachers and scientists at a university lab	We (facilitators) established contact between the teachers and scientists at a university lab and informed them about the students' commission. The teachers organised the logistics of the field trip, and university scientists presented the content through lectures and demonstrations of fuel cell technologies.	Falloon (2013) Tal et al. (2014)
Learning goals and assessment	The teachers developed learning goals for the students and criteria for assessment. The facilitators gave feedback.	Bjønness and Kolstø (2015) Hmelo-Silver et al. (2007) Tal et al. (2014)
Design of the learning activities in the curriculum unit	The classroom-based learning activities were planned by the teachers and included some learning resources suggested by the facilitators. The teachers and the STEM professional collaboratively designed the introduction of the curriculum unit, the field trip to a research station for buses, and the field trip to the STEM professional's main office where the students presented their solutions to the commission.	Remmen and Frøyland (2017) Tal et al. (2014) Houseal et al. (2014) Tytler et al. (2018)
Implementation of curriculum unit	The commission letter provided the focal point for the students' learning about renewable energy, including the operation of fuel cells and solar cells, battery technology, and biomass. Within this context, the teachers and students carried out several classroom and field trip activities. The overall aim of the classroom activities was to support the learning of theoretical knowledge related to renewable energy and to support the students in practicing skills such as comparing technological solutions, argumentation, and communication. The curriculum unit culminated in an oral examination.	

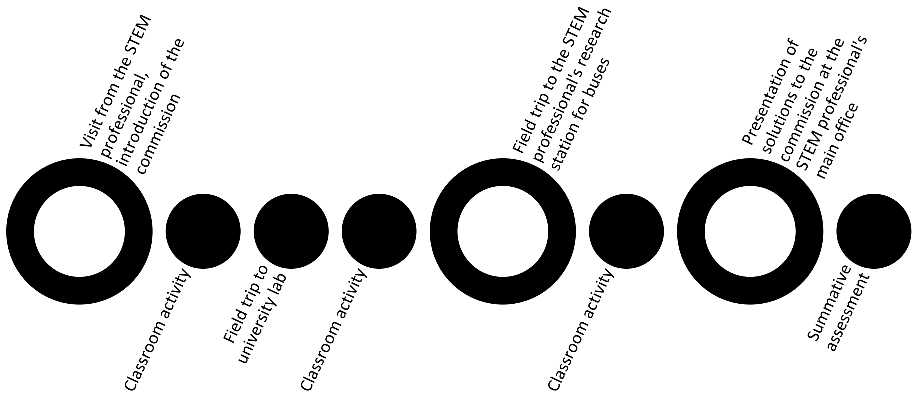

Fig. 1 Overview of the activities in the curriculum unit. Large circles denote activities collaboratively designed by the teachers, STEM professional, and us as facilitators. Small circles denote activities designed or organised by the teachers

curriculum unit as an innovative learning cycle that can potentially lead to new local solutions that become part of our refined practices (Engeström & Sannino, 2010). Table 1 describes the stages of the innovative cycle, including the initiation, development, and implementation of the curriculum unit, and contributions from each partner: the teachers, STEM professional, and us as facilitators. Figure 1 gives an overview of the classroom and field trip activities. Details about the curriculum unit are described in Supplementary Material. The commission given to the students by the STEM professional is illustrated in Fig. 2.

Fossil free 2020 – commission letter

Ruter#

Date: 09.02.2016
To: Students in Year 11, [redacted]

Consider and decide which renewable transport solutions Ruter should choose
Ruter plans, coordinates and provides public transport in Oslo and Akershus. Ruter has been commissioned by Oslo and Akershus County Council to make all public transport run on renewable energy by 2020. The project is called Fossil free 2020. Ruter's subways and trams run on certified electricity, but most buses and ferries use diesel, producing large CO_2 emissions.

Ruter would like the Year 11 students at [redacted] to contribute ideas to help us achieve our goal of making all our public transport renewable by 2020. We hereby give you the following commission:

- Consider and decide which renewable transport solutions Ruter should choose in the future. Your recommendation must take into account scientific, technological, economic and sustainable perspectives.

On April 28th 2016 at 10.00 am, each class will present two proposed solutions to this commission. We look forward to hearing your recommendations on how Ruter can make public transport in Oslo and Akershus fossil free.

We hope that you will take on this commission, and we await your response in the matter.

Sincerely,

[redacted]

Ruter AS

Fig. 2 The commission letter given to the students by Ruter (the letter has been translated and anonymised)

Data collection

As facilitators and researchers, we participated in the design process and then observed part of the implementation of the curriculum unit, such as the visit from the STEM professional in the students' classroom and the field trips (Table 1). This provided a platform for conducting interviews with the teachers and the students one month after the completion of the curriculum unit. We conducted three focus group semi-structured interviews: one with the teachers and two interviews with groups of students (N = 9). The teachers were encouraged to discuss their teaching in science compared to their experiences in the context-based curriculum unit. The students were interviewed in two focus groups – Group 1 (three boys, two girls) and Group 2 (three boys, one girl). We queried the students' views on working with the commission from Ruter (Fig. 2), their perceptions of school science, and how they compared the context-based approach to "normal" teaching.

Data analysis

The interview transcripts were first read by both authors before the first author proceeded to analyse the content of the transcripts in NVivo 12. The first author highlighted sections with quotes relevant to the research question. Then, we asked a colleague to consider the entire transcript to ensure that other relevant information was not missed (Creswell & Miller, 2000). We collaborated to develop codes on the selected passages that were close to the teachers' and students' utterances (Saldaña, 2016). This resulted in a list of codes, which we divided into two broad categories: *teaching activities* and *comparison with normal teaching. Teaching activities* consists of statements addressing the teachers' and students' reflections on the activities that were provided through the context-based curriculum unit, including reflections regarding assessment and field trip experiences. *Comparison with normal teaching* contains the teachers' and students' comparisons between the context-based curriculum unit and their perception of normal teaching in science, similar to Overman et al. (2014). Eventually, we compared our codes to the literature review, enabling us to combine a literature and data-driven analysis. All codes are described in Table 2.

Strategies for ensuring the quality of the research

As partners in the development of the context-based curriculum unit (see Table 1), we have certain roles and interests which require a reflexive approach to our own research process. As an example of reflexivity, we include ourselves as 'we' or 'facilitators' in the representation of the design of the context-based curriculum unit (Table 1), in the interpretation of the data, and in the critical discussion of the findings. Regarding the data analysis, we have tried to enhance the quality by alternating between analysing the data collaboratively and individually to

Table 2 Overview of categories and codes with definitions

Category	Code	Definition
TEACHING ACTIVITIES	*Commission as a purpose for learning science content in the classroom*	Expressed relationship between the commission and the related classroom activities aiming to support students to accomplish the commission
	Engagement for classroom activities	The students' interests, feelings or perceptions of the classroom activities
	Teacher support during classroom activities	Descriptions of type and/or amount of support provided by the teacher during the classroom activities, including formative assessment
	Summative assessment	Descriptions of the assessment at the end of the curriculum unit
	Contribution to society or a client outside school	Expressed experience of a "higher purpose" of doing schoolwork, that the work is relevant to situations outside school, that the work is important and contributes to society and/or the STEM professionals' work
	Connections between field trip experiences and the commission	Expressed connections between field trip experiences and a better understanding of science content relevant for solving the commission or expressed perceptions of not seeing how the field trip experiences are connected to the commission and related science content
COMPARISON WITH USUAL TEACHING	*Context-based curriculum as a different approach*	Reflections on how the curriculum unit differed from their usual classroom teaching and/or prior experiences or expectations of science teaching or learning
	Student outcomes from the curriculum unit	Reflections on the students' cognitive and affective outcomes from the curriculum unit compared to prior experiences or usual classroom teaching

establish a common understanding of the interpretations of the data (Creswell & Creswell, 2018). Additionally, the categories and codes that emerged during our analysis were discussed with a third-party researcher to enhance consistency in defining the codes (Creswell & Creswell, 2018; Gibbs, 2007).

Findings

The teachers' and students' perceptions of participating in the context-based curriculum unit are presented in this section. Findings from the category *teaching activities* are presented first, followed by findings from *comparison with normal teaching*. Indexing of students (e.g., S1, S2) is only used to indicate that different students are interacting. F denotes questions and contributions from us, the facilitators, whereas TA and TB denote teacher A and teacher B.

Teaching activities

The classroom activities were led by the teachers and engaged students in acquiring knowledge and skills needed to solve the commission of recommending future transport technologies (Fig. 2). The commission was frequently mentioned in the interviews, as prompted by our questions, but also initiated by the teachers and students themselves. Both teachers and students reflected on the commission's role in relation to the classroom activities:

> *TA: I think it [the commission] was nice to have as an overall frame over time. Connecting a lot of learning to one project. I think that was really good.*
>
> *F: So you connected the learning to the commission in a way?*
>
> *TA: Yes. We worked with it over several weeks, while at the same time having one project to think about. "Remember that we're working on the Ruter commission". "We're learning this because we're working with the Ruter commission".*
>
> *TB: Yes, "what can we draw from this (…) to answer the commission?".*

As seen in the excerpt, the teachers considered the commission as a purpose for the classroom activities in which they taught about electricity, fuel cells, batteries, etc. Both teachers described what they said to remind their students about the commission and connect the science content in the classroom to it – for example, "Remember that we're working on the Ruter commission". Thus, the teachers used the commission to justify the classroom activities, which led to the code *commission as a purpose for learning science content in the classroom*. We then asked the teachers whether this explicit linking of the commission to the content influenced the students' engagement in the activities:

> *F: Did you recognise any difference in students' engagement while working with the commission compared to normal teaching?*
>
> *TB: I think more students were engaged, even though some students were still disengaged. But more students were participating.*

Engagement in the classroom activities was also confirmed by the students in both groups. The most deliberated reflection emerged in Group 2:

> *S: Yes, because now it was like…now it was someone who took part in this project, whereas…and then you need to be engaged and grasp the content, so you know what to include in your project and what to include in your presentation. You then automatically pay more attention, but normally when you have this theory [science content], it's just for…a test. (…)*

This student described her engagement in the classroom activity (lecture) as a need to understand the scientific knowledge to judge whether it was useful for the commission. Utterances such as these were coded as *engagement in classroom activities* and describe the students' perceptions of the classroom activities.

The students in both groups also discussed how they felt about receiving a commission from Ruter, as seen in the following interaction in Group 1:

> *S1: You felt that you took part in something important, that what you did…*
>
> *S2: You got to contribute.*
>
> *S1: Yes, that you could contribute to something. Like, when you take a test, it's just for your own sake, but now you were also helping someone else. So that's also motivating.*
>
> *S2: Knowing that the work you're doing is…important, is…yes, as I said, important. That's much more motivating than just memorising.*

As seen in the excerpt, the students felt that they contributed to a solution and that this was important for someone outside of themselves. Hence, giving something back appears to be a critical feature of the commission, which was coded as *contribution to society or a client outside school*. In this code we also included responses describing the science content in the curriculum unit as relevant for settings outside school, for example:

> *S: I found it exciting, because often, science can be heavy and demotivating because you're just going to sit down and memorise. But now, we got to see it in practice, and we felt that what we learned was important related to the society as well. And that I found exciting.*

The teachers shared the students' perceptions of the commission as an opportunity to contribute beyond themselves, as seen in the following quote:

> *TA: I find the commission so important. It's not just a random commission to make the students work. It's important.*

However, a student in Group 1 did not celebrate the contribution aspect:

> *S: (…) But what at least I found a bit disengaging was that they have a solution already, so they won't use one of the students' solutions. In that sense it was like: Yeah, yeah, they won't be used anyway. But it was fun to like…try to find a solution.*

Our understanding of the quote above is that the commission was not perceived as entirely realistic. "They won't use one of the students' solutions" describes the student's awareness that the commission was a fictive situation after all, although the problem was realistic and the same problem the transport company grappled with. However, none of the other students in Group 1 agreed to or elaborated on this view.

The field trip to the STEM professional's research station for buses was another activity that was collaboratively designed by the teachers and the STEM professional, with the aim of providing direct experiences with bus technologies that the students could use in their work with the commission. The students described how the field trip contributed to their learning as follows:

> *S1: It was much easier to understand the solutions [to the commission] when we got to see it in real-life.*
>
> *S2: Yes, I also felt I understood more about how the hydrogen buses worked when we visited Ruter and got to see how they handled different challenges and exploited the benefits of using hydrogen in buses. (…)*

Experiencing the different buses and technologies during the field trip helped the students gain a better understanding of the commission and possible solutions, resulting in the code *connections between field trip experiences and the commission*. Such connections were also present in the teachers' reflections, exemplified by the following response:

> *TA: When we talked about fuel cells, it was very good to be able to say that this happens inside the buses, and yes, "you experienced yourselves that it's only water that comes out. You drank the water". Always have something to connect it to. Otherwise, it can be very technical with electrons moving in wires.*

Our interpretation of this excerpt is that the teacher made connections between the students' direct experiences during the field trip and the subsequent classroom activities.

The field trip to the university lab was not mentioned by the teachers. However, the students in Group 1 had many things to say about it:

> *S1: I didn't get what this had to do with it [the commission].*
>
> *S2: (…) we got to see some things inside a lab. And then…It was just a bit…well, I didn't quite get it.*
>
> *S1: It was sort of off-topic. We didn't quite understand what this had to do with biofuels, buses, or hydrogen.*
>
> *S2: Well, it was within the topic, but it was sort of…it was a bit difficult to grasp. It was complicated.*
>
> *S1: And then we got to see a hydrogen car. Then we didn't understand what that had to do with the lecture and the lab.*

As seen above, the students experienced the field trip to the university lab as 'difficult to grasp', indicating that they did not recognise the connection between the field trip and the commission, which we coded as *connections between field trip experiences and the commission*. However, when prompted by us, some of the students mentioned the hydrogen car as an aspect of the university lab that they related to the commission. One student said:

> *S: Yes, the lecture about that [hydrogen] car, that we understood, but we didn't understand much of the lab visit with hydrogen and…*

During parts of the curriculum unit, the students worked independently with the commission in groups. The teachers described how they tried to support the students during the group work by providing guidance and frequently collect written products.

> *TB: (…) We walked around to the groups, guiding them and helping them, and…collected work from them. About once a week, I collected something which they [students] got back and could use in their further work.*

Evidently, the teachers provided feedback on students' written work, which was coded as *teacher support during* *classroom activities*. However, teacher B did not provide any example of the type of feedback, which may be a limitation in our data.

When we asked the students about the kind of support they received from the teacher, the students said that they received help although they could not specify what sort of help. For example, in Group 1, the students could not recall whether they received feedback from their teacher on their work. However, later in the interview one of the students added that more teacher support would be preferable, without specifying what sort of help he was asking for.

The final classroom activity was carried out after the visit to the transport company's workplace (Fig. 1). This was an oral examination, where the teachers asked questions about different technologies related to renewable energy, such as how fuel cells work or how solar cells operate. The information was used to assess the students' learning of the scientific knowledge. The teachers chose to do so because they were more familiar with oral or written tests and found it difficult to assess the students' understanding based on their oral presentation to the STEM professional:

> *TB: Yes, oral examinations are more common at our place. And written tests or digital tests. But I find it incredibly hard to assess a presentation.*

The teachers' and students' descriptions of the assessment of the students' learning at the end of the curriculum unit was coded as *summative assessment*. The students expressed different opinions about the oral examination, exemplified by the following responses from students in Group 1 and 2, respectively:

> *S: During the oral examination it was easy to show everything you knew. You got to show what you'd worked on that you didn't necessarily present, because someone else in the group had to take their part of the presentation even though they hadn't worked on it. So...yes, it became clearer who had been working well on the assignment.*
>
> *S: But I didn't like the fact that we only got assessed on the oral examination and not all the other things, because there was a lot of work before this. We had two presentations, one in the beginning and one presentation for Ruter, and we had ongoing assignments. And we didn't get an overall assessment. Only on the oral examination.*

The first quote presents the view of the students in Group 1, namely that they appreciated the oral examination because it allowed them to demonstrate understanding that did not emerge in the group's oral presentation for the transport company. The second quote above illustrates a different opinion among the Group 2 students. Here, the students were dissatisfied with the oral examination because they felt that their efforts during the curriculum was not appreciated by the teachers' assessment.

Teacher B described the students' presentations as 'fragmented', meaning that the students presented facts for each type of transport technology without comparing them and discussing the best solution. This evoked a reflection on her own teaching and the fact that the students were not familiar with skills such as argumentation and comparing solutions to be part of the assessment:

> *TB: Yes, compare and argue... But it is like...They [the students] are not used to that being something we use to distinguish between grades. That's something they explicitly need to be told, actually. They're used to be awarded with an A if they just come up with enough [content].*

Comparison with usual teaching

Both teachers and students reflected on the curriculum unit by comparing it with how they usually teach and learn school science. In the student interviews, these reflections emerged when the facilitator asked about their effort.

> *F: If you compare the effort you put into this project compared to other projects you have [at school], were there any differences?*
>
> *S1: Yes, most definitely.*
>
> *S2: This was in a way much bigger, and you know it was for Ruter, so it was for a real – how do I put it – client.*
>
> *S3: And it was – we were to design a solution. In school it's just a presentation about a galvanic element or something (...), but now we needed to physically find a solution, so we had to know it. In a normal school presentation, you just need to know the facts and not think yourself. So [in this commission] we got to delve much more into it.*

As seen above, the students in Group 1 emphasised that the curriculum unit inspired them to increase their effort to learn as compared to "usual". This was supported by students in Group 2:

> *S1: (...) I will say, at least for me, I put in a greater effort to learn everything than I would've in normal teaching.*
>
> *S2 (...) I put in more effort, yes, learned a bit more about this and a bit faster, because we were to present for someone who actually cares. (...)*

These types of responses were coded as *context-based curriculum as a different approach*.

For the teachers, reflections regarding the approach emerged when the facilitator asked if they would recommend other teachers to design curriculum activities in collaboration with STEM professionals:

> *TB: If you're looking for advice for teachers, you should say that you see an increase in the students' motivation, that there is something more going on in their heads when using this kind of approach, than during normal teaching.*
>
> *TB: Yes, increased motivation to work with it, not just sitting there memorising concepts and manners of operation, but that they use what they know to argue and discuss, compare…which, after all, is much more important than reciting lots of facts.*
>
> *TA: That they [the students] see that what they learn in school is being used outside the classroom. I think that's really important.*

When asked by the facilitator, the teachers reflected on their students' outcomes compared to normal classroom teaching.

> *TA: (…) the students have become better at thinking and having opinions. They are used to just... reciting facts. But with this project, I think they have increased their thinking.*

As seen above, Teacher A thought that her students had developed their thinking during the curriculum unit, which was coded as s*tudent outcomes from the curriculum unit*. The students in Group 1 had similar perceptions of their outcomes:

> *S1: I, at least, had to reflect much more about what I was doing, and needed to know that everything I did, that I…that I understood everything I was doing, and not just the solution we went for (…) but also: "I do not choose these solutions because I don't think they apply to the commission we are to solve. (…)*
>
> *S2: (…) we were to find a solution; we weren't just presenting about what we had learned. We actually needed to think for ourselves, because that was a part of the assignment.*

Regarding the students' learning of science content knowledge, the following discussion between the teachers and us (the Lektor2 facilitators) occurred:

> *TB: (…) they [students] might be left with more science content knowledge with normal, non-commission [teaching]. But in the end, that's not what I want them to be left with. It doesn't matter if they don't remember how solar cells work (…). It's more important that they know how to compare, argue, weigh the pros and cons, see the sustainable perspective…And that's evident here.*
>
> *TA: But I think they remember this better than if we just say: "Today we are learning about heat pumps" (…). I think they remember better how fuel cells work than heat pumps.*
>
> *F: Yes, that's what you said earlier: everyone knows the result – it's water that's coming out.*
>
> *TA: Yes, and then suddenly everyone knows how electrolysis works. I don't think they would've known that if it weren't for this project and the commission.*

The excerpt above suggests that the teachers had different views on the students' learning of science content from the curriculum unit. Whereas Teacher B believed that the students would have gained more content knowledge from 'normal' teaching, Teacher A disagreed with that by stating that the experiences gained from the context-based curriculum unit reinforced the students' memory of scientific knowledge.

Discussion

The purpose of this study was to describe the experiences of two teachers and their students after participating in a context-based curriculum unit involving support from Lektor2 facilitators, collaboration with a STEM professional, and field trips. The experiences were described in two main categories: *teaching activities* and *comparison with normal teaching*, which revealed that the context-based curriculum provided experiences that were different from their usual practices of science teaching and learning. This did not mean that the context-based curriculum excluded learning activities associated with traditional science teaching, such as lectures. Both the teachers and the students found these more engaging than usual, indicating that the context – that is, the commission to evaluate different bus technologies – provided a purpose for traditional science teaching. This illustrates how context-based teaching aligns with Vision II of scientific literacy, in which solving a complex societal problem becomes the main purpose for learning scientific content and skills (Roberts, 2007; Roberts & Bybee, 2014). However, the interview data revealed discrepancies between the teachers' and the students' experiences that allow us to reflect upon challenges with context-based curriculum units involving collaboration with STEM professionals and science education researchers. Because researchers often are developers of context-based science teaching (Bennett, 2016), we – as facilitators and researchers – will include reflections on how we contributed to (or inhibited) the new practices we tried to develop together with the teachers.

Discrepancy between context and commission

As apparent by the code *contribution to society or a client outside school*, the students' and the teachers' felt they were taking part in something important, and that they had the opportunity to contribute to an ongoing issue in their local area. Most of the students in Group 1 and 2 considered their contribution important because they were helping a client outside school with solving a commission. These experiences align with Gilbert's (2006) notion of 'context as a social circumstance', in which students and the teacher jointly work with real-life problems that are considered important to the lives of their community. Contributing and communicating scientific findings to the local community is one way to promote authenticity in science education (Anker-Hansen & Andreé, 2019; Grossman et al., 2019). In the present study, the authentic experience was enabled by the involvement of STEM professionals from a local transport company. However, one of the students in Group 1 found it disengaging that the STEM professional would likely not use their solutions anyway. Perhaps this student reflected more critically on the commission, with the STEM professionals pretending to involve the students, and the students pretending to offer help to solve the commission. The *context* was realistic – the transport company's transition to renewable transport technologies, but the *commission* – or the problem – was a fictive situation: the transport company did not really need the students' help. This aligns with our earlier study involving a much higher number of participants (Kostøl et al., 2021), in which we argue that the extent to which the commission is genuine – and not fictive – is important for the students' motivation and engagement in context-based curriculum units within Lektor2. Despite the slight difference in the authenticity between the context and commission, the category *comparing with normal teaching* (comprising of the codes *context-based curriculum as a different approach* and *student outcomes from curriculum unit*), reveals that both the teachers and students reported an increased effort among the students compared to normal teaching, and that the students were better at thinking and reflecting. It is known that project-based and context-based teaching can influence students' learning and attitudes towards science more positively compared to traditional science teaching (Bennett et al., 2007; Hasni et al., 2016). More interesting, however, is that the usual science teaching undertaken in the classroom became more meaningful to the students. Hence, it appears that students can experience traditional science teaching as more useful and engaging if it is situated within a context-based curriculum. This supports Lupión-Cobos et al. (2017), who found that teachers perceived their students as more interested, motivated, and involved when teaching scientific competences in the classroom through a context-based approach.

Teacher involvement before and during field trips

Although both field trips (Fig. 1) aimed to provide scientific knowledge relevant to the commission, the students were more enthusiastic about the field trip to the research station for buses (*connections between field trip experiences and the commission).* One explanation may be the teachers' involvement in the two field trips, as teachers' participation in planning and implementation influence students' learning (Tal et al., 2014). For the field trip to the university lab, we – the facilitators – informed the scientists about the students' commission, and the scientists were responsible for planning and presenting content through lectures and demonstrations (Table 1). Hence, the teachers were not really involved in the planning and implementation of the field trip, which can influence the students' perceptions negatively (Tal et al., 2014). Reflecting on our roles as facilitators in the curriculum development, our involvement may have been a disfavour for the teachers and students, as we obviously did not invite them to influence the focus and content of the field trip to the university lab. By contrast, the field trip to the research station for buses was collaboratively designed by the teachers and STEM professionals (e.g., discussing activities and content), which is more in line with the design principle 'field trips should be planned together' (Tal et al., 2014). Hence, the difference in the teachers' and our involvement as facilitators in the two field trips may have influenced the students' perceptions of the relevance of the scientific content presented during the field trips. Support for this can be found in the students' statements in the interviews, for example 'We didn't quite understand what this [the visit to the university lab] had to do with biofuels, buses, or hydrogen' (*connections between field trip experiences and the commission*). As observers at the university lab, we know that the scientific knowledge presented during the field trip was relevant for the students' commission; however, it was not made explicit to the students. That the applicability of the scientific knowledge was not explicitly addressed may be ascribed to the lack of teacher involvement during the university lab visit. However, the students recalled the hydrogen car. Perhaps the car was a concrete representation of innovative transport technologies, which made it possible for some of the students to relate it to the commission of assessing transport technologies. This may be an example of near transfer in context-based courses, which occurs when the student's mental map connected to one focal event is similar to another focal event (Gilbert et al., 2011). Furthermore, the students' ability to relate the hydrogen car to the commission was made individually without the teacher's support, which aligns with other investigations in which students receive little help from teachers to connect the field trip content to the classroom curriculum (Bamberger & Tal, 2008).

At least two lessons can be taken from the discussion above. The first is that facilitators need to involve the teachers in the planning and design of the field trip, particularly when the purpose is to acquire scientific knowledge necessary for solving a commission in a context-based curriculum unit. The second aspect concerns the students finding similarities between the commission (the realistic problem) and the field trip experience. Further research may explore both aspects with the hypothesis that if the teacher is more involved in the design of the field trip, there will be more opportunities for students to relate the field trip experience to the context-based curriculum unit.

Assessment unaligned with the context-based curriculum unit

The curriculum unit was finalised by an oral examination designed and organised by the teachers (Fig. 1). This practice aligns with *summative assessment*, as it aimed at grading what the students had learned at the end of the curriculum unit (Dixson & Worrell, 2016). According to the teachers, there was a need for an individual oral examination because they found it difficult to assess the students based on their group presentations for the transport company. Similar to Lupión-Cobos et al.'s (2017) study, assessment of student learning during context-based teaching appears to be a challenge in our findings as well. One explanation for this could be the lack of focus on assessment in the collaborative design process between us and the teachers (Table 1). Therefore, we will use this as an opportunity to discuss how assessment of student learning can be handled in context-based curriculum units. Our findings from the student interviews can provide some ideas. The students perceived the oral examination differently, as evidenced by the responses in the code *summative assessment*. The students in Group 1 considered the oral examination as an opportunity to show their scientific knowledge to the teacher. By contrast, Group 2 students felt that the oral examination was limiting their competence to the scientific knowledge. They called for an assessment in which the teachers included all the work related to the commission – and not only the scientific knowledge they had gained. We interpret the Group 2 students' view as a call for more coherence between the formative and summative assessments, in which all the activities in the curriculum unit counts in the summative assessment. As revealed by *comparison with normal teaching*, the commission required the students to form opinions and develop arguments for their solutions, which was appreciated by both the students and the teachers (see *student outcomes from the curriculum unit*). Despite this, the teachers' description indicates that the oral examination focused on facts about renewable technologies. Furthermore, the students were not familiar with being assessed on skills such as argumentation or the ability to compare (*summative assessment*). Hence, consistent with other studies (Avargil et al., 2012; Iversen & Jónsdóttir, 2019), it appears to be a misalignment between the students' outcomes celebrated by the teachers and students, and what the teachers emphasised when assessing the students' learning. Some of the responsibility for this can be ascribed to us as facilitators, as the type of and content of assessment was not emphasised in our collaboration (see Table 1). Perhaps we relied too much on the teachers' expertise in designing and implementing assessment adapted to their students. Thus, a lesson learned from this is that teachers and facilitators (science educators) need to collaborate about developing formative and summative assessment practices when students work with a commission from a STEM professional. Such practices need to allow students to demonstrate their learning through, for example, authentic products requiring decision-making skills and reflection on the process of learning (Dixson & Worrell, 2016). Further research may address how both teachers and facilitators like us can assess such performances as part of context-based curriculum units, for example by drawing on principles for assessing student-driven projects (Brennan et al., 2021).

Conclusions and implications

From the discussion above, it appears that the context-based curriculum unit involving collaboration with a STEM professional and us as Lektor2 facilitators provided opportunities for learning that were different from 'usual classroom teaching' for both teachers and students. Overall, both teachers and students experienced context-based learning as engaging, and they appreciated the commission as an opportunity to contribute to the public. However, our discussion proposed at least three challenges with context-based curriculum units that need to be considered in future collaborative design processes involving teachers, STEM professionals and science educators. First, when engaging students to solve a commission or an authentic problem on behalf of a client outside of school, it is important to consider the authenticity of the commission. A following implication is that teachers should discuss the problem's degree of authenticity with the students, especially if it is questionable whether the client genuinely needs the students' help. Second, the field trip to the research station for bus technologies, collaboratively designed by the teachers and STEM professionals, appeared to be more beneficial for the students' learning experience than the field trip to the university lab (not collaboratively designed). Accordingly, teachers need to be involved in the planning and design of field trips involving collaboration with external STEM professionals to help students perceive the experience as relevant to the commission. Third, there appeared to be a misalignment between the knowledge and skills required by the students in the context-based curriculum unit and the type of assessment the teachers used to evaluate the students' learning. We interpreted the summative assessment as traditional, and some of the students found it to be limiting. Thus, further interventions involving teachers and science educators may explore how students' learning can be assessed in a way that reflects the context-based curriculum with STEM professionals.

Supplementary Information

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Additional file 1.

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Authors' contributions
K.B.R and K.B.K collected data through interviews with teachers and students. K.B.K did the first analysis of the data, followed by further analysis and discussions by both authors. K.B.K and K.B.R have contributed equally in the writing of the manuscript. The authors read and approved the final manuscript.

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Availability of data and materials
The dataset used and analysed during the current study are not publicly available due to teachers' and students' privacy, but are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors declare that they have no competing interests.

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