Co-designing cross-setting activities in a nationwide STEM partnership program – Teachers' and students' experiences

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STEM partnerships are popular initiatives but can be challenging to implement in practice. Accordingly, within the context of a nationwide, cross-setting STEM partnership program in Norway – Lektor2 – a co-design tool was introduced to support teachers to collaborate with STEM professionals in developing curriculum units involving authentic STEM problems and practices. Thus, the purpose of this study was to describe the teachers' and students' experiences from the curriculum units based on the co-design tool and how the tool might help facilitate partnerships in STEM education. Teacher and student data were collected in 2015-2018 (N=2479), and responses to open-ended questions were coded using a grounded theory approach. Findings indicate that the co-design tool, particularly "the commission" – where students are commissioned by STEM professionals to design solutions to authentic problems – enhanced teachers' collaboration with STEM professionals, led to changes in pedagogical approaches, and enabled the teachers to differentiate in their teaching. Student experiences from participating in the co-designed curriculum units are characterised as more expansive views of STEM, STEM learning, and increased STEM engagement. We discuss how the co-design tool enabled teachers to overcome partnership challenges and what aspects of the commission appeared to be important for the students' experiences. This study provides a specific example of a co-design tool that can enhance pedagogical designs developed through STEM partnerships.

Keywords: STEM partnership, authentic STEM education, co-design tool, student outcome

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1 Introduction

Collaborations between classroom teachers and STEM professionals working in the public and private sectors (including non-governmental organisations, businesses, government, and higher education institutions) can potentially provide access to authentic STEM experiences that are connected to young people's communities and everyday life (e.g. Braund & Reiss, 2006; Stromholt & Bell, 2018). Such authentic STEM experiences can enhance understanding of scientific inquiry and practices, influence students' attitudes towards science, and exhibit potential career pathways (Houseal, Abd-El-Khalik, & Destefano, 2014), and prepare students for responsible citizenship (European Commission, 2015; Stromholt & Bell, 2018). However, several challenges with STEM partnerships exist, such as challenges with communication between partners (Frøyland & Langholm, 2009; Moreno, 2005), connecting outdoor experiences to classroom curriculum (Anderson, Kisiel, & Storksdieck, 2006), and lack of teacher ownership (Fallon, 2013). This indicates a need to support teachers to design and implement STEM curriculums that involve collaboration with STEM partners outside school.

Accordingly, the present article addresses this need in the context of a nationwide partnership program in Norway involving hundreds of teachers and their students. More specifically, this study describes a co-design tool that was developed to support teachers to design educational outdoor STEM experiences and facilitate collaboration between teachers and STEM professionals. In brief, the co-design tool involves discussing appropriate topics, alignment with the STEM professional practices and the national STEM curriculum, and authentic, local issues faced by the professional STEM community. Within this context, this study aims at describing teachers' and students' perspectives on the curriculum units co-designed by teachers and STEM professionals using the developed co-design tool, and to discuss how such a co-design tool can help overcome common challenges related to STEM partnerships and cross-setting STEM experiences.

Before presenting further details about the study context, method, and findings, the concepts of authenticity and relevance in STEM education are considered, and literature concerning benefits and challenges with STEM partnerships and how co-design and partnerships can be supported, is reviewed.

2 Literature review

2.1 Authenticity and relevance in STEM education

Authentic science experiences are important as it can support the integration of scientific knowledge, enhance student attitudes and interests toward science learning, promote collaboration between students, and enable students to take responsibility for their own learning (Braund & Reiss, 2006).

From a theoretical perspective, authenticity can be associated with situated learning and cognition, which consider learning as a process of participation in a particular community of practice, in which learners acquire the tools, ways of thinking, and culture of a discipline or community by engaging actively in that practice (Brown, Collins, & Duguid, 1989; Lave & Wenger, 1991). Luehmann and Markowitz (2007) build on this view and define authentic practices as engaging students in the complex processes of using scientific tools to, e.g. ask questions, draw conclusions, and report findings. Braund and Reiss (2006) complement this definition, stating that authentic science learning experiences should include activities similar to what professionals do and be student centred and open-ended. Murphy, Lunn, and Jones (2006) distinguish between cultural and personal authenticity, where the former is closely linked to the practices of professionals, and the latter refers to the individual understanding of purpose and relevance while participating in an activity. Thus, personal authenticity can be evident when students follow their personal interests and investigate their own questions, transforming their identity towards or against science culture, or when students actively contribute to out-of-school practices for instance by communicating scientific information to an audience outside school (Anker-Hansen & Andrè, 2019). As an activity can be authentic in terms of science culture, without being personally relevant to a student, it can be useful to define relevance, which is another widely used term in science education (Stuckey, Hofstein, Mamlock-Naaman, & Eilks, 2013). Stuckey et al. (2013) identified three dimensions of relevance: (1) individual, which refers to science activities matching students' interests and providing skills relevant for their everyday life, (2) societal, which can be ascribed to societal participation and the interaction between science and society, and (3) vocational, which refers to awareness and understanding of future professions and careers. Referring to Dewey (1973), Stuckey et al. (2013) argue that relevance is closely connected to meaningfulness, which means that connecting science to students' everyday life makes learning more meaningful. This understanding of meaningful corresponds to Stuckey et al.'s (2013) individual dimension of relevance.

2.2 Benefits and challenges of STEM partnerships

Access to authentic scientific practices and relevant experiences can be achieved by establishing collaborations with settings outside school that provide materials and professional practices that are typically not available in classrooms (Braund & Reiss, 2006; Houseal et al., 2014). Such collaborations between schools and STEM professionals can result in a variety of experiences for students, including cognitive, social and affective learning (Houseal et al., 2014; Shein & Tsai, 2015; Tsybulsky, 2019; Tsybulsky, Dodick, & Camhi, 2018; Tytler, Symington, Williams, & White, 2018). For instance, Houseal et al. (2014), studying teachers' and students' experiences, found that partnerships with scientists enhanced the students' understanding of and about scientific inquiry as well as improved their attitudes towards science and scientists. Such insights can also inform students about possible STEM careers (Archer, DeWitt, & Dillon, 2014; Jensen, 2015), which corresponds to Stuckey et al.'s (2013) vocational dimension of relevance. However, STEM partnerships do not necessarily have an impact on students' career plans. The students in Archer et al.'s (2014) study increased their knowledge and awareness about STEM professions after participating in a STEM partnership program, without changing their career aspirations. Although it may not impact students' career choices, other research indicates that STEM partnerships can promote environmental citizenship (Alkaher & Gan, 2020) and lead to social recognition of young people as contributors to STEM and their community and develop students' personal awareness of their roles as scientifically literate citizens (Stromholt & Bell, 2018). Furthermore, collaborations with partners outside school can give access to STEM experiences across various settings, including, e.g. universities, museums, and industrial premises (Braund & Reiss, 2006; Rennie, Venville, & Wallace, 2018). Such informal environments can be particularly important for developing and validating students' interests, skills, and identities and provide an expansive view of science (Bell, Lewenstein, Shouse, & Feder, 2009). According to Parvin & Stephenson (2004), industrial contexts and contact with industry can also provide students with a reason for doing science and give them a context for learning in the classroom. Accordingly, partnerships offering cross-setting STEM experiences have the potential to enrich and enhance students' appreciation of science by providing them with new connections with science and its applications and relations to society (Braund & Reiss, 2006; Parvin & Stephenson, 2004; Rennie et al., 2018). The potential of societal connections appears to align with Stuckey et al.'s (2013) societal relevance.

Despite the richness in possible outcomes from STEM partnerships, teachers and STEM professionals may experience various challenges in their collaboration. Establishing contact with partners outside school, and lack of support, in terms of dedicated time and financing, from the school are identified as external obstacles (Ng & Ferguson, 2019; Penuel, Lee, & Bevan, 2014; Sagar, Pendrill, & Wallin, 2012; Wormstead, Becker, & Congalton, 2002). Internal obstacles include cultural differences between teachers, students, and STEM professionals, as they differ in terms of knowledge, tools, resources, practices, and attitudes (Falloon & Trewern, 2013; Kisiel, 2014; Penuel et al., 2014). For instance, teachers experience that STEM professionals lack interest in students and have a higher working tempo that does not allow collaboration (Sagar et al., 2012). Such obstacles can impede communication, and consequently, how the partnership is designed and implemented (Falloon, 2013; Moreno, 2005). Studies of collaboration between museum guides and teachers indicate that the communication often focuses on practicalities rather than the content and the pedagogy of the museum visit (Frøyland & Langholm, 2009; Tal, Bamberger, & Morag, 2005), potentially reducing the collaborative activity to a guided tour or a lecture where teachers and students are passive. In a study of teacher-scientist-partnership, Falloon (2013) found that the teachers simply implemented a curriculum unit created by the scientists, resulting in a lack of teacher ownership in the partnership. Dolan and Tanner (2005) describe such partnerships as a "provider-recipient" approach, in which professionals serve as content providers, whereas teachers and students are receivers of their expertise. Possible consequences are that teachers may not perceive the partnership as collaborative, the partnership is treated as "add-ons" by teachers, and the field trip becomes a 'day out' for teachers and students, which is not really connected to the classroom curriculum (Anderson et al., 2006; Falloon, 2013; Moreno, 2005).

2.3 Supporting co-design and STEM partnerships

In spite of various interpretations in the research literature concerning co-design, active participation and involvement from all partners during the design process is commonly emphasised (e.g. Durall, Bauters, Hietala, Leinonen, & Kapros, 2019; Zamenopoulos & Alexiou, 2018). Related to education, Penuel, Roschelle, & Shechtman (2007) define co-design as a highly facilitated process that engages teachers, researchers, and developers in designing, developing and testing educational innovations. This is in agreement with other research, seeing co-design as a facilitated collaboration between researchers and practitioners (Aksela, 2019; Kelly, Wright, Dawes, Kerr, & Robertson, 2019). In the present study, co-design is used to describe the facilitated process where teachers and STEM professionals share their knowledge, skills and resources to collaboratively design a curriculum unit in Lektor2. This understanding is in line with Dolan & Tanner's idea of "true" partnerships, defined as involving 'two or more people, each with expertise or skills to contribute, working towards a common goal' (p. 28).

The literature offers recommendations to support teachers in their collaboration with STEM professionals. Penuel et al. (2014) recommend design principles that engage stakeholders with diverse expertise in a structured, facilitated co-design process, where teachers work with partners to develop, try out, and evaluate an educational innovation. Similarly, Tal, Alon, and Morag's (2014) design principles for field trips recommend teachers and partners plan together and discuss goals, means, and collaboration patterns, as well as connect the field trip to the school curriculum, provide student-centred learning activities, and involve both teachers and partners during the field trip. Shein and Tsai's (2015) model for teacher-scientist partnerships emphasises the collaborative process for planning, implementation and evaluation of partnership activities. During planning, teachers and scientists exchange expertise – teachers provide information about the students, educational and curriculum contexts, whereas scientists provide science content knowledge. Both teachers and scientists bring pedagogical content knowledge into the teaching.

The aforementioned recommendations for STEM partnerships emphasise the collaborative process before, during and after the partnership experience for students. However, there is a need to describe the scaffolds that support teachers in co-designing authentic cross-setting STEM experiences, whether the challenges of partnerships are addressed, and the kinds of experiences students gain from such contexts. The present study was designed to address these gaps by investigating teachers and students' experiences participating in a nationwide partnership program named "Lektor2", where teachers and STEM professionals collaboratively design curriculum units using a developed co-design tool. The study involves 378 teachers, 2101 students and 407 unique STEM partnerships, which contributes to the research literature by including a higher number of participants reporting from a large number of different curriculum units developed through partnerships between teachers and STEM professionals. Accordingly, the following research questions are addressed:

1. How do teachers in Lektor2 describe their experiences with designing curriculum units using the co-design tool?
2. How do students and teachers in Lektor2 describe the students' experiences from participating in the co-designed curriculum units?

3 Study context

Lektor2 is a national STEM partnership program in Norway offering a multi-year professional development for teachers, and financial support for schools, to involve local STEM professionals in their teaching. The term "STEM professional" is used broadly to mean any professionals using STEM in their daily job. Lektor2 aims to promote student learning and engagement in STEM and increase students' awareness of STEM careers. Teachers and STEM professionals collaborate on developing and implementing curriculum units involving cross-setting STEM experiences, such as a field trip to professionals' workplaces, use of professional scientific equipment, or visits from professionals in the classroom. [1]

3.1 The co-design tool

Starting in 2009, Lektor2 has involved STEM professionals in teaching STEM, bringing expert information to teachers and students, and acting as role models. In 2014, an external evaluation of Lektor2 found considerable variation in students' perceptions of quality and learning outcomes (Sjaastad, Carlsten, & Opheim, 2014). While some students found the experience interesting, others described it as "boring" and that they "learned nothing". Many of the partnerships were implemented according to the "provider-recipient" approach (Dolan & Tanner, 2005) and thus remained add-ons for teachers and students, disconnected from the national STEM curriculum. Following Sjaastad et al.'s (2014) recommendations to strengthen the theoretical basis for pedagogical designs, the program staff built on the Extended Classroom model – a design tool for cross-setting learning experiences in science (Remmen & Frøyland, 2017) – to develop the following co-design tool for teachers and STEM-professionals when collaboratively designing curriculum units in Lektor2[2]:

1. *The teacher and STEM professional choose a topic* that is authentic and relevant to the students, the national STEM curriculum, and the work of the STEM professional.

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[1] Lektor2 is funded by the Norwegian Ministry of Education and run by the Norwegian Centre for Science Education. All secondary and upper secondary schools across Norway can apply to participate. Since 2009, 500 schools from all over Norway and 800 different STEM organisations have participated, involving about 15.000-20.000 students each year.

[2] The co-design tool as it is presented to the teachers can be found on www.lektor2.no

2. *The teacher and STEM professional identify a commission for the students* that is derived from the STEM professional's work and engages students in authentic STEM practices.
3. *The teacher identifies the knowledge* (scientific theories, key concepts, etc.) *and practices* (collecting and analysing data, weighing options, communicating results, etc.) *required to complete the commission.*
4. *The teacher and STEM professional discuss how the STEM professional can contribute to authentic experiences for students.* The contributions should reflect the STEM professional's practices and/or workplace practices which students are not exposed to in school.
5. *The teacher designs the activities in the curriculum unit.* Students should participate in activities, both within and outside the classroom, that support them to acquire the STEM knowledge and practices required for completing the commission.

3.2 Commission

Step 2 in the co-design tool asks teachers and STEM professionals to identify and collaboratively design an authentic task for the students – a commission – where the students are commissioned by the STEM professional to do a specific job requiring authentic, complex problem-solving. To clarify what a Lektor2-commission is, five criteria were developed, derived from the literature and analysis of about 200 Lektor2-commissions. A Lektor2 commission is an authentic task that

- replicates authentic situations and problems from the STEM professional's work
- requires students to adopt professional practices requiring application of STEM knowledge and practices – i.e. the solutions cannot be "Googled"
- is sent from the STEM professionals' office, making the STEM professionals "clients" and students "contractors"
- demonstrates the purposes of the STEM professions in society
- engages students in decision-making regarding tools, solutions, approach etc.

The commission is often presented to students in a formal way, such as a commission letter. For example, in one school located in a smaller town in Eastern-Norway, students in year 10 (aged 15) were commissioned by Eidsiva, an energy company, to evaluate new uses for excess heat created at a local heating plant (Figure 1).

Eidsiva

To: Bjørnsveen secondary school
From: Eidsiva Bioenergi AS
Subject: Excess heat from the remote heating plant in Gjøvik
Date: 08.11.2017

Use of excess heat energy

In the near future the remote heating plant in Gjøvik, which burns unused wood chips, will produce an excess of heat energy or 'waste heat' during the warmer months (May through September). Waste heat is thermal power in the form of hot air, water, or steam that is not used and therefore gets lost to the surroundings. The waste heat is a consequence of the demands for heat during the summer being lower than the minimum effect on the chip steam boiler. This means that the boiler is producing more heat than the community is using. Furthermore, Eidsiva plans to start collecting waste heat from additional sources in the city, first by collecting waste heat from the purification plant at Rambekk. This will increase the amount of excess heat in the remote heating plant even further.

The amount of available power and energy is approximately 1500 kW and 5.000.000 kWh/year. The lowest production cost is approximately 0 cent/kWh.

Eidsiva Bioenergi AS requests an evaluation of new possible uses for the waste heat. We would like you to evaluate the following initiatives and propose your recommendations:

- Heating of the outdoor pool *Fastland*
- Heating of a deep pool in Mjøsa
- Extending the season for hothouses or garden-stores
- Heat-driven cooling
- Other possible initiatives

The evaluation and recommendations should include written and visual components, including models, pictures, drawings, etc. The project is to be completed within week 8, and the best solutions will be presented for a committee consisting of employees from Eidsiva Bioenergi in week 10 or 11.

In the case of need for additional information, please contact Eidsiva Bioenergi AS to make an appointment.

Figure 1. The commission letter given to students (15 yrs.) from Eidsiva (translated from Norwegian)

3.3 Facilitation of the co-design process

The implementation of the co-design tool was facilitated by Lektor2 staff (Kostøl & Braathen) and 11 local, trained coordinators, through national conferences, regional meetings, and online resources. Teachers used the co-design tool to develop and evaluate their curriculum units. Figure 2 visualises how the co-design process is facilitated and organised through various activities, resources, staff and participants in the Lektor2.

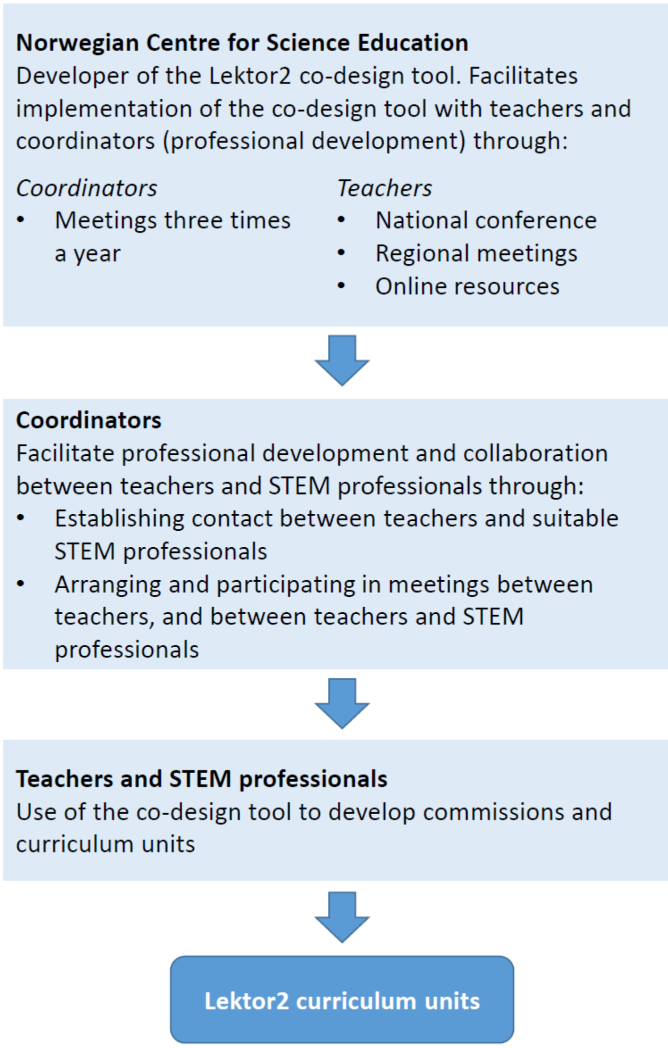

Figure 2. The facilitated co-design process on a national, regional and local level

4 Methodology

4.1 Data collection

To allow all participants in Lektor2 to describe their experiences, electronic surveys were used. This enabled data collection from teachers and students across Norway, which captured a large number of STEM partnerships and hence collaboration with STEM professionals from a variety of workplaces. Although self-reported data have limitations, it was considered appropriate in the present study, as the purpose was to describe the teachers' and students' experiences.

Three surveys (2015, 2017 and 2018) were given to teachers to collect information from both before and after implementation of the co-design tool, and one survey (2017) was given to students in secondary and upper secondary schools (age 13-19) to investigate their experiences from participating in the co-designed curriculum units. The surveys were developed through evaluation and refinement of similar surveys given to previous participating teachers and students in Lektor2. The revised surveys were vetted by the research team to further enhance face validity.

Some teachers designed and implemented two curriculum units with different STEM professionals, resulting in two responses to the survey. In total, responses from 378 teachers and 2101 students were collected, representing 407 unique curriculum units designed by pairs of teachers and STEM professionals using the co-design tool. The surveys and resulting datasets are described below (see Supplemental material for more details).

4.1.1 Datasets addressing RQ1

- *Teacher Survey 2015* collected data about teachers' experiences with Lektor2 *before* the implementation of the co-design tool. The survey was mandatory and was given to all participating teachers. Responses from 205 unique curriculum units were collected.
- *Teacher Survey 2017* collected data about teachers' experiences with Lektor2 *after* the implementation of the co-design tool. The survey was mandatory and was given to all participating teachers. Responses from 202 unique curriculum units were collected.

  In addition to answering closed-questions similar to the questions in Teacher Survey 2015, the teachers responded to the following open-ended question:

   - What do you think of *commission* as a learning approach for the students? (Keywords: different student types, different academic level, work effort etc.)

  Note that keywords were added to guide the teachers' reflections.
- *Teacher Survey 2018* collected data from 71 teachers across Norway who volunteered to respond to open-ended questions about the co-design tool in their collaboration with STEM professionals, and in their teaching practices. Teachers attending mandatory Lektor2 regional meetings were asked to participate.

4.1.2 Datasets addressing RQ2

- *Student Survey 2017* collected data from 2101 students who had participated in a curriculum unit designed by a teacher and STEM professional using the co-design tool. The question that gave qualitative descriptions of student experiences, and hence was analysed, was the open-ended question: "What do you think about participating in a Lektor2 curriculum unit where you have collaborated with STEM professionals?". The completely open question was asked in order to not give the students any direction of what experiences to describe, making it possible for the students to highlight experiences they themselves found to be important, accounting for all student ideas, including unanticipated experiences.
- *Teacher Survey 2017* collected data of the teachers' perceptions on student outcome through the open-ended question: "How would you evaluate the student's outcomes from completing the Lektor2 curriculum unit? (Keywords: learning outcomes, motivation, understanding of how STEM is used in work life etc.)"

4.2 Data analysis

As two of the authors were involved in the program being studied, two independent researchers having extensive knowledge within learning across settings were included in the research team performing the data analysis; one with previous experience with Lektor2 and one external, international researcher with no connection to Lektor2. Open-ended responses in each dataset were coded using a grounded theory approach (Strauss & Corbin, 1998) similar to Luehmann and Markowitz (2007). Codes were not identified beforehand but as emergent in order to privilege teachers' and students' voices and account for unanticipated experiences. The analysis was conducted as follows: 1) All open-ended responses from teachers and students were identified and analysed by a team consisting of the four researchers. 2) Responses that provided a substantial description of experiences or outcomes of the partnership or the co-design tool were subjected to a deeper analysis. 3) Through discussion and collaborative coding of a small set of survey responses, a coding scheme was agreed on, which was applied to the full dataset. 4) The full dataset was coded by the external researcher, resulting in an expanded and revised coding scheme. 5) The revised coding scheme and a subset of data were reviewed and discussed by the research team, revising, elaborating on, and justifying each code. 6) The full dataset was re-coded by the external researcher, attending to disconfirming evidence for each category and revisions when that evidence was found. 7) Finally, the team reviewed the expanded coding scheme and the coded data, analysing a subset for consistency of code application. To identify patterns and better understand the variety of teacher and student experiences, the qualitative data was summarised by calculating frequency distributions and percent frequency of each emerging code. Frequencies are limited in this kind of data as they are difficult to compare across studies and evaluate without further statistics. However, because it can be helpful for, e.g. seeing patterns in the dataset and examine representativeness, it was considered appropriate.

Reliability of the analysis was addressed by including independent researchers and through constant data comparison, comprehensive data use, and inclusion of negative cases. To enhance validity, investigator triangulation and theoretical triangulation (Denzin, 1979) was used, enabling consistency testing and a richer, more careful defining and understanding of the data and codes.

In addition to coding of open-ended responses, responses to closed questions from the teacher surveys in 2015 and 2017, before and after the implementation of the co-design tool, were compared concerning the nature of learning activities provided by the Lektor2 curriculum units. The comparison was made by calculating the percent frequency of reported teaching methods mainly used in the curriculum units in 2015 and 2017, respectively. The research questions with related datasets and analysis are summarised in Table 1.

Table 1. Overview of the data collection and analysis

Research question	Dataset	Total responses	Number of coded responses	Analysis
RQ1: How do teachers in Lektor2 describe their experiences with designing curriculum units using the co-design tool?	Teacher Survey 2015	205	-	Descriptive statistics
	Teacher Survey 2017	202	-	Descriptive statistics
	(closed and open questions)		156	Qualitative coding
	Teacher Survey 2018	71	71	Qualitative coding
RQ2: How do students and teachers in Lektor2 describe the students' experiences from participating in the co-designed curriculum units?	Student Survey 2017	2101	319	Qualitative coding and descriptive statistics
	Teacher Survey 2017	202	174	

5 Findings

In the following, findings from the analyses of teachers' experience with the co-design tool in Lektor2 (RQ1) and teacher and student reflections on student experiences from participating in the co-designed curriculum units (RQ2) are presented.

5.1 RQ1: Teachers' descriptions of their experiences with designing curriculum units using the co-design tool

From the analyses, four types of responses emerged: collaboration with STEM professionals, pedagogical approaches, differentiation, and transfer to teaching in general.

5.1.1 Collaboration with STEM professional

Forty-five of the 71 teachers (63 %) responding to the 2018-survey, expressed that the co-design tool made collaboration with STEM professionals easier and more accessible than before. For instance, one teacher described that it lowered the threshold for initiating contact:

> It [the co-design tool] has made you actually make contact and collaborate. (...)

One-third of these responses mentioned the commission in particular, stating that the commission made the collaboration "more authentic", and that teachers and STEM professionals were more involved in the entire co-design process of planning, implementing, and evaluating the curriculum unit. The following responses illustrate these points:

> The Lektor2 co-design tool makes us collaborate more closely with the businesses. They are involved in the entire process.
>
> The collaboration becomes more authentic when we have a concrete commission as a starting point.

However, three teachers (4 %) described negative experiences with the co-design tool. This was related to the challenges of having the Lektor2 curriculum unit fit into the traditional curriculum and having time for planning together with the STEM professional:

> I think the commission model itself has worked well, but it has been difficult to make the model a natural part of school life and teaching. Need a lot of time for collaboration between the STEM professional and the school, clarification of expectations etc. (…)

5.1.2 Pedagogical approaches

In the 2015-survey, before the implementation of the co-design tool, 38 % of the teachers reported that the Lektor2 curriculum unit mainly consisted of traditional teaching methods, like lectures and guided tours with the STEM professional. However, 24 % of the teachers reported that their students collected and processed data and 37 % stated conducting experiments as an important student activity.

In the 2017-survey, after the implementation of the co-design tool, 88 % of the teachers reported inquiry-based learning activities in the Lektor2 curriculum unit. Specifically, 57 % of the teachers reported that the students collected and processed data, and 61 % stated practical activities where students had to use the equipment.

In the 2018-survey, changes in the pedagogical approaches used in partnerships were highlighted by the teachers. Of 54 teachers who had implemented the curriculum unit at the time of the survey and thus could compare their collaboration experiences with and without the co-design tool, 46 teachers (85 %) emphasised changes in student activities in their responses. Twenty-eight of these teachers (61 %) included the commission in their evaluation, reporting that it led to more student engagement:

> Students have done more practical work at the business than before (not just a guided tour). They have also had a specific goal/commission to work towards (inquiry-based learning).
>
> (…) The students get tasks/commission instead of lectures. The students no longer remain passive but are engaged in the process.

5.1.3 Differentiation

In the open-ended question in Teacher Survey 2017 about commission as a learning approach for students, 40 % of the teachers expressed that the commission enabled them to differentiate the teaching to students with diverse strengths, preferences, and interests. The teachers reflected on the commission as an opportunity for all students to contribute, regardless of academic level. Therefore, these responses were coded as *differentiation*, illustrated below:

> It has been easier than usual to differentiate the teaching (…)
>
> All students regardless of academic level can contribute, a mastering sensation for those who are not "good at school". (…)

5.1.4 Transfer to teaching in general

In 2018, 43 of 71 teachers (61 %) reported that collaborating with STEM professionals through the co-design tool, and on the commission in particular, influenced their teaching more generally. Of these, 30 teachers felt more capable of designing more "practical" or "open-ended" activities, and/or connecting activities to the local community, as illustrated by the following teacher response:

> [I] try to provide commissions requiring students to do a job for someone outside school (fictive or real). More focus on open-ended tasks that have several possible solutions.

Some teachers also used commissions in their teaching of other curriculum units. One teacher even saw opportunities to transfer the commission to other school subjects:

> The commission model makes me think that students can contribute in every partnership with work life (e.g., investigations, data collection, computation, production etc.). There are partnerships between the school and work life in subjects other than STEM and Lektor2, and I hope that the commission-model can be applied in those settings as well.

5.2 RQ2: Students' and teachers' characterisation of the students' experiences from the co-designed curriculum units

The analysis of open-ended responses about student experiences, collected through Teacher Survey 2017 and Student Survey 2017, revealed a diversity of experiences as summarised in Table 2 (see Supplemental material for a complete overview). Relating experiences were grouped into three main outcomes: Expansive views of STEM, STEM learning and STEM engagement. Details about each outcome are presented subsequently.

Table 2. Findings from the coding of responses describing experiences for students

	CODE	DESCRIPTION	STUDENT		TEACHER	
			Frequency	Percent frequency	Frequency	Percent frequency
OUTCOME 1: EXPANSIVE VIEWS OF STEM	**Connection to real world**	Descriptions of connections/relationship between schoolwork and work life, or seeing things "in practice", applicability of school STEM in the "real world".	76	24 %	96	55 %
	Possibilities	New awareness of future possibilities or realising that STEM is not for them.	44	14 %	14	8 %
	Understanding of work life	Understanding of how a business or the real world works, or an assessment of the job type (boring, interesting, etc.). Not just reference to the link between school and work, but to new understandings of what work life is like.	75	24 %	49	28 %
OUTCOME 2: STEM LEARNING	**Content knowledge**	Specific content knowledge.	5	2 %	26	15 %
	Increased understanding	Benefits in terms of greater outcomes or increased learning/understanding.	17	5 %	28	16 %
	Practices knowledge	Student engagement in practices (putting stuff together, calculations, lab work, writing surveys, etc.).	7	2 %	38	22 %
OUTCOME 3: STEM ENGAGEMENT	**Meaningful**	The relevance of the curriculum unit to everyday life, or as personally important/useful.	14	4 %	20	11 %
	Motivating	Catchall code to note the curriculum unit was engaging or that the students were engaged in deeper/different ways than usual.	18	6 %	87	50 %
	Positioning	Specific descriptions of a student in relation to the work – often a new position/role.	8	3 %	4	2 %
		Total number of coded responses (one response often has several codes)	**319**		**174**	

5.2.1 Outcome 1: Expansive use of STEM

The common characteristic across the three codes *understanding of work life*, *possibilities*, and *connection to real world*, described in Table 2, is that both teachers and students experienced connections between schoolwork and STEM related work outside school and a new awareness of STEM possibilities and work life. Therefore, the three codes were merged into the outcome *Expansive views of STEM*. Specifically, the curriculum unit helped increase students' awareness of jobs in STEM, including a deeper understanding of STEM professionals' tasks and practices, and helped students see the applicability of STEM in contexts outside school. These findings are illustrated by the subsequent student response (coded as *connection to real world*, *understanding of work life*, and *possibilities*) and teacher response (coded as *connection to real world* and *understanding of work life*):

> Student: I thought this was fun, fun to see what we learn about performed in the workplace. That what we are working on now can be our future job.

> Teacher: Several of the students expressed: "Now I understand the point of the mathematics we learn!" (...) The students also gained a very good and tangible insight into how important STEM is in a high-tech business.

Along with a deeper understanding of STEM professions, 44 students (14 %) and 14 teachers (8 %) went further to make connections to possible job opportunities for students in the future. As in the quote below, students especially described the Lektor2 experience as giving them a better overview of possibilities for themselves, a better idea of what they want to do, or informing their decisions about further education or professional pathway.

> Student: (...) I have gained a new view of how many jobs exist within STEM and4 the possibilities around this (...)

Expansive views of STEM also included responses from students, such as the quote below, who spoke to the benefit of Lektor2 even though they were not planning to pursue STEM in the future:

> (...) very good for us to see what opportunities exist and especially opportunities for STEM. This makes it easier to choose both profession and upper secondary school, even though I'm not thinking about going into STEM.

5.2.2 Outcome 2: STEM learning

STEM learning comprises the codes *content knowledge*, *increased understanding*, and *practices knowledge*. Three teachers (2 %) reported that the Lektor2 experience did not contribute to their students' learning, whereas 79 teachers (45 %) described positive outcomes regarding STEM learning such as students gaining increased understanding of key concepts and engaging in STEM practices, exemplified in the quote below:

> Teacher: The curriculum unit provides students with a good starting point for discussion, reflection and writing of argumentative texts (...). Students get positive nature experiences and understanding of predator's biology, role in ecosystems, and society.

A few teachers also reported that students gained increased understanding of the importance of STEM education:

> Teacher: They used their knowledge in a new setting. It became more close to reality, and led to increased understanding of why we learn what we learn at school.

While the teachers were specific about content and practices, the students' were more general in their descriptions of STEM learning outcomes, expressing that they "learned a lot" or "got a better understanding". As indicated by the response below, coded as *increased understanding*, some students experienced that Lektor2 helped them to be more engaged in their own learning:

> Student: I think it was far more educational and easier to pay attention when working with the subject in a more practical context.

5.2.3 Outcome 3: STEM engagement

Another important finding was that the Lektor2 curriculum unit engaged students in STEM education, often in more profound or different ways than usual, as described by the codes *meaningful*, *motivating*, and *positioning*. Eighty-seven teachers (50 %) commented that experiencing, applying and practicing STEM work outside school led to increased student engagement, typically described as an increase in students' effort during the curriculum units. In the following example, the teacher's response refers explicitly to the commission as critical for motivating students.

> Teacher: (…) The fact that they were given an authentic commission was motivating in itself, and they have worked very hard with the commission. They have seen that mathematics and science is important in everyday life and in work life (…)

Many students used terms like “interesting” (17 %), “enjoyable” (29 %), and/or “exciting” (19 %) when characterising the curriculum units. Eighteen of these students went further, describing deeper engagement, as illustrated by the following responses:

> Student: I found it interesting, and it made me want to become more competent in the [STEM] subject.

> Student: In short, it was amazing and very inspiring! (…) it made the students in my class participate and be more engaged.

The teachers often explained students’ motivation and deeper engagement by referring to the commission as authentic, meaningful and connected to students’ lives. The following response coded as *motivating* and *meaningful* demonstrates this:

> Teacher: (…) the students were motivated by the fact that this [the commission] is an authentic problem, and easily transferable to their lives.

Fourteen students (4 %) highlighted their experience of working with the commission as authentic, useful and relevant, and not just “doing another task given from the teacher for a grade”. The student responses coded as *meaningful* also emphasised that the commission was connected to their local community or everyday life, inviting them to contribute in decision-making. As with the teachers, the students described how the experience of doing something important led to increased engagement and interest, as exemplified below:

> Student: I think it has been a good unit where you have been given an authentic assignment, instead of something that only is to be graded

> Student: This unit has been fun and educational. It is good that we can collaborate with the people in the municipality and be part of making decisions in our local community (…)

The importance of authenticity was further supported by a teacher describing a situation where the commission lost some of its value. In this case, the students were commissioned by a forest owner to plant trees after logging. This required the students to assess which types of trees to plant:

> Teacher: Great motivation related to the commission. (…) one father informed the student that plants to the felling area had already been bought. This spread rapidly among the students and we lost the context and the feeling of working with a real commission. (…) they considered this as just another school assignment and the motivation disappeared.

Eight students described that working with the Lektor2 curriculum unit inspired them to take a new position or reconsider themselves in relation to STEM. Therefore, these responses, such as the following example, were coded as *positioning*:

> Student: It was really exciting and refreshed my interests, and I became happy and would do it again, and I'm considering STEM.

This code also captured student responses showing a shift or confirmation of their decision of not aspiring to STEM careers:

> Student: Thought it was a great experience that showed me how STEM is being used in work life and showed that it wasn't for me.

Positioning also emerged in 13 of the teacher responses, where teachers expressed a shift in recognition of their students and their assets in the classroom. The teachers described students showing new sides of themselves during their work with the commission, for example, students who were quiet or less motivated engaged more deeply than usual. They also described students who were capable to accomplish new and more complex tasks. Examples of responses illustrating these points are:

> Teacher: (…) A student who earlier took a long time to get started, and did not see the benefits of math threw himself into the task and worked very hard (…)

> Teacher: The commission worked very well. Students show new sides of themselves when they are doing commissions, and it's especially nice to see that some really flourish and show you assets that are difficult to see in regular classroom settings.

Twenty students (6 %) found the curriculum unit to be disengaging, expressing that they did not find the commission interesting, or that it was overwhelming or irrelevant to the national curriculum. However, even the students who gave negative comments most often included something positive when describing their experience with Lektor2:

> Student: Fun to collaborate with work life, but the topic and [what] the workplace was doing was boring. It was more fun than regular education (…)

6 Discussion

The purpose of this study was to describe teachers' and students' experiences from curriculum units co-designed by teachers and STEM professionals, using a specific co-design tool developed within a national cross-setting STEM partnership program. Specifically, teachers were asked how they experienced using the co-design tool, and teachers and students described students' experiences after participating in the co-designed curriculum units. Our findings indicated that the co-design tool, particularly the commission, enabled teachers to collaborate with STEM professionals, design learning activities that engaged students in authentic STEM practices, differentiate teaching for diverse students, and transfer new teaching strategies to other areas of their teaching. The coding of teacher and student responses regarding student experiences resulted in three main outcomes: Expansive views of STEM, STEM learning, and STEM engagement. The two latter outcomes align with cognitive and affective outcomes described in the literature on outdoor science activities (Rickinson et al., 2004), including partnerships (e.g., Tysbulski, 2019). However, within each of the three outcomes, several codes that refine the possible outcomes from such partnerships were identified. Our analyses therefore provide a more fine-grained view of the outcomes students can possibly gain from partnerships involving co-design of curriculum units. One reason for this could be that our study included a much larger number of teachers and students, and a range of different co-designed curriculum units, than what has been reported in the research literature earlier.

Some of the reported codes have a low frequency (Table 2). This can be explained by the fact that not all codes were applied to each student response. This is a consequence of our methodological choice, in that students responded to an open question designed not to lead them in any particular direction (see Student Survey 2017). Therefore, whether each particular curriculum unit resulted in all three outcomes for all students cannot be answered. However, the findings from this study describes what the students themselves chose to highlight as important experiences from participating in the co-designed curriculum units.

When reflecting on the co-design tool, the teachers tended to describe the commission in particular, and both teachers and students described the students' work using phrases such as "authentic assignment", "authentic problem" or "real". Therefore, it becomes important to discuss how the commission, as a specific part of the co-design tool and a unique feature of this study, might address partnership challenges and promote different student outcomes.

6.1 Addressing challenges with partnerships: the teachers' perspectives

In contrast to other studies (e.g. Sagar et al., 2012), teachers participating in Lektor2 did not experience the challenge of establishing contact with STEM professionals. This can be partly ascribed to how Lektor2 is organised – coordinators facilitated contact and meetings between teachers and STEM professionals (Figure 2), in line with design principles for collaboration about cross-setting STEM experiences (Penuel et al., 2014; Tal et al., 2014). Further, the co-design tool helped teachers to reduce the challenges related to collaboration. For instance, the tool enabled teachers to initiate collaboration with STEM professionals, as illustrated by responses describing the collaboration as "closer" and the commission as an effective starting point for the co-design process. This contrasts with previous findings cited earlier, indicating challenges with communication in the collaborative process (e.g., Falloon, 2013; Sagar et al., 2012). Furthermore, the teacher describing the cross-setting activity as "students get tasks/commission instead of lectures" from the STEM professional, and the student expressing that "it made the students in my class participate and be more engaged", show that the curriculum units engaged students as active participants in their learning, in contrast to being passive receivers of information from the STEM professional. The notion of active learning is in line with Tal et al.'s (2014) recommendations for productive cross-setting STEM experiences.

A few teachers shared the view of other research findings, indicating that teachers find it difficult to include partnership activities in their regular classroom teaching (Ng & Fergusson, 2019; Sagar et al., 2012). Notably, only a few teachers emphasised the challenges of using the co-design tool, particularly with respect to time and making the commission fit into school traditions. This indicates that the co-design tool, even though the co-design process is facilitated by Lektor2-staff, does not enable all teachers to overcome the external challenges with STEM partnerships. Clearly, the commission requires teachers to adopt innovative teaching strategies that engage students in scientific problems and practices.

6.2 Aspects of the commission and related student outcomes

The number of teachers and students who chose to highlight the commission when describing their Lektor2 experience, indicate that the commission was particularly important for the students' outcomes from the curriculum units. As seen in Table 2, both teachers and students experienced expanded views of STEM and STEM engagement to a greater extent than increased STEM learning. An obvious explanation for these findings could be that the students were not asked to describe what they learned, as the different curriculum units focused on different topics and the students included in the study ranged from secondary to upper secondary school. Therefore, it becomes important to discuss our findings with respect to the potential of using a commission to support student outcomes from cross-setting STEM experiences across topics and school levels.

6.2.1 Commissions provide authentic experiences that are relevant

As indicated by the relatively high frequency of the codes *connection to real world* and *understanding of work life* in the students' responses, and *connection to real world* in the teachers' responses (Table 2), the curriculum units based on a commission appeared to demonstrate how knowledge learned in school was applicable in real-life situations. This corresponds to Murphy et al.'s (2006) cultural authenticity, defined as relevance for professional practices, and Stuckey et al.'s (2013) societal dimension of relevance. This may be related to the commission's goals of presenting authentic problems and requiring students to adopt professional practices and actively apply STEM knowledge and skills. However, that students appreciate the commission as relevant for the society does not necessarily mean that they perceive it as personally relevant, as suggested by the relatively small proportion of the *connection to real world*-responses that were also coded as *meaningful*. None of the criteria for commissions in Lektor2 requires that the commission should be personally relevant – this would be difficult to achieve given the various interests and backgrounds that exist in a student group.

Regardless, it can be concluded that many students in Lektor2 experienced the commission as relevant in one or more dimension (vocational, societal, and/or personal). This may be ascribed to the co-design process, in which teachers and STEM professionals plan the commission together, as described in Study context, confirming the literature emphasising collaboration between the partners in the planning process (e.g., Shein & Tsai, 2015; Tal et al., 2014). Therefore, in order to make sure that students perceive the commission as relevant in a societal, vocational and/or personal way, it seems important that teachers and STEM professionals can share their expertise to design the commission – the teacher's knowledge about the students and the STEM professional's knowledge about authentic problems and practices.

6.2.2 Commissions engage students as contributors to authentic STEM work

According to many teachers in this study, students engaged more deeply when working with the commission, including students who typically struggle with their motivation for STEM in school. This finding confirms that out-of-school experiences can enhance students' interests and motivation (Braund & Reiss, 2006; Tytler et al., 2018). In addition, our findings suggest that the commission in particular inspired some students to work harder than usual (coded as *motivating*). One reason could be that the commission in Lektor2 put students into roles as contributors by communicating their own findings and new ideas to an authentic "client" – who asks for, and often needs, the students' contributions (see criteria under Commission). As exemplified by the student who highlighted the experience of being part of making decisions in the municipality, the students valued the opportunity to contribute to the STEM professionals' work. This finding aligns with Stromholt and Bell's (2018) argument that students should have opportunities to recognise themselves as contributors to STEM and their community. This was also made clear by a contrasting example, in which the teacher's response described a decrease in students' engagement when they learned that the STEM professional did not really need their contribution after all. Thus, authenticity in commissions – from problem to solution – appears to be critical in order to ensure that students experience the partnership as engaging and meaningful. Furthermore, it might be important to emphasise that Lektor2 differs from citizen science projects where student contribution is typically limited to data collection (Wormstead et al., 2002), as the commission also requires deep STEM knowledge, engagement in STEM practices such as designing solutions to real-life problems, analysing data, and arguing based on evidence, and communicating solutions back to STEM professionals (see Commission).

6.2.3 Commissions make students aware of new possible futures

In addition to relevance, the outcome Expansive views of STEM included perspectives on future possibilities, exemplified by a student stating that the current work with the commission could also be their work in the future. Similar to Archer et al. (2014), some of the students in our study recognised a new awareness of job opportunities within STEM when working with the commission. Notably, there was a slight difference in the proportion of student and teacher responses coded as *possibilities* (Table 2), indicating that more students than teachers recognised the professional relevance – i.e., that STEM-related work and jobs were modelled through the curriculum unit, suggesting that these students themselves made connections between STEM in school and professions. This increased awareness of future professions and careers resembles Stuckey et al.'s (2013) vocational dimension of relevance.

However, not all student responses included reflections on whether they considered the job opportunity as relevant for them personally. This dimension was instead captured by the code *positioning*, in which the student responses signalled a shift or confirmation in aspirations through the Lektor2 curriculum unit. This included both student responses reflecting a willingness to consider further STEM education and a recognition that STEM was not for them. Both are important in order to make informed decisions about possible futures, regardless of whether it is going into STEM or not (Jensen, 2015). Of course, there are uncertainties here, as the survey was anonymous and information about the students' background is therefore not accessible. Nonetheless, given that students often base their career aspirations on previous experiences with STEM (Jensen, 2015), the commission in Lektor2 could be one of several authentic STEM experiences in the process of choosing STEM career pathways.

6.2.4 Commissions provide opportunities for students with different academic capabilities

The commission provided opportunities for students to engage more deeply, collaborate with their peers, and discover new sides of their abilities and learning, as evident by responses coded as *motivating* and *differentiation*. Motivation, collaboration and responsibility for learning can be realised by including outdoor science activities in the formal science curriculum (Braund & Reiss, 2006), but it is worth noting that many of the teachers experienced that students with different academic strengths or interests were able to engage in the commission. This is in agreement with Lesseig, Slavit, Nelson, & Seidel (2016), reporting that teachers experienced all their students, including low-achieving students, to be motivated and empowered when faced with complex, open-ended problems. Thus, it seems that the commission can potentially address the broader purposes of cross-setting STEM experiences as expanding access to STEM learning opportunities to promote equity and diversity in STEM education (Penuel et al., 2014). However, this conclusion needs to be addressed in future research on why and how the commission allows students with different interests and capabilities to participate in STEM education.

7 Conclusions and implications

From our study, it can be proposed that the co-design tool enabled teachers in Lektor2 to overcome commonly reported challenges with STEM partnerships and enabled the design of authentic STEM experiences that resulted in a variety of outcomes for students. Figure 3 visualises the co-design tool as essential for creating connections between teachers, STEM professionals, and students, through facilitation of partnership and co-design of curriculum units. It also summarises the teachers' experiences with designing curriculum units in Lektor2 and descriptions of the resulting student experiences. Specifically, teachers experienced that the co-design tool made collaboration with STEM professionals more accessible and authentic, enabled them to focus more on student-centred activities, and facilitated student engagement in authentic STEM work, regardless of academic level. For students, participation in the co-designed curriculum units in Lektor2 resulted in a variety of experiences involving more expansive views of STEM, STEM learning and STEM engagement.

The commission – a part of the co-design tool that was frequently mentioned by the teachers – has been discussed in order to identify its potential for facilitating the outcomes for students. However, this article only provides an overview of the possible student outcomes from curriculum units based on the co-design tool in Lektor2. Further research may investigate how such facilitated STEM partnership programs contribute to individual student's outcomes across all three domains – engagement, learning and expansive views of STEM. Furthermore, as this study was based on teachers' and students' self-reports, observational studies of co-design processes between teachers and STEM professionals are needed to investigate how such processes may influence students' work with authentic tasks across settings.

Nevertheless, based on our findings we argue that the proposed co-design tool – and the commission in particular – helped the teachers in Lektor2 to overcome some of the recurring challenges related to STEM partnerships, and resulted in curriculum units leading to a diversity of student experiences important for authentic STEM education.

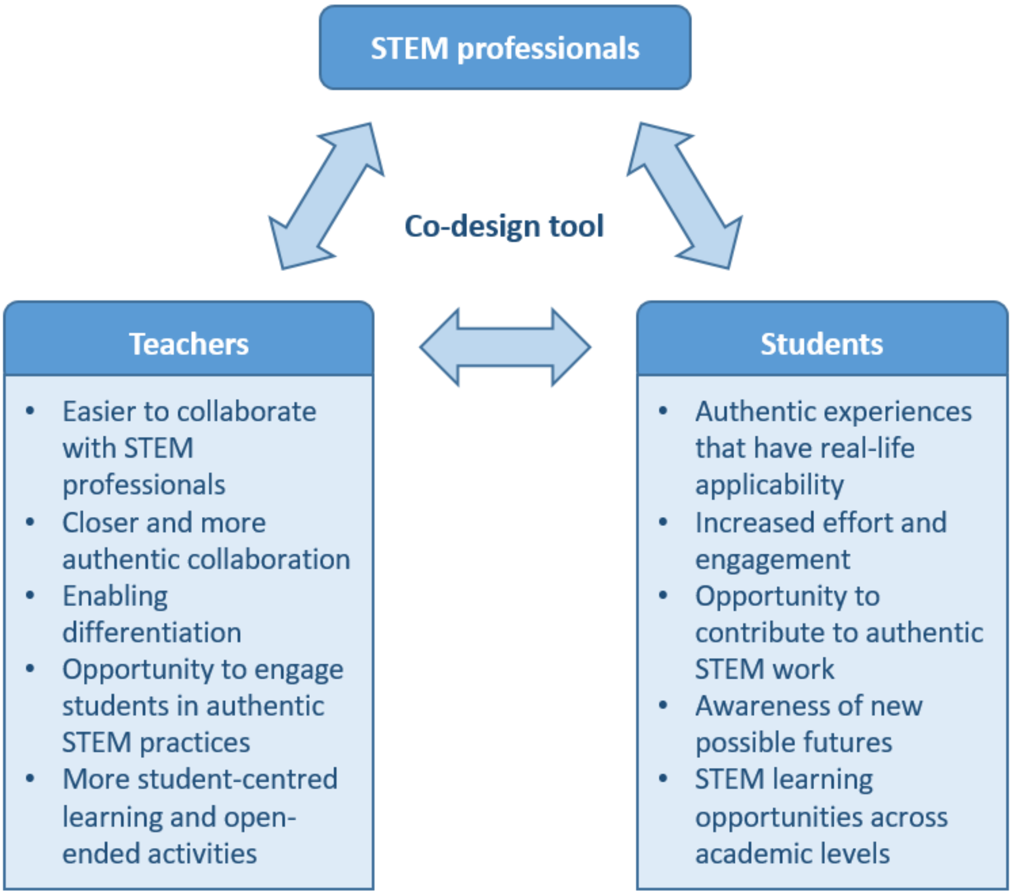

Figure 3. A summary of what the co-design tool can contribute to for teachers and students in Lektor2.

References

Aksela, M. (2019). Towards student-centred solutions and pedagogical innovations in science education through co-design approach within design-based research. *LUMAT: International Journal on Math, Science and Technology Education, 7*(3), 113–139. https://doi.org/10.31129/LUMAT.7.3.421

Alkaher, I. & Gan, D. (2020). The role of school partnerships in promoting education for sustainability and social capital. *The Journal of Environmental Education*, *51*(6), 416–433. https://doi.org/10.1080/00958964.2020.1711499

Anderson, D., Kisiel, J., & Storksdieck, M. (2006). Understanding Teachers' Perspectives on Field Trips: Discovering Common Ground in Three Countries. Curator: *The Museum Journal*, *49*(3), 365–386. https://doi.org/10.1111/j.2151-6952.2006.tb00229.x

Anker-Hansen, J., & Andreé, M. (2019). In pursuit for authenticity in science education. *Nordic Studies in Science Education, 15*(1), 54–66. https://doi.org/10.5617/nordina.4723

Archer, L., DeWitt, J., & Dillon, J. (2014). "It didn't really change my opinion": exploring what works, what doesn't and why in a school science, technology and mathematics careers intervention. *Research in Science and Technological Education, 32*(1), 35–55. https://doi.org/10.1080/02635143.2013.865601

Bell, P., Lewenstein, B., Shouse, A. W., & Feder, M. A. (Eds.). (2009). *Learning science in informal environments: People, places, and pursuits*. Washington, DC: Board on Science Education, National Research Council, The National Academies Press.

Braund, M., & Reiss, M. (2006). Towards a more authentic science curriculum: The contribution of out-of-school learning. *International Journal of Science Education, 28*(12), 1373–1388. https://doi.org/10.1080/09500690500498419

Brown, J. S., Collins, A., & Duguid, P. (1989). Situated Cognition and the Culture of Learning. *Educational Researcher, 18*(1), 32–42. https://doi.org/10.3102/0013189X018001032

Denzin, N. K. (1978). *Sociological Methods: A Sourcebook*. New York: McGraw-Hill

Durall, E., Bauters, M., Hietala, I., Leinonen, T., & Kapros, E. (2019). Co-creation and co-design in technology-enhanced learning: Innovating science learning outside the classroom. *Interaction Design and Architecture(s) Journal – IxD&A 42*, 202–226.

Dolan, E., & Tanner, K. (2005). Moving from Outreach to Partnership: Striving for Articulation and Reform across the K-20+ Science Education Continuum. *Cell Biology Education, 4*, 35–37.

European Commission (2015). *Science education for responsible citizenship* (EUR 26893 EN). http://ec.europa.eu/research/swafs/pdf/pub_science_education/KI-NA-26-893-EN-N.pdf

Falloon, G. (2013). Forging school-scientist partnerships: A case of easier said than done? *Journal of Science Education and Technology, 22*, 858–876. https://doi.org/10.1007/s10956-013-9435-y

Falloon, G., Trewern, A. (2013). Developing School-Scientist Partnerships: Lessons for Scientists from Forests-of-Life *Journal of Science Education and Technology, 22*, 11–24. https://doi.org/10.1007/s10956-012-9372-1

Frøyland, M, & Langholm, G. (2009). Skole og museum bør samarbeide bedre [The need for improving school and museum collaboration]. *Nordisk museologi, 2*, 92–109. https://doi.org/10.5617/nm.3201

Houseal, A.K., Abd-El-Khalick, F., & Destefano, L. (2014). Impact of a student-teacher-scientist partnership on students' and teachers' content knowledge, attitudes toward science, and pedagogical practices. *Journal of Research in Science Teaching, 51*(1), 84–115. https://doi.org/10.1002/tea.21126

Jensen, F. (2015). *The role of Recruitment Initiatives in Young People's Choice of STEM Education* (Doctoral dissertation). University of Oslo.

Kelly, N., Wright, N., Dawes, L., Kerr, J., & Robertson, A. (2019). Co-design for Curriculum Planning: A Model for Professional Development for High School Teachers. *Australian Journal of Teacher Education, 44*(7), 84–107. http://dx.doi.org/10.14221/ajte.2019v44n7.6

Kisiel, J. F. (2014). Clarifying the complexities of school–museum interactions: Perspectives from two communities. *Journal of Research in Science Teaching, 51*(3), 342–367. https://doi.org/10.1002/tea.21129

Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate Peripheral Participation*. Cambridge: Cambridge University Press.

Lesseig, K., Slavit, D., Nelson, T. H., & Seidel, R. A. (2016). Supporting middle school teachers' implementation of STEM design challenges. *School Science and Mathematics*, *116*(4), 177–188. https://doi.org/10.1111/ssm.12172.

Luehmann, A. L., & Markowitz, D. (2007). Science Teachers' perceived benefits of an out-of-school enrichment programme: Identity needs and university affordances. *International Journal of Science Education, 29*(9), 1133–1161. https://doi.org/10.1080/09500690600944429

Moreno, N. (2005). Science education partnerships: Being realistic about meeting expectations. *Cell Biology Education, 4*(1), 30–32.

Murphy, P., Lunn, S., & Jones, H. (2006). The impact of authentic learning on students' engagement with physics. *The Curriculum Journal, 17*(3), 229–246. https://doi.org/10.1080/09585170600909688

Ng, W., & Fergusson, J. (2019). Technology-enhanced science partnership initiative: Impact on secondary science teachers. *Research in Science Education, 49*, 219–242. https://doi.org/10.1007/s11165-017-9619-1

Parvin, J., & Stephenson, M. (2004). Learning science at industrial sites. In M. Braund & M. Reiss (Eds.), *Learning science outside the classroom* (pp. 129–149). London: RoutledgeFalmer.

Penuel, W. R., Roschelle, J., & Shechtman, N. (2007). Designing formative assessment software with teachers: an analysis of the co-design process. *Research and Practice in Technology Enhanced Learning, 2*(1), 51–74. https://doi.org/10.1142/S1793206807000300

Penuel, W. R., Lee, T. R., & Bevan, B. (2014). *Designing and building infrastructures to support equitable STEM learning across settings*. http://learndbir.org/resources/Penuel-Lee-Bevan-2014.pdf

Remmen, K. B., & Frøyland, M. (2017). "Utvidet klasserom" – et verktøy for å designe uteundervisning i naturfag. [Extended classroom: A tool for designing outdoor education in science]. *Nordic Studies in Science Education, 13*(2), 218–229. https://doi.org/10.5617/nordina.2957

Rennie L., Venville G., Wallace J. (2018). Making STEM Curriculum Useful, Relevant, and Motivating for Students. In Jorgensen R., Larkin K. (Eds.), *STEM Education in the Junior Secondary* (pp. 91-109). Springer, Singapore. https://doi.org/10.1007/978-981-10-5448-8_6

Rickinson, M., Dillon, J., Teamey, K., Morris, M., Choi, M., Sanders, D., and Benefield, P. (2004). *A review of Research on Outdoor Learning*. Shrewsbury: Field Studies Council.

Sagar, H., Pendrill, A-M., & Wallin, A. (2012). Teachers' perceived requirements for collaborating with the surrounding world. *Nordic Studies in Science Education, 8*(3), 227–243. https://doi.org/10.5617/nordina.530

Shein, P.P., & Tsai, C-Y. (2015). Impact of a Scientist-Teacher collaborative model on students, teachers, and scientists. *International Journal of Science Education, 37*(13), 2147–2169. https://doi.org/10.1080/09500693.2015.1068465

Sjaastad, J., Carlsten, T.C., & Opheim, V. (2014). *Evaluering av Lektor2-ordningen [Evaluation report of Lektor2].* (NIFU Rapport 2014:20). Oslo: Nordisk institutt for studier av innovasjon, forskning og utdanning.

Strauss, A., & Corbin, J. (1998). Basics of qualitative research: Procedures and techniques for developing grounded theory (2nd ed.). Thousand Oaks, CA: Sage.

Stromholt, S., & Bell, P. (2018). Designing for expansive science learning and identification across settings. *Cultural Studies of Science Education, 13*(4), 1015–1047. https://doi.org/10.1007/s11422-017-9813-5

Stuckey, M., Hofstein, A., Mamlok-Naaman, R., & Eilks, I. (2013). The meaning of "relevance" in science education and its implications for the science curriculum. *Studies in Science Education, 49*(1), 1–34. https://doi.org/10.1080/03057267.2013.802463

Tal, R., Bamberger, Y., & Morag, O. (2005). Guided school visits to natural history museums in Israel: Teachers' roles. *Science Education, 89*(6), 920–935. https://doi.org/10.1002/sce.20070

Tal, T., Alon, L.N., & Morag, O. (2014). Exemplary practices in field trips to natural environments. *Journal of Research in Science Teaching, 51*(4), 430–461. https://doi.org/10.1002/tea.21137

Tsybulsky, D., Dodick, J., & Camhi, J. (2018). The Effect of Field Trips to University Research Labs on Israeli High School Students' NOS Understanding. *Research in Science Education, 48*(6), 1247–1272. https://doi.org/10.1007/s11165-016-9601-3

Tsybulsky, D. (2019). Students meet authentic science: the valence and foci of experiences reported by high-school biology students regarding their participation in a science outreach programme. *International Journal of Science Education, 41*(5), 567–585. https://doi.org/10.1080/09500693.2019.1570380

Tytler R., Symington D., Williams G., White P. (2018). Enlivening STEM Education Through School-Community Partnerships. In Jorgensen R., Larkin K. (Eds.), *STEM Education in the Junior Secondary* (pp. 249-272). Springer, Singapore. https://doi.org/10.1007/978-981-10-5448-8_12

Wormstead, S.J., Becker, M.L., & Congalton, R.G. (2002). Tools for successful student-teacher-scientist partnerships. *Journal of Science Education and Technology, 11*(3), 277–287. https://doi.org/10.1023/A:1016076603759