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How lower secondary pupils work with design in green entrepreneurship in STEM education competitions

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Abstract

This paper analyses how lower secondary pupils experience their participation in the Danish science and green entrepreneurship competition, called Edison. The study uses a qualitative research method to investigate pupils' descriptions, in retrospect, on the process of their entrepreneurial work. We completed semi-structured interviews with two teachers and six groups of pupils from two schools. Independence and being able to determine their own product were motivating factors. Often the pupils included other actors, particularly family members, on their own initiative as part of their work. The pupils' interest in STEM education did not appear to have been affected except for two pupils who broadened their educational perspective. However, the awareness of sustainability issues has for some of them been supported, one of them with a change of lifestyle. By including engineering design process models in the analyses, the concept of entrepreneurship in science and technology became more process oriented and operational, which may also help both the teachers' facilitation and the pupils' inventing process.

Keywords STEM education · Entrepreneurship · K-12 · Competition · Green entrepreneurship · Engineering

Introduction

This paper focuses on how lower secondary pupils perceive their participation in STEM (science, technology, engineering, mathematics) competitions focused on green entrepreneurship. The introduction provides an overview of how competitions and green entrepreneurship activities have been implemented in STEM education internationally and its implication for pupils' interest in STEM. This leads to a formulation of the research question for the paper.

Competitions are part of K-12 education all over the world and many schools participate in for instance FIRST LEGO League, International Science Olympiads, etc. within

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STEM education with the aim of promoting STEM learning and careers (e.g. Gumaelius et al., 2016; Walan & McEven, 2018). Studies have shown that such educational activities, different from traditional classroom teaching (e.g. competitions, outreach, explorative projects), can create and stimulate motivation, but both the immediate and long-term benefits are uncertain and hard to measure (Nielsen, 2017). Correspondingly, Dierking et al. (2003) argue that there is a need for studies on other educational activities than traditional classroom teaching. Several single studies document some effect of pupils' participation in afterschool programmes on e.g. developing pupils' social skills and excitement for learning (Afterschool Alliance, 2014; Cachaper et al., 2008). McCombs et al. (2017) and Huang et al. (2006) conclude that such programmes in general are effective on producing the primary outcomes that they are designed for—i.e. academic programmes can improve pupils' academic achievement. However, a study by Park et al. (2012) shows less effect on the academic performances for Korean pupils in grades 8 to 10, although it shows effects on social matters such as better relationship with teachers and friends. Most pupils appear to learn best by participating in authentic inquiry-based activities with problems that are relevant to them (Nielsen, 2017; Rocard et al., 2007; Stuckey et al., 2013). To address a lack of meaningfulness and authenticity in STEM teaching, it is important to connect teaching in school with contexts and problems from real life out-of-school settings and thus bridge these different learning environments (Eshach, 2007; Stocklmayer et al., 2010). Grunwald (2012, 2019) goes one step further and describes *how* educators can integrate out-of-school learning environments (e.g. public and private companies, STEM education institutions, municipalities) into formal education.

Science as one of the 'STEM disciplines' (Bybee, 2013) is among the less popular subjects in school and a science career is not appealing to most pupils in industrialised countries (Jenkins & Nelson, 2005; Sjøberg & Schreiner, 2010). Osborn and Dillon (2008, p. 8) further state that 'most students develop their interest in and attitudes towards school science before the age of 14'. A study in Denmark shows that the declining interest in science happens mainly during the ages between 11 and 15 and once it is lost, it is difficult to rekindle (Jørgensen et al., 2019). A US study quotes research stating that pupils lose their interest in science and mathematics as early as in grades 6–8 (Moskal & Skokan, 2011). However, Lykkegaard and Ulriksen (2019) document upper-secondary pupils who move 'in as well as out of STEM trajectories' (p. 1600). Nevertheless, the age around 14, and grade level below around 8 (depending on national system), seems crucial. Therefore, this paper focuses on the pupils' perspective on science competitions in green entrepreneurship for pupils just below 14 years.

In terms of "STEM", there are different approaches to integrate the specific subjects (S, T, E, M) with each other. Technology, engineering and mathematics have been introduced and integrated in science education for many years in different ways (see e.g. Bybee, 2013). Additionally, entrepreneurship education has been introduced in school teaching (European Commission, 2011, 2013; Lackéus, 2015). Nevertheless, there is a need for 'better theoretical and empirical understanding of the antecedents of entrepreneurship education' (Ruskovaara & Pihkala, 2015, p. 1) and *process-oriented methods* are useful for the pupils' learning outcome. While Ruskovaara and Pihkala (2015) focus on the teachers' background, Vossen et al. (2020) argue that there is also a need for the pupils' perspective. We agree that the pupils' perspective is very much required when combining science and environmental education with entrepreneurship. Jørgensen and Bager (2020) find entrepreneurship important for creating for instance more sustainable solutions, but they are very critical when entrepreneurship is framed to save capitalism as they perceive it as being too focused

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on more production and consumption. A critical reflection on the use of entrepreneurship education in schools is therefore needed.

Science competitions and green entrepreneurship

The purpose of science competitions is often to enhance pupils' knowledge of and interest in science and a STEM career. Other purposes are to show young people that science 'can contribute to solving the problems faced by society' (Osborn & Dillon, 2008, p. 18) or to make them better equipped to deal with the modern technological world (European Commission, 2015). Based on studies from several countries, Walan and McEwen (2018) find a 'statistical significance between students who participated in competitions and their future choice of graduate studies in science and technology' (p. 392). Gras-Velazquez et al. (2014) evaluate science competitions in ten European countries and find that after participation, the majority of pupils state that they have become better at teamwork, finding solutions, more excited about studying science, and more attracted to a scientific career. We, however, lack knowledge about science competitions within entrepreneurship and how they support pupils' interest in STEM education.

Regarding the connection between environmental interest and interest in STEM subjects, Mohaupt et al. (2017) conclude that this research area is under-exposed, but they point out that there is a potential for environmental issues to support interest in STEM education. Both Mohaupt et al. (2017) and Gupta et al. (2018) describe Environmental Education and Science Education as often disconnected. The so-called E-STEM gives the possibility of incorporating Environmental Education into STEM Education (Pitt, 2009). Thus, more study is needed on how pupils participate in and conceptualise learning activities that are different from traditional classroom teaching with a combination of E-STEM and science competition in an entrepreneurial process. As stated by Stocklmayer et al. (2010), learning as 'both a process and a product' must be investigated (p. 116).

Research question

As discussed above, little is known about the pupils' learning process and their conceptualisation on what they did and learnt when they develop a green physical product through an entrepreneurial process within science and technology education. By asking the pupils retrospectively about their experience with the process and how it affected them, we contribute to the theoretical and empirical understanding of entrepreneurship education and how it affects pupils' interest in STEM education. This paper therefore focuses on the Danish Edison competition in green entrepreneurship in 2018 (see description of Edison and the Danish education system in the section 'Case'). The age group is 6th grade pupils (12–13 years old). Based on the pupils' oral reflections on their entrepreneurial process and products after the end of the competition, the research question is: *How did the pupils, in retrospect, describe the green entrepreneurial process when developing their product, including to which extent it affected their interest in STEM education?*

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Theoretical framework of the entrepreneurial process and interest

This section consists of three subsections. First, we present a general theoretical conceptualisation of the entrepreneurship process in school education. Second, we describe entrepreneurship in science, and we include two models of the engineering design process to make up for a lack of a directly applicable process dimension in the general entrepreneurship model. We discuss how entrepreneurship in science has resemblance to an engineering design process. These three models later become the analytical framework for our analysis of the pupils' description of their entrepreneurial work. Third, we include the concept of science interest to discuss to which extent the Edison experience affects their interest in STEM education.

The entrepreneurial process in education in general

The Danish Foundation for Entrepreneurship [hereafter *Foundation*] is a non-profit organisation and the national knowledge centre for developing entrepreneurship teaching for all levels in Denmark. The Foundation (Nybye & Rasmussen, 2014) defines entrepreneurship as not solely connected with the start-up of new businesses, it also encompasses cultural and social entrepreneurship presented in a four-dimensional model for entrepreneurship education (Fig. 1):

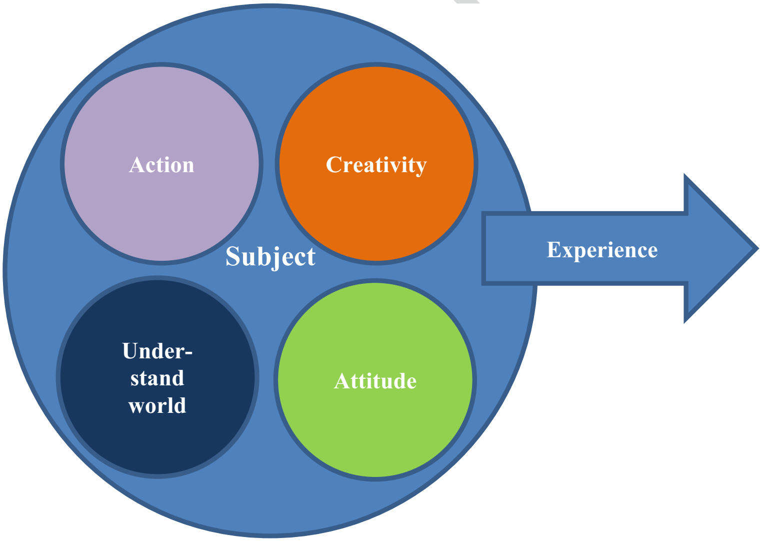

Fig. 1 Model for entrepreneurship education (Nybye & Rasmussen, 2014, p. 160). Redrawn, edited, and translated by the authors

The four dimensions, which are taught separately or in combination are:

- *Action* Value-creating initiatives and their implementation through collaboration, networking, and partnerships. The ability to communicate, organise, plan, lead activities, and analyse and manage risks.
- *Creativity* Create ideas and opportunities including the ability to combine knowledge, experience, and personal resources from different areas in new ways. Create and revise personal performances, experiment, and improvise to solve problems.
- *Understanding the outside world* Knowledge about and understanding the world, locally and globally. Likewise, the ability to analyse a context socially, culturally, and economically to create activities.
- *Personal attitude* Meet challenges and tasks and believe in being able to act in the world to realise dreams and plans. Furthermore, work persistently and overcome uncertainty and complexity as well as accept and learn from others' and own mistakes and carry out ethical reflections.

The pupils revisit entrepreneurship several times during their school life, thus gradually improving their entrepreneurship skills. Thus, the model shows a progression with a continuous repetition of the circle in Fig. 1. The Foundation's four dimensions are identical to the ones stated in the curriculum (Danish Ministry of Education, 2018a). We focus on how the pupils experience entrepreneurship for the first time.

Although the Foundation and the Danish curriculum have a clear definition of entrepreneurship, the literature on international level is in general not clear about entrepreneurship and its integration in education (Palmer & Johansson, 2018). One reason is a lack of knowledge about which types of teaching have which learning effects, and uncertainty about the purpose of such teaching (Fiet, 2001; Nybye & Rasmussen, 2014). Different actors also have different definitions. Carcamo-Solís et al. (2017), from a Mexican perspective, define entrepreneurship as:

> centred on opportunities … it represents a combination of risk, creativity, personal success, and innovation. In addition, entrepreneurship must adopt financial, moral, and social responsibility to establish a new and profitable business idea that can contribute to solving social problems (p. 292).

Some of this definition is in line with that of the Foundation and the Danish curriculum as it includes innovation and solving problems. However, it also includes, for example, financial and moral responsibility when setting up new businesses, which is not included explicitly by the Foundation, which more generally refers to 'ethical reflection' as part of the *Personal attitude*. The European Commission (2011), in line with the Foundation, applies a broader definition of entrepreneurship education:

> A process through which learners acquire a broad set of competencies [that] can bring greater individual, social and economic benefits … an individual's ability to turn ideas into action. It includes creativity, innovation, showing initiative and risk-taking, as well as the ability to plan and manage projects (p. 2).

Thus, comparing various conceptualisations internationally, we see that the European definition does not explicitly describe the learning process, whereas the learning dimension is directly stated in the Foundation's explanation of *Personal attitude* as 'learning from others' and 'one's own mistakes'. We apply the Foundation's definition due to its clear inclusion of a learning dimension. However, we notice that the Foundation's entrepreneurship model does not have a process-aspect, at least in the first learning circle illustrated in Fig. 1. We get back to this below.

Two points are worth noting here. (1) In the literature, the terms ‘skills’, ‘ability’, and ‘competence’ are often used interchangeably when discussing entrepreneurship although they are different. It is beyond the scope of this paper to discuss this in more detail. We use the term *competence* to refer to competence, skill, and ability. (2) Some definitions of entrepreneurship include innovation (Carcamo-Solís et al., 2017; European Commission, 2011), while others refer to entrepreneurship *and* innovation (Danish Ministry of Education, 2018a; Nybye & Rasmussen, 2014). Again, it is beyond the scope of this paper to go any deeper into an analysis of these terms. When we discuss entrepreneurship, we see innovation as one of its elements alongside with, for instance, creativity.

Entrepreneurship within STEM education

This section discusses the relationship between science, entrepreneurship, and engineering. The STEM-concept has multiple interpretations and the boundaries between the four subjects are ‘typically less defined in the real world than in this model’ (Lyons, 2018, p. 38). Kelley and Knowles (2016) argue for an integrated STEM subject. Most studies report positive results about entrepreneurship being integrated with science education (Deveci & Cepni, 2017) and the European Commission (2015, p. 9) states that one objective of science education is: ‘Strengthening connections and synergies between science, creativity, entrepreneurship and innovation’. Deveci and Cepni (2017, p. 127) argue that ‘scientific entrepreneurship means the process of producing innovative, science-based products based on the ability to forecast a new product that is not on the market’. Hence, we see that there are many connections between entrepreneurship and science. As stated above, the entrepreneurship model (Nybye & Rasmussen, 2014) does not have a clear process aspect. Such a process aspect is, however, very clear in various engineering design models, which we will discuss below.

The engineering design process in workplaces can be summarised as follows (Dowling et al., 2013) (see Table 1):

Table 1 Engineering in the workplace

1	Begin with a problem or a need
2	Research the problem to better understand it and define suitable criteria and constraints for the solution
3	Decide on some suitable solutions (requires creative and divergent thinking)
4	Evaluate the solutions against the criteria and constraints using available data and tools
5	Choose one or more suitable solutions
6	Make a recommendation for further action such as implementing the solution(s)

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When pupils do engineering *in school*, there are some differences to engineering in the workplace. Engineering is, however, not part of the Danish curriculum yet. Since Auener et al. (2018) developed a didactics for engineering in school science, engineering has begun being integrated in the curriculum (Engineer the future, 2020) in schools in some municipalities. The Auener-model is divided into seven steps and the model shows an iterative process going back and forth (see Table 2).

The Engineering in school didactics includes teachers' formative evaluation of pupils' learning during the process at step 7, where pupils present their product (Astra, 2020; Auener et al., 2018).

We wish to argue that the processes of engineering and the process of entrepreneurship in science have many similarities as both engineering processes require the pupils to be able to perform within the four entrepreneurial dimensions. For instance, from the perspective of the engineering models, the pupils cannot *construct* or find *solutions* (items in the engineering models) without *action*, *creativity*, *understanding the context*, or a *personal attitude* that makes it possible to deal with uncertainty (elements in the entrepreneurship model). On the other hand, the engineering processes show a structured phase-wise process which the four entrepreneurial dimensions do not. Reversely—from the perspective of the entrepreneurship model, three entrepreneurship dimensions (action, creativity, understanding the outside world) are clearly identifiable in the two engineering design models (i.e. to *research the problem* requires *actions*; you cannot *get ideas* without being *creative*; *understanding the outside world* is needed to understand customers' *needs* etc.). Without these, it would not be possible to do any engineering. However, what is made more explicit in the entrepreneurship model than in the two engineering design models is the *personal attitude* like overcome complexity and meet challenges. Without a suitable personal attitude, no entrepreneurship or engineering would take place.

The model of entrepreneurship with its four dimensions offers little help on how to design the entrepreneurial process. Here, the application of engineering design models make entrepreneurship (in science) more operational and provide a more detailed description of the pupils' entrepreneurial process. Thus, this can help both the teachers' facilitation

Table 2 Engineering in school

1. Understand the challenge or the problem Starting point: The teacher, together with the class, initiate the project. The teacher presents the challenge. Pupil groups and teachers agree on goals and frameworks for the work. The groups describe the challenges in their own words
2. Investigate Pupil groups map and acquire relevant knowledge
3. Get ideas Pupil groups develop, negotiate, and select ideas they want to move forward with
4. Concretise Pupil groups concretise, outline, and choose materials for the specific idea. They plan the further work and distribute the tasks
5. Construct Pupil groups realise their idea creating a prototype with selected materials and tools
6. Improve Pupil groups test, evaluate, and improve the prototype
7. Present Pupil groups present the solution, the design process, and decisions taken along the way. Teacher and class finish the project

and the pupils' inventing process, e. g to get ideas about how to proceed when the pupils get stuck.

Although the two engineering design models have many similarities, we see that the process of Dowling et al. (2013) is not specific about creating ideas whereas Auener et al. (2018) identify three distinct steps (investigate, get ideas, concretise). Another difference between the two models is how they begin. Dowling et al. (2013) begin with an external problem, or need from a customer, while Auener et al. (2018) start by understanding a given problem, which is also external but often a societal problem provided by the teacher to the pupils. This exemplifies a difference between engineering in the workplace and in school—problems in the latter are defined more broadly within the curriculum whereas in real life, engineers solve problems from external customers. The remaining steps are quite similar. School projects end with a presentation of the whole process, and although presentations are also part of the engineering profession, these would focus on deciding on a solution, not reporting the whole process. Table 3 gives an overview of the two engineering design models, with our interpretation of the overall steps in the column to the right.

The three models discussed in this section become our analytical tools, which is described below.

Interest

As stated in the research question, we also study if participation in Edison affected the pupils' interest in STEM. The impact of individual interest can be analysed at two different levels (Krapp & Prenzel, 2011). The first level perceives interest as a relatively stable tendency to occupy oneself with an object of interest. The second level refers to interest as a current engagement (interestedness) and describes it as a state or an ongoing process during an interest-based activity. More specifically, interests in science can be defined at either a generalised or a concrete level (Krapp & Prenzel, 2011). At the generalised level, science interest comprises the whole body of science-related subjects—at least as far as a pupil is knowledgeable in science. At the concrete level, a pupil's science interest is limited to a particular school subject or to activities within a subject domain (e.g. acquiring knowledge about micro plastic in the Ocean), a discipline

Table 3 Authors' comparison of Engineering in the workplace and Engineering in school

Engineering in the workplace	Engineering in school	Overall
- Begin with a problem or a need		Real external problem
- Research the problem to better understand it	- Understand the challenge or problem	Understand and analyse the problem
- Decide on suitable solutions. Creative and divergent thinking - Evaluate the solutions - Choose suitable solutions	- Investigate - Get ideas - Concretise - Construct - Improve	Develop creative ideas, develop solutions, evaluate, refine, and choose solution(s)
	- Present product and process	Present solution(s)
- Recommendation for further action	- Teacher evaluation of the pupils' learning	Next step in the process

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(e.g. physiology) or a research field (e.g. importance of protein for human health). Haeussler and Hoffmann (2000) develop a model particularly aimed at assessing pupils' interest in physics. They differentiate between three main dimensions of interest in a particular: (1) *topic* of physics; (2) *context* in which a physical topic is presented; and (3) *activity* within that topic. Transferred to the context of STEM education competitions within green entrepreneurship, we understand interest as: interest in (1) a special topic/theme related to the Edison competition, (2) a particular context to the topic/theme, and (3) a pupil activity related to (1). We will return to this in the analysis.

Case

Below we describe the Edison competition, the Danish education system including the teaching of science, and the chosen municipality.

The Edison competition in green entrepreneurship

The Danish Edison competition within E-STEM (environmental STEM) is an entrepreneurship competition organised by the Foundation since 2008. Edison targets pupils in grades 6 and 7 (aged 12–14 in Denmark) and its purpose is:

> to give pupils the opportunity to participate in an innovative learning *process* [emphasis added] at an early stage of their school education and possibly awaken their interest in entrepreneurship. The teaching is cross-curricular, and the pupils get the opportunity to work independently (Foundation, 2019).

The Foundation determines the overall theme each year in collaboration with the participating municipalities. Before the pupils start on their projects, the teachers participate in a one-day camp where they learn to facilitate the pupils' learning *process*. During the autumn, the pupils develop their product at school and present it at a competition where referees give marks. In 2018, the competition took place on 31 October and the theme was Green Entrepreneurship, which is a science area, but in other years, the theme has not been in science. Nationwide about 11,000 pupils participated in 2018 (of a Danish population of 5.8 million).

The Danish compulsory education system and science

Danish compulsory education starts with a pre-school class, grade 0, the calendar year the child turns 6. In 2018, Edison focused on science, which in grades 1–6 is taught in the subject 'Natural sciences/technology' (*Natur/teknologi*). The subject integrates science and technology. In grade 6, where children are 12–13 years old, the subject is allocated 60 h during the school year. After grade 6, science is divided into separate Geography, Biology, and Physics/chemistry subjects.

As part of 'Natural sciences/technology', the pupils develop competencies to work and think innovatively and entrepreneurial in relation to natural sciences and technology. A competition or a competing competence is not stated in the curriculum. Science is described as a tool with which to make decisions and action regarding the environment (Danish Ministry of Education, 2018a, b, c). This is in accordance with Schreiner and

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Sjøberg (2005), who state that science is an important subject when working on environmental issues, and for a person to be able to meet environmental challenges, it is necessary to have a general feeling of being able to influence the future of the world. Hence, Edison has the potential to prepare pupils for finding technical solutions to environmental problems, which is also in line with the curriculum.

The municipality and its schools

Rebild Municipality authorities decided in 2018 that all municipality schools should participate in Edison, which amounted to around 350 pupils. Rebild Municipality (2019b) covers an area of 628 km^2 with 29,000 people with 7500 living in the Municipal seat, 20 km from the fourth largest town in Denmark with a population of 136,000 people. In Rebild Municipality (2019a), the pupils achieve marks a little above the national average in the mandatory 9th grade school leaving exams, and the pupils' well-being in grades 4–9 are at national level.

Methods

Selection of schools and pupils

Both authors were referees at the municipality competition on 31 October 2018, representing our university. In advance of that day, we asked for permission from the organisers of Edison to contact teachers for research reasons. We got in touch with two teachers from two different schools through informal talk during the competition. The two municipality schools (pseudonyms) were:

- *Forest School* Town school with 700 pupils. Grades 0–9.
- *Valley School* Rural school with 200 pupils. Grades 0–6, then the pupils transfer to a larger municipality school.

In general, both schools get good evaluations with a high level of well-being and achievement (Rebild Municipality, 2019a). Although competitions are not part of the curriculum, they are part of the two schools' annual plans. None of the participating pupils has partaken in Edison, or other entrepreneurship competitions in school before.

We emailed both teachers, repeated the purpose of the study to ensure a clear agreement. At the same time, we asked to interview their pupils 'sometime in December'. We chose this relatively long timespan to be able to study the pupils' perceptions of the entrepreneurial process in the long-term. The two teachers made sure that our visits were approved by the school managements. Thus, the selection of schools was through convenience sampling (Robson, 2002) and the schools were two separate cases that only represented themselves. When selecting which pupils to interview, we relied on the teachers' knowledge of the pupils. We asked the teachers to identify three well-functioning groups. The number of pupils in each group ranged from 3–4, while some were absent for the interview. We also wished to talk with pupils who had disliked Edison, but these pupils did unfortunately not agree to speak with us. For that reason, as well as some practical issues with time scheduling, we did not meet all the pupils in each class. This is a limitation of the study as it would be very interesting to learn from the experience of these pupils. But we cannot force pupils to participate, and we did meet most of the pupils who had an experience of Edison that we can learn from. We did not have a gender focus, so pupils are reported without mentioning their gender to further anonymise their identity.

Interviews with teachers and pupils

We collected background information from the teachers through interviews and emails to triangulate with the pupils' explanations in the interviews. The first email contact was about two weeks before the pupil interviews in December, and we asked how they generally had worked with Edison ("Appendix 1"). The second time was during our school visits and the questions ("Appendix 2") focused in more detail on pupils' work. We emailed the interview guide for the pupils ("Appendix 3") to the teachers some days in advance to (1) make sure that the questions were appropriate, and (2) make the teachers informed. Both authors interviewed the teachers and the pupils. The interviews with the teachers were not audio taped, as they were not formal interviews; instead each author wrote a summary after the meeting, and we compared the summaries, which on all essentials were comparable. The pupil interviews were audio taped and each lasted 20–30 min. One author took the lead, while the other kept notes and asked follow-up questions. We swapped roles. The pupils were interviewed in their groups as group interviews were likely to make them less nervous and 'simulate a microcosm' (Albrecht et al., 1993, p. 59).

Analysis

The pupil interviews were analysed applying Kvale's contexts of interpretation (1996). In the 'self-understanding' context, the 'interpreter … attempts to formulate in a condensed form what the subjects themselves understand to be the meanings of their statements' (Kvale, 1996, p. 214) and thus we condensed what the pupils had said. In the 'theoretical understanding' context, 'a theoretical frame for interpreting the meaning of a statement is applied. The interpretations are then likely to go beyond the subject's self-understanding and also to exceed a commonsense understanding' (Kvale, 1996, p. 215). In the latter, we applied the three models (the entrepreneurship process and the two engineering design processes) discussed in our theoretical framework. Kvale's framework suited our purpose as it focused on understanding the pupils' reflections and understandings about their own process.

In the three sections below, we first summarise the main points from our interviews with the teachers, second, we provide the self-understanding of the entrepreneurial process of each of the six groups. Third, we apply the theoretical framework to understand pupils' process and their interest in STEM education, and furthermore discuss our findings, including the process dimension with relationship between entrepreneurship and engineering.

Main points from the teachers

The pupils spent 30–35 lessons (of 45 min) on Edison, mainly lessons taken from 'Danish' and 'Natural sciences/technology'. It was hard for the pupils to structure their time and the start-up phase was particularly frustrating. The teachers tried to prepare the pupils for this phase by, for example, telling them that they were going to be frustrated but 'you will get through it' (all such quotes are translated by the authors). The Valley School pupil worked on energy and climate in 5th grade, and it was helpful that they already had a lot of knowledge about the topic. It was difficult for the pupils that the theme was big, in the sense of being general and unmanageable and not a small task. Here we saw some differences between the two schools. At Forest School, to begin with, the pupils wanted to save the world and think globally but they needed the teachers' help to make their products doable. The teacher, however, argued that had the projects been smaller to begin with, the pupils would not have been able to go through the whole process of limiting the problem, so the frustrating start was worth it in the end. Contrary to this, at Valley School, the pupils did not think globally to begin with. Here, the teachers needed to help the pupils think of local issues that needed solving, to get started. Some pupils then began to, for instance, look at the problem of littering from a local fast-food restaurant. Later, they gradually began thinking globally. Once the pupils got on target, they worked 'full speed' and were very independent and motivated. Many were driven by the competition element. The pupils also learnt that it was important to write correct Danish when in contact with the external world and they found it interesting to speak with real people. However, the teachers also said that Edison was hard for pupils diagnosed with, for example, Asperger's and pupils with anxiety.

The groups were created differently. At Forest School, the teachers used the material from the camp to create groups of four pupils so the pupils would complement each other. This material (Foundation, n.d.) was based on Gardner's (2011) theory of multiple intelligences and the process included that the pupils argued for their strength and weaknesses. At Valley School, the pupils chose their own groups, and the teachers did not apply the material from the camp.

Many pupils from both schools involved their family members in developing their projects. However, a year later at the one-day camp for Edison 2019, we met some teachers (not from Forest or Valley schools) who told us that at their school, the pupils in 2018 did not get any help from such network.

The pupils' descriptions – in the 'context of self-understanding'

Here we summarise the self-understanding of the six groups based on the interviews. Every group is specific in its composition, process, and approach and details about their work is therefore essential to understand each group and their specific entrepreneurial design process. Those details are needed when applying the theoretical framework (see next subsection). To protect the pupils' identity, it is not revealed which pupil said what in the quotes below.

Valley school

Group 1 (V1, three pupils): Created a backpack with a solar cell to charge mobile phones. The two pupils at the interview explained that their idea came from the non-present third pupil. Other ideas had not been discussed. They identified a problem (charging mobile phones) and focused both on the aesthetics and the functionality of their product. It was difficult to find where on the backpack, solar cells got the most light: 'We thought about where the solar cells gain the most [light], and then we placed them at the top [of the backpack] … It actually looked fine' (all such quotes are translated by the authors). They used an old school bag to create a prototype. They needed help to put the solar cells together with a charger but a father (electrician) of one of their friends helped them. In terms of collaboration: 'We divided the work. One began with the bag and then we were two on the poster [for the competition] and then occasionally we needed to google a bit. … and then we swapped'. They bought real solar cells online. They had some disagreement about the layout of the poster and where to place the solar cells, nevertheless they found a solution. They helped each other when someone found something difficult. 'Towards the end, we were pressed for time – so do not be too stressed then we fall out – I have learnt this for other groups'. One of the pupils found it most exciting to see what others had done at the competition, to the other pupil it was most interesting to make their product, find the solution. In terms of doing invention in general: one was moderately exciting, but it had more to do with that it was 'not school'. The other pupil would certainly like to try something like Edison again. Interest in STEM education was not affected. In terms of future jobs, one pupil found it important to make a difference and liked Edison. The other pupil wanted to be a farmer, and Edison had not changed that. They expressed that they did not use what they learnt in Edison at school, but privately – pollution and not throwing things out—but they also thought about this before Edison.

Group 2 (V2, four pupils): Created a water mill in a downspout to create electricity for a house. They started with one idea but moved to the idea about the mill as they were not certain that the original idea would work, particularly given the timeframe. That idea came from a father of one of them. They found it very simple knowledge wise, they just needed to create the water mill, and one of the pupils had the items for this at home. Two pupils and this father spent a day building the prototype during their autumn break in this father's workshop, where the father had the idea about using a bicycle wheel. After Edison, one pupil spoke with an uncle about how to improve the mill. In terms of collaboration, they divided the work: 'Some made the poster, and others wrote what one was supposed to say [to the referees at the competition]'. Sometimes they had disagreement for instance about which items to use in the mill and which colours to put on the poster. They voted to solve the differences and agreed that it should not always be the same who compromise each time. They helped each other proactively, and they became better at collaboration – give and take: 'ask the others if there was anything they needed help with before the end of the teaching hour so that we could finish one thing at a time'. There was no time planning, but they did not feel too busy towards the end. It was easy to get ideas throughout the process. In terms of attitudes to STEM education and green entrepreneurship, they did not think that Edison changed anything since they thought about the environment before, but Edison might have reinforced it. The competition element was a motivating factor but 'The two most exciting things were to test if it [their product] was working, and to come out and see the others' products'. They would very much like to do something like Edison again – it was more fun than grammar in Danish. One pupil was particularly motived by developing something not done before, another by making the world greener. They found it to be too soon to talk about what they want to be as grownups.

Group 3 (V3, four pupils): Created protein pills to replace meat. Their overall problem was 'something about CO_2—too much in the atmosphere'. Their first idea was to make plastic bags that can be dissolved in water, but they rejected it—what if it rains? They had unsuccessfully tried out the first idea on a cup. A new idea was to put insects etc. into pills to replace meet, which would be good for vegetarians and CO_2. Insects have some of the same proteins as meet. They got the idea from the internet where they saw pills made of seaweed, but instead of seaweed they used insects, mushrooms, and algae. They argued that such pills would be good for old people who cannot chew. They found knowledge by

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asking parents, and one of their mother's found literature about CO_2 for them. They had learned about nutrition at school, but also searched more info about protein. They bought gelatine capsules and made pills. Most of the pupils were clearly willing to do something like Edison again to continue to develop their product. What some liked best about Edison was seeing what others had done, and what others thought about their product, but it was also interesting to talk about their own idea and become better informed about it. In terms of collaboration, they distributed the work, helped each other shop for mushrooms, made a logo etc. They made most things together or talked about who should do what. Through Edison they have learnt to listen to other people's ideas: 'I have learnt that if one has got a good idea and the others also have a good idea, one should remember to also look at the others' idea and see if this is better and not just dismiss it'. Concerning helping each other, one explained: 'I said what he should write, and he wrote it'. To some extent, some of their behaviour changed. One pupil had become a vegetarian and they used their mobile phones less. They did not want to pursue a career in green entrepreneurship or STEM, but they would like to read about it and perhaps do something in their free time.

Forest school

Group 1 (F1, three pupils): Created bottle lids made of bamboo. The group began with different ideas to handle the problem of plastic pollution, but proceeded with the bamboo idea since no one else worked on this. Furthermore, 'We began by visiting stores to find out if this was actually a good idea'. They made prototypes in wood but chose bamboo after they learnt that it grows quickly. The pupils worked very closely together, distributed tasks and encouraged each other. They improved their ability to cooperate (they have not worked together before) and to think differently – get ideas. Some made the lid, others researched the internet. They meet at the beginning of the day to discuss what to do. The group received help from teachers, especially when constructing a prototype using the school laboratory. They had to find a new way to screw the lid as you could not screw in bamboo—so they decided to put rubber inside the lit so it can click on. The self-chosen topics led to great commitment, even after school. The pupils emphasised that they had been allowed to develop and work on their own ideas, and they had to work in a creative way using both the brain and their hands. Interest in STEM did not appear to have been affected. One pupil, who was not very engaged in school before, had already thought about working creatively before Edison: 'I had thought I'd do something that changes something and is good for the world.' To what extent Edison has reinforced this desire is unclear. The most interesting to them was to be in the competition and do it well. They would like to do something like this again—exciting and different—get out of the classroom.

Group 2 (F2, four pupils): Created straws made of palm leaves. From the start, they knew that they wanted to work with the problem of many straws and plastic in the sea. They were very self-motivated and contacted two companies that produced products (plates etc.) made of palm leaves. They'brainstormed a lot … cut down trees … it should not be too expensive. Then we learnt that one can make cups, cutlery, plates etc. of palm leaves and then we thought, that it is also possible to make straw out of it'. One of the companies responded, and a pupil pointed out that the company treated them seriously, 'not just like children, but in the right way'. They needed teachers' help only at the very beginning. It was frustrating to be stuck but it became a good experience when they could move forward in the process. Edison taught them to collaborate and think 'out of the box', meaning, 'that we can find things ourselves so that we do not have to ask our teacher all

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the time' and 'If you are only able to work by yourself, you cannot collaborate with others'. They divided the work, some made the presentation and investigated a lot of things, others 'have been out in the city asking people what they think of our product so that it is not just what we think'. The most exciting thing was to develop their own ideas, deciding what they wanted to work with and how, and learning that they by themselves could find the answer without knowing much about it beforehand. Edison opened their eyes to being able to work with a problem or an idea that they could imagine as adults. All would clearly like to do something like Edison again.

Group 3 (F3, four pupils): Created a filter made of linen and natural rubber for a kitchen sink to catch micro plastic. The two pupils at the interview found it difficult to get ideas at first. They started with spending a lot of time on a problem about pollution with cigarette butts, but since others had the same idea, they developed an idea from an older brother (9th grade) of one of the group members. They formulated the problem as: pollution in water, more people on earth, we eat fish, but fish eat micro plastic. They divided the roles, some started to google, and others started drawing prototypes. They learned that it was good to be able to collaborate with someone they were not used to collaborate with as they would later change class, and: 'When you work with the same person all the time, you do not learn a new way of learning things. Working with an unknown person may mean learning to see things in a different way'. They gathered knowledge and investigated if someone else had already found the solution. The older brother and a father helped. The best thing about Edison was to talk about the results to the referees and to see what others had done. Co-determination and ownership of an idea were important: 'We could do what we wanted. It was MY idea, like that. It was pretty cool'. One pupil would like to participate in Edison again, the other not. Both pupils thought more about the environment and their own and others' behaviour. One pupil had a very strong career aspiration that was not changed by Edison, however:'Ever since I was little, I wanted to become a physio therapeutics, but now when one has been part of Edison, then I feel like I am sort of being opened up … taste samples'. The other pupil, who previously wanted to work in the music industry, was now thinking of working on animal protection in Africa.

The pupils' descriptions—in the 'context of the theoretical understanding'

In the 'theoretical understanding', the outset is the four dimensions in the entrepreneurial process (see Fig. 1). The two engineering design models are applied further down when we discuss how the entrepreneurial process in science can be more operational.

The four dimensions and how the pupils described the entrepreneurial process

We now go across the six groups, i.e. we discuss how the groups corresponded to the four dimensions. The groups are characterised as having 'complete' or 'partial' processes in each of the four dimensions. This conceptualisation highlights to what extent each group appears to be either more or less fully able to act according to the description of the dimensions, or if the group only did this to a lesser extent. We could also have chosen a 'not seen' category, but this was not needed for these six groups. The distinction between 'partial' and 'complete' is a qualitative judgement. We are sceptical towards applying a more fine-grained distinction as this would need even more in-depth interview. The notation V1-V3 indicates the groups from Valley School and F1-F3 refers to Forest School.

The *Action* dimension of entrepreneurship. All groups needed help in the initiating phase creating ideas for starting up the process. However, we also saw pupils being able to initiate value-creating initiatives and implement these, for instance, through contacting companies or interviewing people (F2), buying equipment on own initiative (V1, V3), visiting stores to explore options (F1), or spending a part of a vacation in a father's workshop. Several groups rejected their first idea (V2, V3, F3) after doing some investigation. The selection of the problem to be solved was sometimes made by comparison with other groups (F1, F3). Some of the problems were quite specific (V1: charge mobile phone, F2: plastic straw in the sea, F3: fish eating micro plastic) others general and vague (V3: something about CO_2 and pollution, F1: plastic pollution). One was mostly focused on the product (V2: water mill). The pupils in all groups divided the tasks among themselves, some groups specifically mentioned that they helped or encouraged each other and handle difficulties (V1, V2, V3, F1, F2, F3). In one of the groups (V3) some of the collaboration was characterised by some pupils telling other pupils what to do. Two of the three groups from Forest School (F1, F3), where the teacher had decided on the group composition, clearly stated that they had learnt to collaborate with someone they did not usually collaborate with. They were able to handle time and/or time pressure (V1, V2) and all showed their ability to implement ideas through collaboration. The most exciting thing in the Edison project was to present their prototype in front of the referees in the competition and see what others had done (V1, V2, F1, F3). Some pupils in some of the groups were also motivated by the competition element (V2, F2). Several times pupils in most groups mentioned that it was very important for them that they took the lead and that the ideas were their own (V1, V3, F1, F2, F3). Thus, it was clear that all groups were able to perform at the action dimension. The pupils also learnt a lot about collaboration and improved their ability to support each other, in line with the findings from Gras-Velaszquez et al. (2014). Although it is hard to distinguish the groups, it seems that V2 stood out as they were not focused on solving a problem, hence the verdict 'partial' in Table 4 below, and they were one of the groups being very focused on the competition element. The five other groups are more complete in their activities here, and the differences among them are minor.

The *Creativity* dimension of entrepreneurship. It was difficult for some groups to get ideas in the beginning of the process, and to get started. This step required support, which they were able to provide. They used personal contacts (often family members: V1, V2, V3, F3), the internet and teachers to find new ideas and knowledge during the process. In V1, it was even the father of a friend. One group (V3), with a very overall formulation of a problem, found an interesting product on the internet, and changed the composition and thus developed a solution with a new product. F1 changed the material for the part of a known product, and F3 developed their own construction. For F2, we saw that they were able to combine knowledge in different ways to find the answer without knowing much about it beforehand. Thus, these groups found new solutions. Thus all groups were therefore rather 'complete' in relation to creativity.

The entrepreneurship dimension, *Understanding the outside world*. We saw groups where they both had a focus on the aesthetics and the functionality of their product (V1), bought items of their own to produce their product (V3), and made an investigation of the local cultural, social, and economic context (F1, F2), one of them even asked potential customers on the street (F1). Working with green entrepreneurship made the pupils learn more about environmental problems, their dimension globally and locally, possible

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Table 4 Ability to perform in each of the four dimensions

	Actions	Creativity	Understanding outside world	Personal attitude
Valley 1	Complete	Complete	Complete	Complete
Valley 2	Partial	Complete	Partial	Complete
Valley 3	Complete	Complete	Complete	Complete
Forest 1	Complete	Complete	Complete	Complete
Forest 2	Complete	Complete	Complete	Complete
Forest 3	Complete	Complete	Complete	Complete

solutions, and own behaviour. To some pupils (V1, V2, F1), Edison has not made them think more about the environment; they already did. For other pupils, participation in Edison meant that they thought more about environmental problems and expressed that they were prepared to change behaviour (V3, F3). Hence, Edison either consolidated already learnt knowledge about the environment, or raised the knowledge of it. Thus, we again see clear understanding of the outside world in the groups, however to a somewhat a little lesser extent in V2, which is why V2 is labelled 'partial' in Table 4.

The dimension, *personal attitude* involves the ability to meet challenges, realise dreams and overcome uncertainty. All pupils found it was challenging to work on a joint project, but they overcame the challenge and worked persistently. Persistency was also seen in that some pupils, by own decision, spent their autumn vacation or free time on the Edison project (V2, F1), one group even continued to ponder about the project after Edison (V2) or expressed interest in continuing to work to improve their product or and perhaps do something in their free time in the future (V3). This indicated an impact of interest as a current engagement (interestedness) (Krapp & Prenzel, 2011). It was important to many pupils to make a difference (V1, V2, F1, F3) and realise own ideas, which conforms with Schreiner and Sjøberg (2005) who found that it is important to pupils to feel that they can influence the future. Interest in STEM was mainly not affected (V1, V2, V3, F1) except in two cases as for instance one pupil who previously wanted to work in the music industry was now thinking of working on the protection of animals and another who testified to now being 'opened up' to see other opportunities (both pupils are in F3) or more generally opened their eyes to being able to work with a problem (F2). Some were just happy to get out of the classroom (V1, V2, F1). We saw traces of science interest at the concrete level (Krapp & Prenzel, 2011) for instance how to put solar cells together with a charger (V1). The above-mentioned wish among the pupils to make a difference (in the world) was, however, on a generalised level (Krapp & Prenzel, 2011), and related to responsibility and the competence to act in a democratic society (Grunwald, 2019) within sustainability but not directly connected with science and STEM education. In the conceptualisation of Haeussler and Hoffmann (2000), we saw all three dimensions. Some pupils in some groups (V1, V2, V3, F1, F2, F3) would very much like to participate in something like Edison again while other pupils were moderately excited here (V1, F3). All groups were clearly able to work within this dimension.

Discussion of results

The four dimensions and how the pupils described the entrepreneurial process

All groups appeared to have worked rather successfully in all four entrepreneurship dimensions, although they also needed support. This is in line with English et al. (2012) where one of the conclusions of a study of 7th graders in Australia in an engineering education activity was that teachers need to scaffold pupils on various parts of the process. For this reason, Auener et al. (2018) developed a differentiated model of scaffolding pupils depending on their need of support. Some groups went directly from stating a problem to develop their product (V1, V2). This is not uncommon for novices in design: 'Students tend to skip doing research and start working on design ideas immediately, a phenomenon that frequently occurs in beginning designers' (Crismond & Adams, 2012, p. 658). The reason is that novice designers like pupils often start from their first idea and continue to pursue

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single, finalized solutions (Christensen et al., 2018; Crismond & Adams, 2012). This is called 'idea fixation' (Crismond & Adams, 2012) or 'ideation fixation' (Schut et al., 2020) and leads to poor performance in design education. According to Schut et al. (2020), pupils are often not motivated to think of other ideas than their first one, because they have not understood the possibilities of accepting and rejecting ideas, and would like to apply the work they have already done. Pupils' 'fixation on the constructed image of the final design prevents them from further developing their idea' (Shut et al., 2020, p. 956). In order to avoid fixation, the phase before creating an idea is very important. Christensen et al. (2018) suggest for middle school classes to have 'field study' before 'ideation'. In line with a problem-based perspective (Kolmos et al., 2004), the investigation of an initiating idea leads to a specific formulation of a problem that points to a solution. This process must be guided by teachers. In addition, in both the start-up and during the entrepreneurial process within science and engineering, it is essential that teachers make clear that test, acceptance or rejection of ideas are elements of a creative process. We saw various ways the groups reached agreement, one of the groups voted (V2), which is not a process based on informed arguments. Teachers should encourage discussion and decision-making based on arguments. A reason why pupils do not recognise the complex nature of design problems is, in our case, probably that they are not used to working this way, and their relatively low level of knowledge in science, and importance of context, has not yet introduced them to the complex nature of problems. In fact, we are (positively) surprised to see that many groups (V3, F1, F2, F3) by themselves were able to conduct such investigations, in grade 6. For instance, as also described above, V3 abandoned their first idea after unsuccessful trials and creatively got an idea to put insects etc. into pills to replace meet from seeing someone else making pills of seaweed. F1 made a problem analysis through visiting stores to find out if their idea was good. Also, F3 made a problem analysis when they researched if others had already found the solution they were developing. F2 made a needs assessment when they went out in the city to ask people what they thought about their product idea. These investigations correspond to elements in the engineering processes illustrated in Table 3, for instance investigation, get ideas, refine, and improve. A limitation of the study is that we focus on the pupils' perspective and, although we interviewed the teachers, we may not have enough knowledge of e.g. the teachers' guidance (scaffolding) in knowledge acquisition and methodical procedure as well as how to create ideas.

The relationship between engineering and entrepreneurship

The four dimensions do not stipulate a certain procedure and are less specific than the phases in the engineering design models, hence the teachers and pupils receive less help getting started from the four-dimension model. An engineering or entrepreneurial process never consists of discrete steps where one step is completed before the next is begun. This is also seen in how the pupils worked as they, for instance, start over after attempting one plan. However, the stage-models of the engineering design processes seem to be reflected in the order of things explained by the pupils. All groups start with a theme, or relatively overall problem, researched, got ideas, constructed a solution, and refined it. Item 6 from Dowling et al. (2013) is not seen in any of the pupils' explanations, obviously because it is a school project. Levels 1–2 from Dowling et al. (2013) are less visible in the interviews, perhaps because green entrepreneurship has already been advanced as the answer to environmental problems. The model of Auener et al. (2018) suits the pupils' description very well even though this is an engineering design model, not an entrepreneurship model. In real life activities, these processes might be quite similar. All groups work within the four entrepreneurship dimensions and all, except one group, within the seven steps of school engineering, see Table 5.

Table 5 below declares that V1 and V2 have a 'brief' step 1–2 as they go almost directly from idea to development of product; i.e. they had an idea fixation. F2 is also different as they did not create their product in palm leaves, they merely *planned* how to do it. Hence steps 4–5 in workplace engineering and 5–6 in school engineering are lacking.

The fact that different groups 'fell out' at different times in the three columns representing the engineering processes and the entrepreneurship dimension, underlines the need for all three models in describing how the pupils has worked in Edison.

However, the overall picture is that the groups are fairly similar and they all perform more or less well at all the steps and dimensions described by the three models. Can we therefore argue that the processes of engineering design and entrepreneurship in science are basically identical? Is entrepreneurship in science so like engineering design that it would be extremely hard to make a distinction between two groups of pupils doing one of each? Another thing that engineering and entrepreneurship have in common is that none of the processes exist by themselves, they are all processes that act on something else. For instance, in Edison, the pupils employ entrepreneurship in an area of science, but it is perfectly possible to do science without being entrepreneurial. We wish to contend that one cannot be entrepreneurial in science without in fact do engineering.

An observation is important here: We speak of entrepreneurship *in science*, not entrepreneurship in other topics such as social science. In fact, the Edison competition for 2019 had the theme 'Valuable Communities' and focused on social community solutions. Thus, in 2019, the pupils were not supposed to be entrepreneurial applying science, but to be entrepreneurial applying social science. The four-dimensional entrepreneurship model is universal and is meant to cover all subjects. One might argue that a model specifically designed to show entrepreneurship in science would be able to catch more differences between engineering and entrepreneurship in science.

It is worth noting that neither the pupils nor the teachers had received any explicit instructions on engineering design. Hence, when discussing engineering design, it is our interpretation that entrepreneurship in science has many similarities to engineering design.

Interest in STEM

In terms of interest, we the pupils' interest in STEM education did not appear to have been affected and the competition element was a main motivation for many pupils. But this does not mean that interest in science was absent. We saw interest in science at a concrete level (Krapp & Prenzel, 2011) and the pupils became 'interested' in for instance the science in Edison, not due to the science in itself, but due to other factors, e.g. the competition element, the fact that it was 'not school', they could make a difference etc. We also wish to argue that the fact that many groups involved their family testifies to the level of interest involved in creating the products. Perhaps one can argue that the interest shown by the family to being willing to help the pupils reinforced the interest they already had.

Generalisability

The two schools represent two different cases. Both schools get good evaluations and the pupils are generally thriving. One difference is that pupils at the town school (Forest

Table 5 How the groups worked on entrepreneurship and engineering design. The column concerning the entrepreneurship dimensions is a summary of Table 4

	Entrepreneurship dimensions	Workplace engineering – 6 steps	School engineering – 7 steps
Valley 1	All 4	1–2 (brief), 3–5	All 7
Valley 2	Action and outside world ’partial’	1–2 (brief), 3–5	All 7
Valley 3	All 4	1–5	All 7
Forest 1	All 4	1–5	All 7
Forest 2	All 4	1–3	1–4, 7
Forest 3	All 4	1–5	All 7

School) were initially more inclined to look at global issues while the pupils in the rural school (Valley School) needed more help. We cannot judge to what extent this was a coincidence or something generally about town versus rural schools. Also, the fact that we term one of the schools a town school, is a relative term as the population in the town is 7500. Many countries have towns with populations that are 100–1000 times higher. However, we saw that Edison required competence in global thinking, which is not easy for all grade 6 pupils.

Is Edison beneficial for all pupils? As stated above, we only had access to pupils who were relatively successful in Edison. Some pupils clearly preferred the 'normal school'. However, we also saw clear evidence of several pupils being motivated by Edison being 'not school'. Pupils are different. Perhaps it is unrealistic to aim at education activities that will reach each pupil. Edison is clearly not an activity that suit every pupil; however, Edison is clearly an activity that suits a lot of pupils.

Conclusion

The pupils were quite articulate about the process leading up to the development of the Edison product. All six groups but one, acted in alignment with the four dimensions (action, creativity, understanding the outside world, personal attitude; see Fig. 1) and they also mostly went through the engineering design processes such as finding a real problem, understanding it, develop ideas and solutions and refine these, and finally present these at the competition (see Tables 1, 2, 3). The pupils had no prior knowledge of these formal models, but their explanations can be interpreted in support of these.

However, we also learnt from the pupils' respective description, that it was hard for some of them to start the process. Often it seemed that they quickly picked a theme and immediately started working with the solution—the development of their product. The reason was a too vaguely formulated environmental problem and eagerness to develop the product. We therefore conclude that in order for educational activities aimed at teaching pupils entrepreneurial, it is not sufficient to demand that the pupils express a problem in a few words, longer formulations and justifications should be required from the pupils as this would necessitate that they spend more time on this phase and are more specific.

Working with the Edison competition was, according to the teachers, hard to many pupils, particularly the lack of structure. The teachers need to scaffold in relation to pupils' abilities in the dimensions illustrated in the model for entrepreneurship education (Nybye & Rasmussen, 2014), on their abilities for action, creativity, understanding the outside world, and personal attitude. Some pupils, i.e. those with various diagnosis even need extra help managing projects like Edison. This research shows that pupils could benefit from a structured entrepreneurial process within science with help of an engineering design procedure (Table 3). Such structure could help the pupils maintain an overview of their work and it could help teachers scaffold the pupils learning process.

Independence and being able to determine their own product was emphasised by many pupils as essential. For example, many pupils wished to further develop their product even after Edison had finished. It would be interesting to have educational activities that stipulate that pupils after a competition, or other presentation of their work, are asked to go back and revise/revisit their work. In this sense, the competition/presentation become more like a formative assessment. This is also in line with how engineers and entrepreneurs work – where projects are presented for feedback at various milestones.

Edison did not contribute to enhance pupils' interest in science, however, some of the pupils, even relatively long after Edison, had an increased interest in entrepreneurship, make a difference, make inventions, and environmental issues, but not STEM or a STEM career. This is a contradiction and need further research. A recommendation might be to have STEM education more embedded in a social science and humanistic context, which is in line with the recommendation from Sjøberg and Schreiner (2010) who write about the need to "humanize" school science. Most of the pupils profoundly enjoyed being part of Edison. They had a good experience with entrepreneurship in science, and also indirectly with engineering design as these processes are quite similar. It merits further study to investigate the relationship between entrepreneurship in science and engineering design. However, initiatives such as Edison, have the potential to attract pupils to STEM education.

It was interesting to see that the pupils also included other actors than those originally scheduled as part of Edison, namely their families. The pupils thus include the informal learning environment. It seems that without these resources, their projects would not have been as successful as they were. In this light, we can perhaps conclude that Edison did not only reach, and teach the pupils, about green entrepreneurship, but it reached a whole community. All pupils were from schools with a high level of well-being and achievement and a resourceful network that was included and provided informal learning. How pupils in less resourceful networks would cope with a competition such as Edison also merits a further study.

Potential next steps could go in several ways. One could be a long-term study of some or all the pupils we report on in this paper. For instance, do the pupils actually use their mobile phones less (as they foresaw), do they keep informed about environmental issues, what education do they chose, and how would they later look back at their Edison participation? Another route could be more theoretical where the combination of engineering design and entrepreneurship is further developed, and models combining these presented to teachers and tried out at pupils. A third route could be a further investigation of the competition element. Many pupils testified to the competition element as the driving force while others revealed that the fact that they could make a difference in the world was the driving force. Finally, the relation to interest in STEM, including E-STEM is essential for future youth in terms of the need for innovation in STEM.

Appendix 1: Questions emailed to the teachers before the meetings

About the work with Edison

- How was it organised in class before the competition? When did you begin and how many hours did the class spent on developing the concept and their solution?
- Which subjects were involved besides natural sciences/technology?
- Did the class participate in the one-day camp described on the website?

Practical matters

- We would like to speak with three groups of pupils. Can you select these for us? If possible, one high achieving group and two medium achieving groups with a mix of boys and girls.

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- Can you shortly describe what the groups worked with?
- Would it be possible to see some of their material when we come?

Appendix 2: Questions to the teachers when meeting them at the schools

The subjects and the process

- How did the subjects collaborate during the process?
- Has the teaching of the subjects changed after Edison?
- How did the groups find their ideas? Did they have a problem statement?
- How much do they remember later?
- Can we see their material?

Attitudes

- How did the pupils feel about having to be inventors?
- Is the subject Green entrepreneurship suitable to create interest in STEM?

Appendix 3: Interview guide for the pupils

Subject and processes

- What did you make for Edison?
- Which ideas did you have to begin with?
- How did you select the idea you ended up with?
- What was your final problem formulation?
- What was the content of the idea subject-wise?
- How did you investigate your problem?
- How did you find information?
- How did you use other subjects than natural sciences/technology?
- How did you distribute the work within the group?
- How did you help each other?
- Who else helped you?
- What surprises did you experience? Things that did not work as anticipated.
- How much do you remember of the knowledge you used in Edison?
- How do you use what you learnt in Edison in your learning now?

Attitudes

- What was the most exiting?
- What is the most important thing that you learnt about green entrepreneurship and sustainability?
- How did participation in Edison affect your interest in environmental issues?
- Would you like to try something like Edison again?

- Would you like to work with environmental issues or other natural sciences/technology things when you grow up?
- Would you like to design your own investigations, models and products when you get a job?
- When is a person creative? Which school-subject does this belong to?

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