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Perceptions of STEM-based outreach learning activities in secondary education

J. Vennix[1] · P. den Brok[1] · R. Taconis[1]

Abstract We investigated and compared the learning environment perceptions of students, teachers and guides who participated in Science, Technology, Engineering and Mathematics (STEM)-based outreach activities in secondary education. In outreach activities, schools and teachers work together with companies and other external institutions in learning activities in order to motivate students for the STEM domain. In this study, we identified characteristics of outreach activities that explain variance in perceptions of students. Data were gathered from 729 high-school students as well as 35 teachers and guides in 12 activities both in the US and the Netherlands. A questionnaire was used to asses outreach activities based on subscales from validated questionnaires such as the What Is Happening In this Classroom, Constructivist Learning Environments Survey, Classroom Environment Scale and the Learning Climate Questionnaire. Teachers' perceptions were more positive than students' perceptions for most scales, while guides perceived the outreach learning environment in almost the same way as students. Student perceptions were very positive for outreach activities. Outreach activity characteristics such as teaching method and emphasis were found to be the most important factors in explaining variance in students' perceptions between activities. Long-term problem-based activities and the perspective of new views of science and scientists were perceived as providing the most positive learning environments. Additionally, outreach learning environments can create opportunities to increase students' motivation in STEM.

Keywords Outreach learning activities · Secondary education · STEM · Student perceptions

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Introduction

In today's society, knowledge and information are emphasised more and more. Knowledge is more specialised and is expanding, and information and communication technology influence the way of working and communicating (Binckly et al. 2012). As a consequence, workers in the STEM field need new knowledge and skills, such as flexibility, multidisciplinary problem-solving, teamwork and communication (e.g. so-called twenty-first century skills; Partnership for 21st Century Skills 2009; Voogt and Roblin 2010). In response to these developments, STEM education in several countries is changing as well. First, education is being changed by putting an emphasis on the promotion of positive attitudes towards STEM and by efforts to increase the number of students choosing STEM courses and careers in several countries (Bettinger 2010; Krapp and Prenzel 2011; OECD 2006). Second, more emphasis is given to twenty-first century skills that emphasise the connection of classroom knowledge with the outside world (Krapp and Prenzel 2011). In order to meet these new demands, it is not only necessary to keep students motivated, but also to *increase* motivation for STEM among groups of students who usually do not choose STEM (Angell et al. 2003; Atkinson and Mayo 2010; Binckly et al. 2012). In the current study, we proposed outreach as a possible means to achieve this.

What many contemporary STEM courses share is an attempt to intertwine contexts from real life with those in schools. Colleges and universities have developed several activities to bridge the gap between high schools and higher education during the last decades (Jeffers et al. 2004; Markowitz 2004; Poole et al. 1999). These activities include the development of web-based materials, summer science programs in which students experience authentic science investigations and student workshops in summer schools with hands-on activities. More recently, the industrial and corporate world joined with educational institutes in developing both in-field and in-school activities. This serves to increase student motivation for choosing STEM by connecting textbook theory with 'real' life science.

A particular and increasingly popular type of activity that has been developed is outreach. The general definition of outreach according to the Merriam-Webster dictionary is "the activity or process of bringing information or services to people". In STEM education, the activity is performed by employees of STEM-based companies (either private or public), the information or services are educational STEM-based activities related to the STEM-based company, and the people are K–12 students and their teachers. In the literature, outreach refers to activities whose main objective is to promote awareness of STEM in real life and to make a contribution to STEM education to motivate learners (Jeffers et al. 2004). More awareness of STEM in real life will increase motivation for STEM and choosing STEM in the future (Lee and Erdogan 2007; van Griethuijsen et al. 2015). To increase the motivation for and relevance of STEM education, twenty-first century skills, such as hands-on activities, small-scale activities and working together are often mentioned in research (Deci and Ryan 1985; Kelly 2011).

Within this broad definition, a diversity of outreach activities towards STEM education is possible. We refer to outreach by using the word 'activity' because most outreach refers to relatively short interventions as an addition to the regular STEM education. Examples of outreach activities are: guest lessons by experts from research institutes (either public or private); an industrial laboratory inviting students to its work environment to show and teach them their way of working, or assignments that are developed by experts from

industry, are executed with the students' teacher, and are real problems that have to be resolved within their company.

This widespread and active participation of the industry in education is a relatively new development. In the Netherlands, a 'youth and technology network' (Jet-Net) has been launched so that STEM industries can work with high schools to create activities that show how high-school science (STEM) is applicable from a student's perspective in the world (Jet-Net Policy Beleidskader 2011–2016 2011). In 2012, the Jet-Net Model has been launched in Denmark as well. In the US, Project Lead the Way, New Tech high schools and the pTech program are the largest examples of industrial collaboration for integrating school science and real world science (Tai 2012; Tech Valley High; Tucker 2008).

By adding outreach, the learning environment of the regular classroom is extended with new elements via the unique collaboration with the industry and higher education. As a result of the involvement of the corporate world, outreach adds real-life components and incorporate twenty-first century skills such as multi-disciplinary tasks, team work, problem solving and critical thinking (Laursen et al. 2007). Guides who participate in outreach are supposed to motivate students about the joys and possibilities of STEM (Poole et al. 1999). In general, guides hold a Master or PhD degree in STEM, but do not have a teacher education certificate, because their daily work is about research, engineering and sometimes management.

The new elements in the outreach learning environments often concern learning outside school and a more informal way of learning. This means an environment that is outside school and free of choice, where learning takes place unconsciously (Rennie 2007). Jarman (2005) distinguished informal environments in free-of-choice and open settings, on the one hand, and more-structured settings with a desired outcome on the other. This last approach applies to activities with higher education and the industry.

Outreach activities deviate from in-school courses not only by the unique participation of a guide from industry and content supplement to the curriculum, but in certain activities also by the addition of an industrial environment. This last element can increase learning by adding a physical and place-based learning environment where students feel at ease (Zandvliet 2014).

Although successful outreach activities, such as Mutual Benefit Partnerships (MBPs, Bouillion and Gomez 2001), are described in the literature, a more quantitative description and evaluation of the outreach learning environments is relatively absent in the literature (Cooper et al. 2010; MacLeish et al. 2012). Despite the recommendations to add these kinds of activities to the curriculum to motivate students for STEM, little research has been undertaken on outreach and role of industry in these (Angell et al. 2003; Lyons 2006; Piburn and Baker 1993). In addition, because there are different roles for and backgrounds of teachers and guides, it is interesting to address the differences in perceptions of activities between both these parties. In addition, it could be interesting to compare the perceptions of teachers and guides with those of students, because is it known that teachers generally perceive their environment more positively than students (Trickett and Moos 2002; Wahyudi and Treagust 2003). However, whether this also applies to external guides is unknown.

From an educational perspective, outreach activities create a different learning environment from those present in regular classes. In this study, we assessed these new learning environments and address the characteristics that lead to more positive perceptions of these environments. Therefore, the main research question addressed in this study was: *What characteristics of outreach activities are associated with more positive perceptions of STEM-based learning environments?*

Theoretical framework

Learning environments researchers attempt to describe the educational context and to identify relationships between content, teaching practices and environmental variables (Fraser 2007). From learning environments research, there is evidence that perceptions of the learning environment are linked to student outcomes such as attitudes, interest and cognition (Baeten et al. 2013; Dorman 2001; Kingir et al. 2013; Ogbuehi and Fraser 2007).

In science learning environments research, several dimensions have been proposed to describe the orientation of the learning environment and the effects on the attitude towards science and interest. Moos (1980) distinguished three dimensions that characterize the learning environment: relationship, personal growth, and system maintenance and change. The relationship dimension refers to the relationship domain and assesses the extent to which students are involved in the social and physical setting. The personal growth dimension refers to opportunities for personal development. The system maintenance and change dimension refers to the extent to which the environment is orderly, is clear in it expectations and responds to change. The assumption is that, when all three dimensions are emphasised, both social and academic outcomes are facilitated. Too strong a focus on one dimension can have negative effects on student outcomes (Moos 1980). Most of the learning environment questionnaires constructed in the past cover all three dimensions as suggested by Moos (Fraser 2007).

The main objective of outreach learning environments is to motivate students for STEM. Motivational research proposes that intrinsic motivation is related to three dimensions or types of needs that should be met via the learning environment. The first dimension is the need for autonomy and refers to the extent to which students feel volitional in their decision to engage in academic activities (Deci and Ryan 1987; Ratelle and Duchesne 2014). The second dimension is the need for competence and refers to the extent to which students understand and have the relevant skills to succeed (Deci and Ryan 2000). The third dimension is the need for relatedness and refers to the need to establish significant and satisfying relationships with other students (Baumeister and Leary 1995). When needs relatedness, competence and autonomy are all equally and to a sufficient degree present, students are more intrinsically motivated. Intrinsically motivated students have a positive attitude towards STEM courses and are more likely to choose STEM in the future (Eccles 1983; Meece 1990).

There is conceptual overlap between the dimensions proposed by Moos (1980) and the dimensions conceptualised in (intrinsic) motivation research, as is shown in Table 1. Relatedness and relationship overlap: both dimensions focus on interaction with the social environment. The relationship dimension focuses also on involvement with the physical setting of the environment, and the need for competence covers the relation between student and content. Competence and personal growth are related: the need for understanding and having the skills to succeed are important for personal growth. Personal

Table 1 Moos' and motivation dimensions

Moos dimension	Motivation dimension
Relationship	Relatedness Competence
Personal growth	Competence Autonomy
System maintenance and change	Autonomy

growth is supported by feelings of autonomy. An environment that is orderly and clear in its expectations and is able to respond to changes is important for autonomy as well. In addition, both assumptions focus on the enhancement of positive student outcomes such as motivation and achievement and argue for a balance in emphasising the dimensions by creating a stimulating environment.

In the learning environment, satisfaction of the basic motivational dimensions (autonomy, competence and relatedness) can be supported through teacher behaviour, activities and educational material. A teacher can enhance the autonomy of a student through exercising less control and through allowing more ways to complete a task. Whenever the purpose of a task becomes meaningful to a student, it contributes to the autonomy of that student (Assor et al. 2002; Reeve and Jang 2006). Feelings of competence can be stimulated through setting challenging and suitable goals, while providing informative feedback. This makes students feel empowered and gives them the confidence to explore alternative possibilities (Boggiano and Ruble 1979; Deci 1971). Commitment strengthens even further when the teacher or task installs a sense of respect in the student by, for example, expressing admiration or giving examples with which the student identifies. The teacher then serves as a role model (Sjaastad 2012): the relatedness need is then fulfilled.

Because the emphases of outreach activities are the use of real-life connection, guidance from a person outside school and a different learning context, we have to address these emphases in assessing the outreach learning environment. Therefore we included in this study the following concepts from prior learning environments studies that have addressed those elements: personal relevance, real-world connection, uncertainty, cohesiveness, involvement, innovation, teacher support and autonomy. The outreach learning environment has a unique and innovative way of connecting real-world applications and industrial environments with the school environment to enhance the personal relevance of STEM for students. Because a main objective of outreach is to motivate students for STEM by showing them the STEM world outside school, relevance for students and real-world connection are expected to be an important part of the learning environment.

Personal relevance refers to the extent to which school science is relevant to students' everyday out-of-school experience. As is mentioned in the informal learning literature, out-of-school learning is different from regular school science in the sense that real-world science has more uncontrollable variables than school science; everyday science can be characterised by conflicts and uncertainty (e.g. climate); and social and cultural aspects influence interpretations of scientific knowledge (Rennie 2007). *Uncertainty* refers to the extent to which opportunities are provided for students to experience that scientific knowledge is evolving and culturally and socially determined. Outreach activities involve active learning as a model of the real world, such as hands-on, teamwork and project based learning, supported by a teacher or guide: students experience a learning environment where they have to make their own choices about how to solve a problem. In addition, the presence of a guide has a different interaction with students. Therefore, in outreach activities, students experience a less-controlled environment and thus more *autonomy*.

Because students experience a different person (guide) and setting of the content, the psychosocial aspects within the group dynamics and how students are supportive to one another (*cohesiveness*) and the interest in participation in discussions and enjoyment of the activity (*involvement*) are important aspects as well. In addition, the teachers' role is important for guiding the students in the outreach learning environment. *Teacher support* refers to the extent to which the teacher helps, befriends, trusts and is interested in students.

Third, the content is a context delivered by industry or a higher education institute. Because there is a diversity of approaches, this context can be either the company

environment or a certain product that is shown or worked with, and it can be used either as a starting point for the development of (scientific) ideas about STEM or used as a connection with the science topic taught in the regular classroom. The content of the real-life applications gives the students the opportunity to build their new knowledge by using their existing knowledge. Subjects can be strongly related to school science, strongly related to a community problem or based on a technological application. Therefore, this *innovative* aspect, the extent to which new or unusual activities, assignments or teaching methods are employed by the teacher or guide, needs to be addressed.

To assess students' and teachers' perceptions of the learning environment, a variety of widely-applicable questionnaires have been developed and validated in the last decades. Examples include the What Is Happening In this Class? (WIHIC, Fraser et al. 1996) questionnaire, Constructivist Learning Environment Scale (CLES, Taylor et al. 1995) and Classroom Environment Scale (CES, Fisher and Fraser 1983). More recently, in learning environments with an emphasis on motivation, the Learning Climate Questionnaire (LCQ, Deci and Ryan 2000) has been used. These instruments are related to the abovementioned concepts in the following way: teacher support, student cohesiveness and involvement have been operationalised in the WIHIC, personal relevance and uncertainty with the CLES; innovation with the CES; and autonomy support with the LCQ.

Prior learning environments research

In this section, we review perceptions of regular science courses as assessed by these instruments. To compare perceptions, we transferred scores in these instruments to a 5-point scale. We refer to scores between 2.8 and 3.2 as neutral perceptions, scores below 2.8 as negative perceptions and scores above 3.2 as positive perceptions.

Some researchers have investigated students' perceptions of science classroom environments using the WIHIC. In general, the WIHIC scale of Cohesiveness was perceived positively in all studies. Both Teacher Support and Involvement perceptions varied between slightly negative and positive.

Turkish biology students perceived their teacher support as negative, whereas other scales such as cohesiveness and involvement were perceived as neutral to slightly positive (den Brok et al. 2010). In Korea, the perceptions of 8th grade students of both cohesiveness and involvement were positive. Teacher support was perceived as neutral (Kim et al. 2000). Students, both 8th and 10th graders, were very positive about teacher support and cohesiveness. The students perceived involvement as neutral (Helding and Fraser 2013). Science students in both Hawaii and Indonesia had similar perceptions of both cohesiveness and involvement (Singh and MacNeil 2014). In Indonesia, 9th grade students perceived their science course positively for cohesiveness and slightly negatively for teacher support and involvement. Teachers' perceptions of those scales in the same study were more positive for both cohesiveness and especially for teacher support. Both teachers and students perceived involvement in the same (Wahyudi and Treagust 2003). In the US, a similar pattern was found for the perceptions of 8th grade science students. Cohesiveness was perceived positively, and teacher support and involvement were perceived slightly negatively (Wolf and Fraser 2008).

The CLES questionnaire assesses personal relevance and uncertainty and these scales seem to be relevant for our study. In general, personal relevance was perceived as neutral to very positive, uncertainty perceptions varied between neutral and slightly positive. Science students perceived personal relevance as slightly positive and uncertainty as negative (Nix et al. 2005). Mathematics students (8th grade) perceived personal relevance

as neutral (Dorman 2001; Ogbuehi and Fraser 2007). In Turkey, 8th grade science students and in South Africa 9th grade science students perceived personal relevance and uncertainty as positive (Kingir et al. 2013; Luckay and Laughksch 2015). Other 8th grade science students in Turkey perceived personal relevance as positive and uncertainty as neutral (Ozcal et al. 2009).

The CES has a scale that assess the perception of innovation in the learning environment. In science classrooms, innovation was perceived as neutral to slightly positive (Fraser and Fisher 1982; Trickett and Moos 2002).

Although autonomy support in learning environmental research has not been reported as widely as the other questionnaires scales, in some studies, autonomy support varied between negative and slightly positive values. In Canada, 10th grade science students' perception of autonomy support was measured with the learning climate questionnaire (LCQ). The average perceived autonomy was negative, with a wide variance. When students perceived high supported autonomy by the teacher, students felt competent to work on their science course (Lavigne et al. 2007). In the US, the LCQ was used to assess the perceived autonomy support of college students attending an organic chemistry course. Autonomy support was neutral to slightly positive (Black and Deci 2000).

Research questions

To answer the main question in this study the following more specific questions were investigated:

1. What are students' perceptions of the STEM-outreach learning environment across different activities?
2. What differences exist between students', teachers' and external guides' perceptions of the outreach learning environment?
3. What characteristics of outreach activities can be identified to explain variance in perceptions between these activities?

Methods

Sample

The participants were 729 students (grades 7–11) from 12 different outreach activities that were conducted with 35 different schools, 15 companies, 13 teachers and 22 guides. The companies enabled the guides to work with schools on a voluntary basis. Most guides were experienced in working with students because they were involved with the development and implementation of the activities. Guides who participated in guest lessons had a short didactical course. Of these outreach activities, two activities were located in the US and nine activities in the Netherlands.

In the study, there were 319 girls (43.8 %) and 409 boys (56.1 %), while gender was unknown for one (0.1 %) student. The group of teachers and guides consisted of 35 participants, with 27 males (77.1 %), 7 females (20.0 %) and 1 person (2.9 %) giving no indication of gender. The grade level distribution across all activities was as follows: 3.2 % of the students were in grade 7, 37.8 % in grade 8, 30.9 % in grade 9, 5.7 % in grade 10 and 22.3 % in grade 11. The outreach activity sizes varied from 19 to 109 students, with an average of 60 students per activity.

Activities

A variety of outreach activities were assessed in this study. Activities differed much in teaching method (lectures and workshops), duration (from one lesson to multiple days), location (in-school, out-of-school and a combination of both), emphasis (enhancing interest, enhancing understanding of science, or new views of science and scientists) and subject (science content or a societal problem). Because some of the longer projects took much time and had sufficient overlap with the curriculum, teachers decided to replace parts of the curriculum by the activity. Table 2 give an overview of the different activities included in this study and describes them briefly in terms of the main characteristics used in the analysis.

Instrumentation

To asses perceptions of the outreach learning environment, we created a questionnaire based on the WIHIC (Fraser et al. 1996), CLES (Taylor et al. 1995), CES (Fisher and Fraser 1983) and the LCQ scale (Deci and Ryan 2000). For our questionnaire, we used scales suited for the outreach learning environment and with an emphasis on the motivational dimensions; see also the theoretical framework and Table 3 for this overview and sample items. All scales used a five-point Likert response scale ranging from (1) strongly disagree to (5) strongly agree. The questionnaire was completed by students, teachers and guides.

To investigate the validity of the questionnaire, several analyses were undertaken. The Cronbach's alpha coefficient, indicating scale reliability, ranged between 0.67 (for innovation) and 0.91 (for autonomy) for different scales. Thus, the scales displayed satisfactory internal consistency (Field 2013; Nunnally and Bernstein 1994).

Also, correlations between the scales were computed (Table 4) to see whether they assessed distinctively different aspects of the learning environment. Correlations ranged between 0.21 and 0.67. Some scales showed some overlap, particularly teacher support and involvement (0.65), involvement and innovation (0.59) and involvement and autonomy (0.67). However, the correlations were sufficiently low to indicate that the scales seemed to measure distinct aspects (de Jong and Westerhof 2001). Therefore, the instrument was deemed suitable for conducting further analyses.

Based on the activity descriptions in Table 2, the activity characteristics that we used for the factorial ANOVA (to answer the last research question) are summarised in Table 5. Also, gender was used as a student characteristic covariate in the analysis.

Analysis

To answer the first research question, the means and standard deviations for all the scales were computed for the entire sample of students. To answer the second research question, the means and standard deviations of all the scales were computed for the sample obtained from teachers and guides. These means were compared with the student results from an ANOVA with respondent type (student vs. teacher vs. guide) as the explanatory variable.

To answer the last research question, mean scale scores for activities that were most different were graphed. Also, an ANOVA was used to compare the activities and examine at the percentages of variance at the level of the activities. In these analyses, characteristics of activities as shown in Tables 2 and 5 were included as independent variables and a

Table 2 Names and descriptions of assessed outreach activities

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
	Students	Schools	Companies						
1 'Guest-lesson' LCD (NL)	157	5	1	Lecture with an added experiment	In-school	8/11	A company application of technology	Giving students a perspective of STEM outside school	No
The liquid crystal display (LCD) guest-lesson is about the working and application of LCD's. Students make their own simple LCD and test it. Although the content is not part of the curriculum, teachers are able to intertwine the content with the curriculum. The lesson is based on the expertise of the guest teachers' company. Students are able to work with material provided by the company									
2 'Guest-lesson' relativity and chaos (NL)	31	1	1	Lecture	In-school	11/12	Scientific	Increasing students' understanding of scientific contexts	No
This lesson was a lecture1 (100 min) and was executed by University scientists as part of a start for senior students' orientation for their final graduation project. The content was beyond the curriculum. Scientists were visiting the high school. The content was based on University courses about relativity and chaos									
3 'Guest-lesson' medical imaging (NL)	19	1	1	Lecture and tour	Out of school	10/11	A company application of technology	Giving students a perspective of STEM outside school	No
Students were visiting a health tech campus for a lecture about medical imaging techniques such as magnetic resonance imaging (MRI) and X-ray imaging. A tour-guide showed them real equipment and the possibilities with the equipment									

Table 2 continued

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
	Students	Schools	Companies						
4 'Make the match' (NL)	109	1	2	Students worked in groups over a period of 6 weeks, 4 h per week on this project	In-school and out of school to meet with experts	8	Developing and produce a prototype for elderly and disabled people to connect the school science with the community	The project is started to enhance interest and engagement in STEM	No

As this project based activity took several weeks, the teachers decided to use the project as part of the curriculum. Assignments are formulated by the local STEM-based companies, such as solutions for redesigning the railway station, taking into account the accessibility for disabled people, and designing a dishwasher for elderly people. Students worked in groups of 4–6 students. The customer (i.e. the STEM-based company) will probably use parts of the solutions the students came up with. The students have accountability to the STEM-based companies. This project was developed to make a match between students and their local community

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
5 'MRI-project' (US)	22	3	1	Students worked in groups over a period of 4 weeks, 5 h per week on this project	In-school and out of school for a field trip	11	Developing a technical solution	Showing new views of science and scientists	No

This project based activity was used in the twenty-first century academy of a local high school. Students worked in groups. Assignments were formulated by a local MRI factory. A factory tour, expert visits were part of the activity. The best technical and cheapest solution for a tool that determines the center of a magnetic field within 1 mm precise will be used. The students have accountability to the MRI-factory

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
6 'MRI-health-project' (US)	28	1	1	Students worked in groups over a period of 4 weeks, 5 h per week on this project	In-school and out of school for a field trip and video-taping	11	Developing a brochure or video for a STEM-based company to inform young adults	Showing new views of science and scientists	No

As part of the pTech program, students had an assignment from a local health teach company. They had to either make a folder or a short video to inform their peers about MRI, how it works, what kind of information you can get out of a scan and the procedure. As part of the US–health system, people can ask about a certain procedure when you are informed about an application. This assignment was designed to increase the awareness of students about their own health

Table 2 continued

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
	Students	Schools	Companies						
7 'Technasium' (NL)	89	1	Several	Students worked in groups over a period of 6 weeks, 4 h per week on this project	In-school and out of school for a field trip or visit an expert	7–11	Design prototypes or doing research to connect the school science with the community	Showing new views of science and scientists.	No

This project based activity is a curriculum course: research and design. All assignments are formulated by local STEM-based companies and can be different. The assignments are real problems that companies have to solve. The student groups have accountability to these companies. Lower grade students for example had to design something for easy filling of candy bags. Higher grade students had to design an app

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
8 'Research-day' (NL)	104	3	1	½ a day, working in groups at inquiry based small projects	Out of school, visiting a STEM-based company	9	Several info focused on applications and designs that are developed in the company	The main emphasis is to enhance interest for STEM	Yes

Different schools selected students to visit a private research lab. The students participated in different workshops in groups of 10 students. Each workshop highlighted the work of a research group. Students had to make a kitchen mixer soundproof and learned by experience how a piezo electrical element worked

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
9 'Keurig kiezen' (NL)	69	1	1 (multiple departments)	1 full day, experience the university by student-guides. Students worked at inquiry based small projects	Out of school	9	Several info focused on applications and research that is linked to school content	The main emphasis is to enhance interest for STEM	No

Students of one school visited the university. They experienced the university by talking to their student guides and participating in workshops from different departments such as making an electrical circuit to measure temperature or making soap

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
10 'Beta2you' (NL)	23	1	1	1 day-problem-based projects	In school project work	8	Working on a solution, theme light; the problem is linked to the students' world	Showing new views of science and scientists	No

One school is working with 23 8th graders on a project defined by a role model of a STEM-based company and a teacher. The students have to come up with solutions for safety issues concerning visibility in traffic. The role model and light-expert is visiting the school to guide the students

Table 2 continued

Activity title	Sample size			Teaching method	Location	Grade	Context	Emphasis	Selection
	Students	Schools	Companies						
11 'Mcee'-masterclass enjoy engineering (NL)	33	25	1 (2 departments)	Inquiry based projects, students worked at for 6 days	Out of school project based, 5 days in 6 weeks. Some lectures are added with background information	11	Working directly on scientific projects that are more challenging than the usual schoolwork	Increasing students' understanding of scientific contexts	Yes

Students were selected based on a motivation letter to work on a project during school hours at the University. This work took 6 days spread over 6 weeks and students worked in groups with students from other schools, guided by university students. The assignments were closely linked to the department of electrical engineering, such as 'pulsed power purification'. Students learned how to purify water and air with electromagnetic waves. The last day students had to present their findings to a public of teachers (both high school and university), parents and other students

| 12 'High Tech Room' (NL) | 36 | Several | Several | During the school year students meet each other and experts, 10 times. Partly lectures and project work | All meetings take place outside school | 11 | Working on a problem that will connect the school science and STEM with the community | Increasing students' understanding of scientific contexts | Yes |

Students were selected based on a motivation letter to work on a project during school hours at different companies. The project was defined by the municipal council as 'how to involve the community more in the STEM-world as the Eindhoven region wants to be the Dutch center of STEM'. The students had to deliver a consultancy report. This work took 18 days spread over a whole school year period and students worked in groups with students from other schools, guided by different experts. The last day students had to present their findings to a public of teachers (both high school and university), parents, other students, company experts and client

Table 3 Dimension descriptions for subscales used in our study

Learning environment scale	Description	Sample item	Motivation dimension	Moos dimension	Cronbach's alpha
Teacher support (WIHIC)	The extent to which ..the teacher helps, befriends and is interested in students	The (guest) teacher takes a personal interest in me	Relatedness	Relationship	0.86
(Student)-cohesiveness (WIHIC)	..students are friendly and supportive of each other	I know other students in this activity	Relatedness	Relationship	0.90
Involvement (WIHIC)	..students have attentive interest, participate in class and are involved with other students in assessing the viability of new ideas	I explain my ideas to others	Autonomy	Relationship	0.79
Personal relevance (CLES)	..school science is relevant to students' everyday out-of-school experiences	I learn how STEM can be part of my out-of-school life	Competence	Relationship	0.67
Uncertainty (CLES)	..opportunities are provided for students to experience that scientific knowledge is evolving and culturally and socially determined	In this activity, I learn the views of science have changed over time	Competence	Relationship	0.79
Innovation (CES)	.. how much students contribute to planning classroom activities, new or unusual activities, assignments or teaching methods are employed by the teacher	New ideas are being tried out in this activity	Autonomy	System maintenance and change	0.78
Autonomy support (LCQ)	..students perceive autonomy	I feel that my (guest) teacher provides me choice an options	Autonomy	Personal growth[a]	0.91

[a] This dimension is not mentioned in the dimensions of Moos

factorial ANOVA was used to see which characteristics were related to differences in student perceptions. The following characteristics were included in the analyses: location of the activity, context that the activity addresses (from scientific to more domestic), selection (whether all students participate or only a selected group), teaching method of the

Table 4 Scale intercorrelations for the questionnaire used

Scale	Scale intercorrelations						
	Cohesiveness	Teacher support	Involvement	Innovation	Personal relevance	Uncertainty	Autonomy
Cohesiveness	1						
Teacher support	0.33**	1					
Involvement	0.34**	0.65**	1				
Innovation	0.21**	0.50**	0.60**	1			
Personal relevance	0.25**	0.47**	0.48**	0.50**	1		
Uncertainty	0.23**	0.50**	0.51**	0.44**	0.57**	1	
Autonomy	0.26**	0.76**	0.67**	0.55**	0.52**	0.61**	1

** $p < 0.01$ (2-tailed)

Table 5 Activity characteristics as used for analyses

Factor (activity level)	Categories
Location	In-school
	Out-of school, with own school
	Out-of school with multiple schools
	Combination, both in and out-of school
Context	Scientific context
	Community context
	Company context
	Student personal life
Selection	No selection of students
	Selection
Teaching method	Long project
	Short workshop
	Short project
	Lecture-based
Emphasis	Enhance interest and engagement in science
	Understanding of science and scientific concepts
	New views of science and scientists

activity (from short lecture to longer problem-based projects) and emphasis of the activity (from understanding concepts to enhancing interest).

Results

What is the average student perception of the STEM outreach learning environment?

To answer research question one, results are presented graphically in Fig. 1. As can be seen in this figure, students perceived the outreach learning environment positively on all selected dimensions. Students rated the outreach most positive for cohesiveness (4.07) and innovation (3.70). The lowest score was for autonomy support (3.48) and this scale had a standard deviation of 0.88, showing considerable variation in perceptions between students. As can be seen from Fig. 1, the difference between average scale scores was relatively small when comparing the different concepts.

What differences exist between students', teachers' and external guides' perceptions of the outreach learning environment?

To answer research question two, scale means and standard deviations for the sample of students, teachers and guides are given in Table 6 and Fig. 2. Teachers' perceptions of most scales were positive, except for cohesiveness and uncertainty. The scores for the perception of the guides were close to the scores of the students. Relative to teachers and
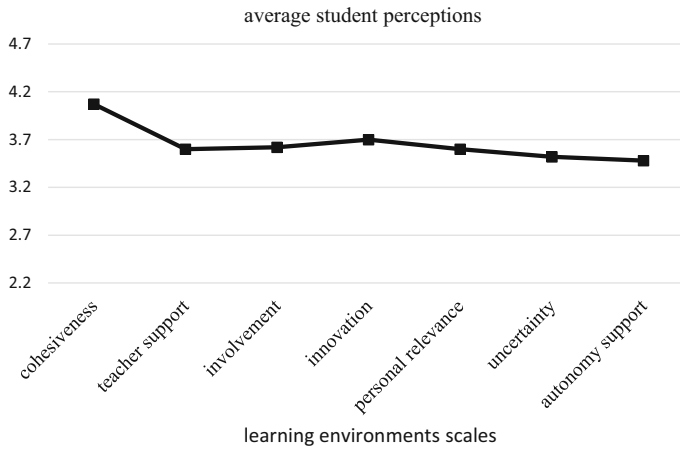
Fig. 1 Students' average perceptions of the outreach learning environment

Table 6 Mean and standard deviation for students', teachers' and guides' perceptions of the learning environment

Subscale	Students (N = 729)		Teachers (N = 13)		Guides (N = 22)	
	M	SD	M	SD	M	SD
Cohesiveness (WIHIC)	4.07	0.60	3.57	0.63	3.69	0.50
Teacher support (WIHIC)	3.60	0.80	4.14	0.71	3.72	0.84
Involvement (WIHIC)	3.62	0.74	3.93	0.84	3.70	0.72
Innovation (CES)	3.70	0.72	3.74	0.94	3.50	0.69
Personal relevance (CLES)	3.60	0.85	4.23	0.64	3.57	0.99
Uncertainty (CLES)	3.52	0.82	3.33	0.68	3.40	0.63
Autonomy (LCQ)	3.48	0.88	3.94	0.80	3.48	0.78

guides, students had statistically significantly more positive perceptions of cohesiveness ($F(2, 760) = 8.50$; $p < 0.00$; $\eta^2 = 0.027$). Also guides' and teachers' perceptions differed statistically significantly for personal relevance. Teachers thought that outreach was more personally relevant for students than either guides or students themselves thought ($F(1, 33) = 4.61$; $p < 0.01$; $\eta^2 = 0.12$). Although not statistically significant, a trend could also be seen for autonomy, with both students and guides perceiving the learning environment with less autonomy than teachers. In general, teachers had more positive perceptions than students and guides.

To what degree do students' perceptions differ between different outreach activities?

To show the magnitude of differences in perceptions between activities, Fig. 3 provides an overview of four selected activities and displays students' average perceptions of the learning environment for these activities. The activities with the lowest ('MRI' guest
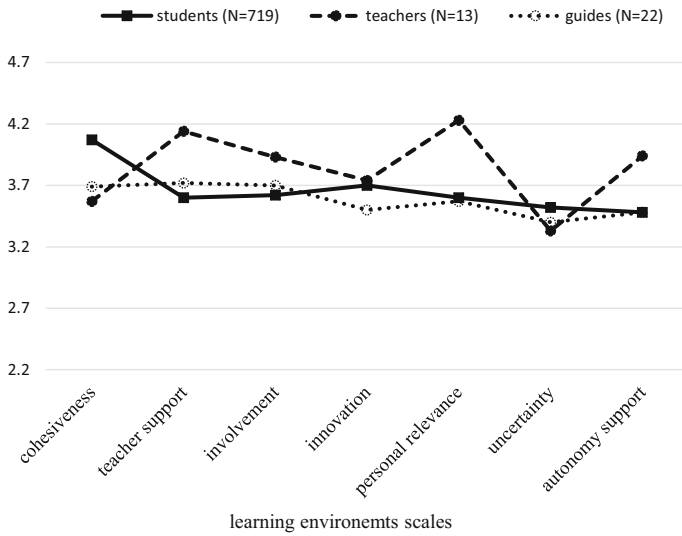
Fig. 2 Students', teachers' and guides' average perceptions of the outreach learning environment
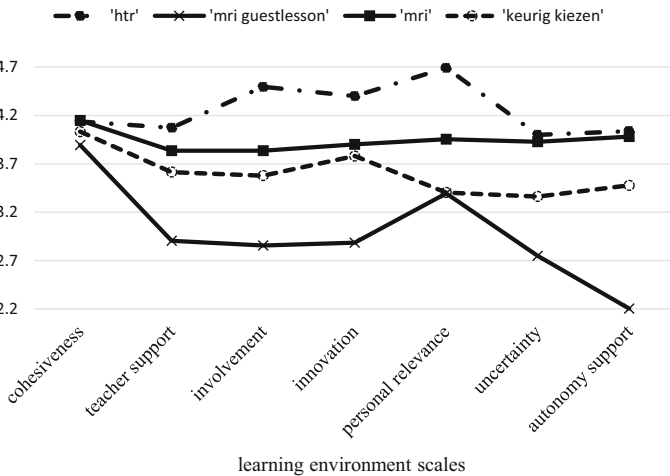
Fig. 3 An overview of four different activities and students' perceptions of the outreach learning environments

lesson, the Netherlands) and highest (High Tech Room, the Netherlands) average perceptions are shown, together with two other activities (MRI project in the US and 'keurig kiezen' in the Netherlands) with less extreme perceptions. As can be seen from Fig. 3, the lines representing different activities do not cross. So activities differed with respect to the magnitude of the learning environments dimensions measured.

The autonomy and involvement, scale means differed the most (almost two units), from negative to high positive scores, for different activities. Cohesiveness scores showed only minor differences for different activities and were all positive. Teacher support and personal relevance scores differed the least for different activities differences were the

smallest of all subscales. Students' perceptions of personal relevance was positive for all activities. Students' perception of teacher support for the MRI guest lesson was slightly negative.

Overall, scores differed between the 12 activities for most scales by almost one unit on a five-unit scale. Differences between activities also were clear from analysis of variance (ANOVA) (Table 7). The variance in students' perceptions of different activities ranged from 12 % (for uncertainty) to 35 % (for involvement). Thus, differences in students' perceptions were related for 12–35 % to activity characteristics, while the remainder related to differences between individual students within these activities.

The activity for which students perceived the learning environment most positively was the 'High Tech Room' activity. In this outreach activity, students from different high schools in the region of Eindhoven (the Netherlands) were selected for participation based on their motivation and grades. In this activity, a group of 14–16 students worked on an assignment with experts from different STEM based companies. They met outside school 18 times during the school year and worked in small groups on their project about 'how to involve the community more in the STEM world as the Eindhoven region wants to be the Dutch centre of STEM'. During every meeting, students met an expert from a different company. At the end, students had to present a report with their advice.

The students perceived 'guest lessons' less favourably than other outreach activities. A guest lesson is typically a short activity. Some lessons took place in school, such as the LCD (=liquid crystal display) lesson or the lessons about relativity, whereas other guest lessons (medical imaging) were on location, sometimes with an extra tour in the company. During all guest lessons, an expert gave a lecture and, in the LCD lesson, student experiments with special material from the company of the expert were available. Because these lessons were for all students of a certain grade level, no selection took place. Typically, the subject of guest lessons was closely related to curriculum subjects.

What characteristics of outreach activities can be identified that explain variance in perceptions between activities?

In our factorial ANOVA, the characteristics as defined in Table 4 were used as fixed factors and scales as dependent variable. The five characteristics at the activity level were teaching method, location of the activity, context used, selection of students' and main objective. We added gender as a fixed factor to check gender differences in students' perceptions of the outreach learning environment. No statistically significant differences according to gender were found. Table 7 gives the results of the factorial ANOVA (Table 8).

Table 7 Scale means, standard deviations and ability to differentiate between activities (ANOVA results)

Subscale	M	SD	F	p	η^2
Cohesiveness (WIHIC)	4.07	0.60	13.62	0.00	0.17
Teacher support (WIHIC)	3.60	0.80	11.42	0.00	0.15
Involvement (WIHIC)	3.62	0.74	34.52	0.00	0.35
Innovation (CES)	3.70	0.72	14.98	0.00	0.19
Personal relevance (CLES)	3.60	0.85	10.02	0.00	0.13
Uncertainty (CLES)	3.52	0.82	9.21	0.00	0.12
Autonomy (LCQ)	3.48	0.88	20.94	0.00	0.25

Table 8 ANOVA results of activity characteristics for explaining variance in perceptions

Subscale	Teaching method			Selection			Location			Context			Emphasis		
	F	p	η^{2a}	F	p	η^{2a}	F	p	η^{2a}	F	p	η^{2a}	F	p	η^{2a}
Cohesiveness (WIHIC)	14.61	0.00	0.058	13.11	0.00	0.018	12.80	0.00	0.051	4.39	0.01	0.018	12.60	0.00	0.033
Teacher Support (WIHIC)	9.95	0.00	0.040	Non-significant			Non-significant			9.11	0.00	0.025	Non-significant		
Involvement (WIHIC)	24.49	0.00	0.094	Non-significant			19.55	0.00	0.076	24.64	0.00	0.00	Non-significant		
Innovation (CES)	10.51	0.00	0.043	9.31	0.00	0.013	5.11	0.00	0.021	3.94	0.01	0.016	7.13	0.00	0.020
Personal Relevance (CLES)	8.23	0.00	0.034	11.14	0.00	0.015	3.73	0.01	0.016	4.77	0.00	0.020	Non-significant		
Uncertainty (CLES)	6.11	0.00	0.025	14.52	0.00	0.020	Non-significant			4.89	0.01	0.018	4.24	0.01	0.013
Autonomy (LCQ)	11.70	0.00	0.047	10.51	0.00	0.015	Non-significant			15.78	0.00	0.043	Non-significant		

[a] Partial η^2

In the ANOVA, teaching method explained most of the variance between activities. At the level of the activities, the variance explained by teaching method ranged between one-fifth to one-third for the different scales. The other characteristics (in particular, selection and context) appeared not to be statistically significantly related to some scales (in particular, teacher support). The maximum variance explained at the activity level was up to 30 % for location and up to 15 % for context. Students in projects for a longer period generally perceived the learning environment statistically significantly more positively but, for activities that used lectures, students' perceptions of cohesiveness were statistically significantly more positive. When students participated in a workshop with hands-on activities, both long and short, perceptions of teacher support and autonomy were statistically significantly higher.

The next factor for explaining variance was the emphasis of the activity. Although the different emphases varied for different scales, students perceived statistically significantly more cohesiveness and autonomy for an activity that had the emphasis of creating new views of science. Perceived personal relevance was statistically higher for activities emphasising understanding. Perceived Involvement was statistically higher for activities with an emphasis on interest enhancement.

Although location is clearly different for outreach activities compared with regular classrooms, location was not a variable that showed statistically significant differences for all scales. When students participated in out-of-school activities with students whom they never met before, or when students had to visit a company for their project, they experienced statistically significantly more teacher support, innovation, personal relevance and involvement. The combination of location and in-school work seemed to invoke the most positive perceptions. Thus, when a guide visited a school, students perceived statistically significantly more cohesiveness.

Both type of context and student selection showed only minor associations with students' perceptions. Nevertheless, an emphasis on a society or community problem-based context resulted in statistically significantly higher autonomy and cohesiveness perceptions. A company-emphasised context was statistically significantly less favourable for perceptions of involvement, innovation, personal relevance and uncertainty. Students selected by motivation perceived their learning environment statistically significantly more positively for the scales innovation, personal relevance, uncertainty and autonomy (but not cohesiveness).

Discussion

Conclusion and interpretation

In this study, we explored students' perceptions of their outreach learning environment by using a questionnaire composed of different scales from existing learning environment questionnaires (WIHIC, CLES, CES and LCQ). In our view, the findings have shed light on some interesting insights that might be of general value to learning environments researchers.

First, the students in the sample rated their outreach learning environment positively in terms of cohesiveness and innovation, and slightly positively for teacher support, involvement, personal relevance, uncertainty and autonomy. No neutral or negative scores were found. These findings supported our expectations of positive student perceptions of

the outreach learning environment because these activities are designed to motivate students. In general, an emphasis on motivation in the design of the learning environment is likely to be associated with more-positive student perceptions of the learning environment (Baeten et al. 2013; Fraser and Fisher 1982; Kingir et al. 2013). Compared with studies of students' perceptions of regular science classroom environments (Trickett and Moos 2002; Wahyudi and Treagust 2003), involvement and autonomy support seem to be rated more positively in the outreach learning environment. However, autonomy support is not often assessed in learning environment research. Because positive scores for scales such as involvement and personal relevance are indicators of positive attitudes towards STEM, positive scores in the outreach learning environment are indicators of possible motivation for STEM. Thus, adding outreach activities to the regular learning environment would potentially add value for students' intrinsic motivation for science and science learning, assuming that more positive perceptions of the learning environment elements would also lead to higher satisfaction of the three needs of relatedness, autonomy and competence (Black and Deci 2000; Jang et al. 2010; Lavigne et al. 2007). However, the degree to which these environments indeed satisfy these needs and the (strength of the) relation between the different learning environment elements and the needs is something to be investigated in future research.

Second, differences between students, teachers and guides were statistically significantly different for perceived cohesiveness for students on the one hand and teachers and guides on the other. Another difference was found for personal relevance between teachers on the one hand and guides and students on the other. Such differences might be expected and have been found in regular science classrooms (den Brok et al. 2006; Fraser 2007; Wahyudi and Treagust 2003; Wubbels et al. 2006) and have been attributed to the fact that teachers have an active role, rather than an observer role, in the learning environment. However, this argument does not hold in the outreach environment, where the teacher's role is generally more of an observer one and the guide's role is more active. Teachers are active in a different way. First, guides make the choice to be involved in outreach because of relevance for students and, second, the other learning environment is different, unknown and the guide is an expert in a field unfamiliar for the teacher. The consequence of this relationship is that the teachers might look up to those guides and that might increase their perceptions of a more-relevant learning environment for students. The guides had in common that they had a STEM background, served as experts and role models and considered their contribution of added value. Guides differed in experience in activities in education and didactical education. Within the (small) group of guides, no differences were found in perceptions of the learning environment. The roles of both teachers and guides seem to be worth focusing on in further research, as is further investigation into the reasons of why differences in these types of learning environments occur between teachers, guides and students.

Third, there was a wide diversity in perceptions between different outreach activities. For some activities, students perceived the outreach learning environment similarly to a regular learning environment. These activities were short and lecture-based and involved less active involvement of students. This difference in perceptions between more-active learning environments and more-passive lecture-based environments was found by Orion et al. (1997) as well. Only students' perceptions for cohesiveness were statistically significantly more positive for lecture-based activities. Probably these activities are for the whole class, and so students know each other already. Autonomy was experienced less for short lecture-based activities, for which students do not have any influence on how these lessons proceed. If more activities, such as experiments, were added to a guest lesson,

students perceived more involvement and autonomy and rated their learning environment more positively than students who just had to listen. In addition, teaching method appeared to be the characteristic of activities that had the most effect on the students' perceptions: activities with active participation and input from students were rated most positively. These findings are consistent with the literature (Assor et al. 2002; Orion et al. 1997; Reeve and Jang 2006). For our dataset, we did not find differences between the US and Dutch activities because we only assessed two activities in the US.

Learning environment research is relatively new in the out-of-school context of the outreach learning environment. This context of learning environments can be studied systematically with existing instruments. In this study, it became clear that the outreach learning environment adds important elements to the regular learning environment, particularly in terms of more autonomy. It seems to be worth the investment to investigate, first, the impact (or effect) on students' motivation for STEM by joining these activities and, second, the role of both teachers and guides in future research.

Suggestions for further research

Some limitations of the present study might have implications for further research. Because students' perceptions of their outreach learning environment tend to be more positive than their perceptions of the regular learning environment, motivational needs might be more fulfilled in the outreach learning environment. Subsequent research is needed to verify a possible relation between, first, the scales and the defined needs according to the Self-Determination Theory and, second, the perceived learning environment and motivation for STEM. Administering a questionnaire, observing and interviewing students, teachers and guides might provide information about these relations.

In the present study, we found a positive influence of some characteristics of outreach learning environments such as teaching method, location and objective. These characteristics might be used to define an optimal activity in terms of perceived learning environment. An intervention study might be useful for identifying an optimum. Interviews with guides might be added to study the feasibility from an industrial point of view in terms of investment of time and benefits.

Third, activities with a short duration were found to be less favourable compared with activities with a longer duration. These activities were easier to organise, needed less time investment, for a STEM-based company, and involved a relatively large group of students relative to longer and time-consuming activities for a relatively small number of students. Subsequent research is needed to verify whether multiple short activities have the same effect on students' perceptions of the learning environment and motivation for STEM as longer projects. This could be accomplished through a longitudinal study involving the surveying of students after attending at least four short activities and interviewing guides who participated both in short-term and long-term outreach activities.

Fourth, in the (small) group of guides and teachers, males were over-presented (77.1 %). Although no gender differences were found in the present study, the overall male perspective might affect the points of view of students about the STEM field. All guides participated in activities because they thought that it was important to show students their STEM-based work environment. Only a small group of these guides had attended an educational course. This might affect the interaction between the guides and students and the way they taught in the activity.

Last, although activities in our sample were chosen on the basis of variety, the sample size only involved 729 students and 35 teachers and guides and a relatively limited number of activities. Therefore, results cannot be easily generalised.

Several implications can be drawn from the results of the present study. Because the outreach learning environment was generally perceived positively, teachers and schools could focus on adding a variety of outreach activities to their curriculum as students and teachers to give a glimpse of the STEM world outside school. Choosing hands-on, project-based activities and new subjects is likely to enhance students' autonomy. Students experience more competence when activities are focused on understanding STEM and are subject-based. Activities with a focus on enhancing interest will be experienced with more involvement and interest by students. A good embedding of outreach into regular curriculum is needed, because students benefit by seeing new contexts and possibilities within the STEM-based world that might influence their attitudes towards STEM. This embedding will give them the opportunity to connect school science with the outside world by themselves.

Teachers benefit from seeing new contexts that might be used as an inspiration in regular science courses; the possibilities within the STEM-based world might refine and update their point of view of STEM. From this perspective, teachers might inform students about the STEM-based workforce.

Last, it can be concluded that the present study expanded learning environments research beyond the classroom in a different way from other studies to date. More research is needed before generalising these results and for investigating possible relations between learning environment and motivation more closely.

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