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Effects of a STEM-oriented lesson series aimed at inclusive and diverse education on primary school children's perceptions of and sense of belonging in space science

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ABSTRACT

The number of women and underrepresented individuals working in science, technology, engineering and mathematics (STEM) fields does not reflect the diversity of our societies. Even if children have an interest in STEM, they may not consider choosing a study or career in that direction if their perception is that they would not belong in science. This study examines the effects of a STEM lesson series aimed at inclusivity and diversity on children's perception and sense of belonging in space science. Before and after the lesson series, children filled out a questionnaire aimed at eliciting their perception of space science and space scientists. After the lessons, a subsample of children was interviewed about the effects of the lesson series on the children's perception and sense of belonging regarding space science. Six months after the last lesson took place, children from two classes filled out a short survey with open questions to measure retention. The results of this study showed that the lesson series had a significant impact on children's perception of space scientists, and that the implementation of the lessons facilitated thinking about (a future in) space science. This lesson series has succeeded in changing children's perception of space scientists as a diverse and international group of people.

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Introduction

Science, Technology, Engineering and Mathematics (STEM) literacy and skills are increasingly important for full participation in civic life as well as for employment (Irwin, 2001;

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Rothwell, 2013). Global challenges concerning sustainable energy sources, health, or climate change require an interdisciplinary STEM perspective (Shernoff et al., 2017). Likewise, these challenges require creative and innovative solutions that can best be reached through a diverse STEM workforce with people who contribute a variety of perspectives (Roberge & Van Dick, 2010). However, the group of people pursuing careers in STEM consists disproportionately of people who are male, middle-class and from ethnically dominant backgrounds of society (AAUW, 2010; Smith, 2011). The lack of representation of women and underrepresented minorities in STEM is problematic. But a more diverse workforce is not the only issue. There is also ‘a social justice case to be made for the value and need for all citizens to be able to participate in STEM, to be literate, and shape STEM developments in society’ (Archer et al., 2014, p. 200). Therefore, STEM education should be inclusive for all individuals to foster STEM literacy, joy and involvement in STEM worlds, and critical thinking in general (Takeuchi & Dadkhahfard, 2019).

One of the reasons for the underrepresentation of women and minorities in STEM is non-inclusive STEM education. Studies show that (informal) educational STEM activities are not inclusive (Dawson, 2014) and in many cases alienate girls and underrepresented minorities from pursuing a career in STEM fields (Bauer, 2017). Stereotypical images by parents and educators regarding gender or ethnicity dimensions of science influence the way they involve children in scientific activities in and outside the classroom (Alexander et al., 2012; Newall et al., 2018; Rascoe & Atwater, 2005). For example, boys are more often called upon in class during science subjects, and parents generally expect boys to outperform girls in mathematics from an age as young as six years old (Miller & Halpern, 2014; Newall et al., 2018). People of colour are also consistently underrepresented in the STEM (Beede et al., 2011). In a school environment, Black culture for example is linked to (perceived) problematic behaviour by teachers and leads to an underestimation of students’ academic abilities (Gillborn & Youdell, 2000; Rollock, 2007). Women of colour in particular, are more likely to feel like they do not belong in science (Johnson, 2012; Rainey et al., 2018), sometimes also due to parental expectations of what are suitable career directions for their daughters (Aschbacher et al., 2010). Informal science education environments are also not experienced as welcoming places for people with minority ethnic backgrounds (Dawson, 2014).

In the Netherlands, where this study took place, socio-economic status is recognised as a predictor of performance in mathematics and science (OECD, 2019). Dutch children with a disadvantaged socio-economic status more often come from families with a migration background.¹ Some independent Dutch organisations publish educational materials to promote inclusion and diversity in general (such as ECHO, the Expertise Centre for Diversity Policy²) or more specifically the inclusion of girls and women in STEM (such as VHTO, the National expertise office for girls/women in science/technology³). A study by the latter organisation into children’s attitudes towards science and technology, found that boys perceive science and technology as more fun than girls, and more often consider it as a future career (Jansen & Van Langen, 2016). However, Dutch girls score higher than Dutch boys on science (OECD, 2021).

To develop an intervention that would make *all* children feel included in STEM education and to develop STEM identities, we used the existing body of literature that describes various interventions aimed at making girls and children from underrepresented minorities feel more welcome in the science and technology classroom. In this

study, we have developed and tested an inclusive lesson series about black holes and studied the impact this lesson series had on students' perceptions of space science and their sense of belonging within space science. We chose for a space science context because underrepresentation of women and minorities is relatively worse in certain STEM fields that are related to astronomy (like computer science, engineering, and physics) in comparison to other STEM fields like biology and chemistry (Cheryan et al., 2017); and because space science 'has been promoted as a physical science with the capacity to inspire both boys and girls' (DeWitt & Bultitude, 2020, p. 1). Taking space science as an interesting context we aimed to ignite excitement among a diverse group of students, and also to acquaint students with STEM fields that are usually considered less inclusive, like computer science or physics.

Literature review

Firstly, we would like to state that, in this paper, we report on differences between gender based on biological sex. However, we acknowledge that gender is a more complex and fluid concept than just the biological male/female distinction. We view gender as someone's perceived femininity, masculinity and anything in between or outside that spectrum. Furthermore, like Archer et al. (2014), we acknowledge gender as a gender 'performance' which in turn also intersects with ethnicity and social class (Calabrese Barton & Brickhouse, 2006). This is also why children from underrepresented minorities face many challenges when engaging in STEM activities, because their ethnic backgrounds, socioeconomic status and gender may all play a role in (their perception of) the accessibility of a STEM domain. This is called intersectionality. Intersectionality means that all these aspects of one's identity (race, gender, class, sexual orientation) interact with each other, shaping multiple dimensions of one's experience (Crenshaw, 1991).

The underrepresentation of girls in STEM

Although there are little gender differences in boys' and girls' attainment in science and mathematics (Smith, 2011), girls are less likely than boys to choose a STEM related study or career path, especially in the physical sciences and engineering (Cheryan et al., 2017). Girls have been shown to exhibit less positive attitudes to science than boys and more often have the belief that science is not for them (Aschbacher et al., 2010; Sjøberg & Schreiner, 2005). In the Netherlands, fifteen year old girls are less likely than boys to aspire a STEM-related profession and these numbers are lower than in other countries (Van Langen & Meelissen, 2019)

Cheryan et al. (2017) describe three possible interacting factors that lead to the underrepresentation of women in STEM: (1) masculine cultures in STEM; (2) insufficient early educational experiences; and (3) a reduced sense of self-efficacy. Children tend to strongly associate science with being clever, smart or 'brainy' (Archer et al., 2014), whereas cleverness is often seen as a masculine trait (Carlone & Johnson, 2007). Girls as young as 6 or 7 years of age are already less likely to associate being smart with being a girl (Bian et al., 2017). Another problem of the association of science with cleverness is that it excludes children who do not perform as well in school, or who do not identify themselves as the prototype of 'the good student'. The 'ideal learner' is often (subconsciously) viewed as white,

male and middle class (Archer, 2007). This results in ‘the exclusion of working-class girls not only from the identity of the ideal student but also, in particular, from science-related future aspirations’ (Archer et al., 2013, p. 185).

The underrepresentation of children from ethnic minorities in STEM

Beede et al. (2011) show that US Black and Hispanic communities are half as likely as all workers to have a career in STEM; thus, they are being consistently underrepresented in the STEM work field. Formal education might already influence the chances of children from ethnic minorities to participate in STEM. Strand (2012) showed that UK students from a Black-Caribbean background might be disproportionately allocated to lower tier test papers by their teachers, compared to their White peers. A reason Strand gives is that teachers underestimate the academic potential of a student when their behaviour is problematic, or is even only *perceived* as problematic. Rollock (2007, p. 275) describes this as

The appearance and behaviour of Black pupils, particularly those engaged in what is termed ‘Black street culture’, are seen as directly at odds with the aims of the school and therefore minimise their likelihood of attaining success in exclusive terms.

The linkage of decreased academic potential to (perceived) problematic behaviour, regardless of a student’s actual academic ability, has been described in other studies as well, often disadvantaging Black students in particular (Gillborn & Youdell, 2000). Aschbacher et al. (2010) also found that African American and Latino students perceived their educators to have lower expectations of their performance in science than of others (Asian American and White students). In the Netherlands a similar situation is apparent with pupils from a migration background getting a lower advice for high school tracks from their primary school teachers than their test scores allow (Biermans et al., 2003). However, in the Netherlands, as in the rest of Europe, data on ethnicity or migration background is often not collected because of privacy concerns (Farkas, 2017). Therefore not many studies include specifics on ethnicity of participants.

Interaction between gender and ethnicity

The interaction between ethnicity and gender makes it even more difficult for some girls in underrepresented groups to consider science as an optional career or as something to be interested in. Students from underrepresented groups, and especially women of colour, are more likely to feel like they don’t belong in science (Johnson, 2012; Rainey et al., 2018). In the study of Carlone and Johnson (2007), it became clear how important it is that women of colour receive recognition by meaningful peers in science. Women who did not experience this recognition because of gendered, ethnic and racial factors often had disrupted scientist identities (Carlone & Johnson, 2007). Aschbacher et al. (2010) found that Latina girls felt more pressure to conform to traditional family patterns (caring for the home and children), and that their parents also valued college and careers less for girls than boys. These expectations of certain cultural and gender typical behaviour, not only from society or teachers but from their own families, pose an extra barrier for girls of colour to participate in STEM. Since teachers also have their own (unconscious) biases towards

ethnicity and intelligence, the linkage of science with cleverness poses a problem for children from underrepresented minorities as well (Strand, 2012).

Theoretical framework

In order to investigate how a lesson series can improve this situation for girls and ethnic minorities within science, we focus on children's perceptions of STEM professionals and sense of belonging in science as these have shown to be important factors in children's choices to pursue science careers and in feeling comfortable around STEM topics.

Perception of STEM professionals

Perception of science can be described as the way in which one views science-related careers and scientists. Prior work studied for example children's images of scientists by having them draw what they thought a scientist looked like (Draw-A-Scientist-Test; Finson, 2002). Often, these studies show that scientists are depicted as white males, who often work alone, wearing lab coats and glasses to illustrate intelligence. Moreover, Kerkhoven et al. (2016) showed that in STEM educational materials there were more men than women depicted with a science profession and that more women than men were depicted as teachers. Students' own perceptions of what science is and what a scientist looks like likely influence their perception of whether or not science would be a suitable activity for them. Students who hold stereotypical images of scientists will likely not aspire to pursue a science as an interest or career (Archer & DeWitt, 2016, Gardner, 1980).

Sense of belonging in STEM

Sense of belonging refers to feeling liked, respected, accepted, valued, included, and encouraged by others, which often differs for specific environments such as the home situation, a classroom environment, or a STEM work field (Goodenow, 1993; Master & Meltzoff, 2020). Feelings like exposure or social risk, for example when showing ambition or interest in STEM fields, might be counterbalanced by having a sense of belonging in that environment (Goodenow, 1993). In addition, sense of belonging may support the value that students contribute to STEM in their daily lives (Stout & Blaney, 2017). Sense of belonging could also be described as the opposite of so-called 'belonging uncertainty': when one feels unsure of their capability to 'fit in' in a certain academic field (Smith et al., 2013). Women and underrepresented minorities are more susceptible to this uncertainty, partly due to stereotypical images of what type of person does science and who does not, alongside with the numerical underrepresentation in STEM fields (Smith et al., 2013).

Since a sense of belonging, especially for underrepresented communities, is associated with academic achievement, retention, and persistence in college (Strayhorn, 2012), it is of vital importance that *all* students feel like they could 'fit in' in STEM, even if they do not wish to pursue a STEM career. It has been noted that diversity within a team may increase group performance. However, this requires a feeling of belonging in STEM through promoting a collective identity and psychologically safe climate (Roberge & Van Dick, 2010). Therefore, a sense of belonging is a valuable factor to help increase inclusion in STEM education.

Possible solutions to make STEM education more inclusive

Women's and minorities' perception of STEM professionals and their sense of belonging has been shown to be positively impacted by a number of factors, including peer relationships and support (Espinosa, 2011; Johnson, 2012; Rainey et al., 2018). Teachers can for example support children by validating their competences and skills and stimulating good teacher-student and peer-to-peer relationships (Tuitt & Reddick, 2008). An activity aimed to validate children's competences and perceptions created by the Dutch national expertise office for girls/women in STEM increased the positive image of science and technology for both boys and girls (Jansen & Van Langen, 2016). They saw science and technology less as a 'boys' thing' and could associate new kinds of skills and traits (not related to stereotypes) to being a scientist.

Science teachers who value all personal identities of students, especially those of students of colour, and make use of the students' own cultural resources in science education, have an important positive influence on the development of scientific identities in children (Archer et al., 2014). Teaching approaches to enhance inclusion in the classroom such as giving specific praise to students, ensuring equal participation of both boys and girls, having guest speakers and showing a video of scientists of colour, can decrease stereotypical perceptions that children hold of scientists (Bohrmann & Akerson, 2001). Exposing children to role models in science in real life or in video's to highlight the diversity of STEM professionals, has also been shown to be an effective means for inclusive education (Miller et al., 2015; NUSTEM, 2018; Tuitt & Reddick, 2008). These visits or videos of professionals could also be used to actively debunk stereotypical ideas that children might have about scientists (NUSTEM, 2018).

Inviting professionals into the classroom can have more beneficial effects, next to countering the existing stereotypes. When STEM practitioners talk with students about the effort and struggles they had to overcome while working in STEM, it shows students that effort, rather than congenital intelligence, is important to achieve success (Smith et al., 2013). Another problem with the perception that a scientist is born with innate high intelligence, is that 'cleverness' is often associated with being a masculine trait. Debunking this stereotype of scientists being clever will likely improve the sense of belonging of girls and overall children who do not comply with the typical image of 'the good student' (Archer, 2007). There are indications that primary school children's prior interest in STEM predicts the strength of these stereotypes related to gender and science (Blažev et al., 2017). This is why raising interest in STEM and countering stereotypes is already of great importance in primary school children.

Girls tend to take a greater interest in topics related to health and biological sciences, opposed to boys who in general express greater interest in technology and physical sciences (Sjøberg & Schreiner, 2010). STEM content that is more related to societal problems has the potential to interest more children who are not inherently attracted to science. It is important that educators present children with a wide array of 'what counts' as science, also in the activities that they administer, such as creative or active learning to stimulate curiosity of children who had before not considered science to be for them (Archer et al., 2013; Dawson, 2018). Lastly, involving family in the development of science capital, or informing them about future science careers as an option for their children, can have a positive influence on children's perception of science as 'for them' (Archer et al., 2013; Archer et al., 2015; NUSTEM, 2018).

Current study

In this study, we describe the impact of a STEM-oriented lesson series aimed at inclusivity and diversity on the development of children's perceptions and sense of belonging in space science. This innovative project provides evidence-based, co-created science education materials while involving three research institutes and two organisations specialised in diversity and inclusion in (STEM) education. These co-created STEM materials contribute to broadening youth participation in STEM learning and stimulate youth participation from underrepresented minorities and girls in the Netherlands in cutting-edge research. This study directly contributes to the Dutch National Research Agenda's Portfolio for Research and Innovation (NWO, 2016), namely '(...) make the student population majoring in science as diverse as the Dutch population by 2040'. (...) by implementing a STEM education project, evidence-based and dealing with research topics of fundamentals of matter, space and time.

Research questions

- (1) What is the impact of a STEM lesson series aimed at inclusive education on primary school children's perceptions of space science and space scientists?
- (2) What is the impact of a STEM lesson series aimed at inclusive education on primary school children's sense of belonging in space science?

Methodology

Using a mixed methods approach, we studied the impact of a newly developed, co-created lesson series 'Journey to a Black Hole'. We collected several types of data (see Figure 1).

Context: the lesson series 'Journey to a Black Hole'

The context in which this study took place is the Dutch National Research Agenda (NWA), a funding scheme of the Dutch Research Council (NWO) with the goal to make a positive and structural contribution to the global knowledge society, where new questions from practice and society quickly and naturally find their way into new research (NWO, 2016). One of the structural goals of NWA is to 'make the student population majoring in science as diverse as the Dutch population by 2040' (NWO, 2016, p. 14). In order to enhance children's involvement in STEM education, the lesson series 'Journey to a Black Hole' was developed through three co-creation sessions with teachers, experts on education, science communication, diversity and inclusion of women and underrepresented minorities in STEM. We also used guidelines for inclusive education for girls and underrepresented minorities found in literature (see Table 1) during the development of the educational materials. The lesson series 'Journey to a Black Hole' consists of six lessons of 60–90 min each (see Table 2 for a summary of the content of the lessons), and is specifically targeted at girls and children from underrepresented minorities of the age group 8–12. This age group was chosen because a

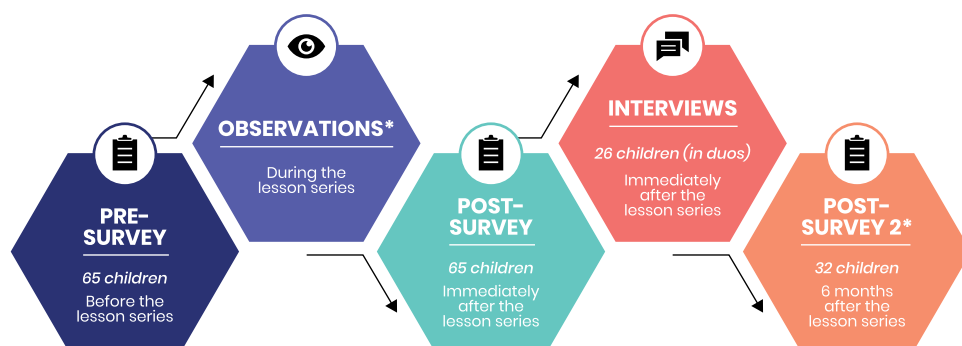


Figure 1. Study overview. The methodology included different approaches: Surveys, observations and interviews.

majority of children around the age of 10 have fairly positive attitudes towards science (Murphy & Beggs, 2005), whereas these attitudes appear to decline around the age of 14 (Osborne et al., 2003). We have specifically chosen to aim the lesson series at all children, not just girls or just students from a minority background in order to be truly inclusive instead of excluding other groups. This was also suggested by the experts present at the co-creation sessions. The lesson series and its list of resources is available online (Vossen, Russo, et al., 2020; Vossen, Tigelaar, et al., 2020).

Participants

A total of 65 children from three Grade 5 classes (children aged 10–12) from two Dutch primary schools participated in this study. The primary schools were situated in low-income and ethnically diverse neighbourhoods from two medium sized cities in the urban agglomeration in The Netherlands. For this study, we wanted to specifically involve schools with many children from migrant or lower socio-economic backgrounds. We asked children for their age and gender to be able to give an overview of the demographics of our sample. One Grade 5 class from school 1 participated, and two Grade 5 classes from school 2 participated (see Table 3 for number of students and age range per class). The study took place from 1 November 2019 to 9 January 2020. All schools completed the lesson series before the end of December 2019, however, the final interviews

Table 1. Guidelines for inclusive education as found in literature linked to specific content of the lesson series.

Guidelines for inclusion	Implementation in lesson series	Literature
Exposure to role models to highlight diversity	4 videos of different professionals (women, persons of colour)	Tuitt and Reddick (2008), Miller et al. (2015), NUSTEM (2018)
Active debunking of stereotypical ideas	Discuss videos in relation to self-drawn space science persona	DeWitt et al. (2013), NUSTEM (2018)
Validation of competences and skills	Talent cards	Tuitt and Reddick (2008)
Involvement of family	Talent cards for parents/caretakers and inviting family to show&tell presentation	Archer et al. (2013), Archer et al. (2015), NUSTEM (2018)
Active learning and stimulating curiosity and creativity	3 lessons dedicated to inquiry and design-based learning	Archer et al. (2013)

Table 2. Summary of the content per lesson of the educational activity 'Journey to a Black Hole'.

	Content
General information	Goal and structure of the lesson series Background information on black holes, gravity, collapsing stars and mass Frequently asked questions and answers
Lesson 1 Journey to a Black Hole – who's helping?	Introduction to the lesson series and black holes Guided fantasy (audio story) and brainstorm about professions in space science Students draw their own space science persona, based on their own ideas of what a professional does and looks like
Lesson 2 Professions and skills in space science	Videos of four different space science professionals, classroom discussion in relation to the drawn space science persona's in lesson 1 Filling out Talent cards to describe their own and their peers' unique skills
Lesson 3 Experimenting with black holes	Conducting two to four different experiments to simulate how black holes originate and work Filling out a knowledge map about the concepts
Lesson 4 Designing for a space mission	Start of design project in teams of three-four students Generating possible solutions for the design problem in a post-it brainstorm Choosing the idea for the design
Lesson 5 Making the final product	Finish the prototype of the design project Preparing a poster for the show & tell exhibition Preparing questions for the visiting (space) science professional
Lesson 6 Show & Tell exhibition	Showcase of design prototypes and posters about the project to parents and peers Q&A with visiting (space) science professional

with children of School 2 could not be held earlier than the second week of January due to holidays.

Ethics statement

All teachers were personally informed about the nature of the study and the data collection procedures. Prior to distributing the questionnaires and holding interviews, active informed consent was gained from parents or guardians of all participating children.

Questionnaire design & analysis

All 65 children of the three Grade 5 classes (see Table 3) participated in the Perceptions of Space Science Questionnaire (PSSQ) that was distributed before and after the

Table 3. Participating classes and teachers.

	School 1	School 2	
	Grade 5	Grade 5A	Grade 5B
Number of children	24	20	21
Girls ^a	18	13	11
Boys	6	7	10
Mean age of children	10.3	10	10.4
Age range of children	10–12	9–11	9–12
Teachers ^b	Fiona (female)	Mehmet (male) Ozan (male)	Violet (female) Yara (female)

^aWe acknowledge that gender is not a binary construction, but rather a spectrum in which male or female are by no means the only two options. However, going into detail about the complexity of gender is beyond the scope of this study. In the context of this study it is important to make a distinction between men and women, because there is overwhelming evidence that women often feel alienated from science, which is a problem we want to address. Therefore, we have decided to simplify gender into only 'girls' and 'boys'.

^bTeacher names are pseudonyms.

implementation of the lesson series. This is a shortened version of the Perceptions of space science survey (DeWitt & Bultitude, 2020) which we adapted to fit the context of the lesson series 'Journey to a Black Hole'. The scales we used are: Space science as a profession; Space science and my future; Positive attitudes to space science; Preparing for work in space science (see Table A1 in Appendix I for an overview of all items per scale). A Dutch translation of the original English items was already developed and tested in Dutch primary schools by DeWitt & Bultitude, 2020. The survey was then pilot-tested with a teacher educator and a 10-year-old girl from Grade 5 (from a different school than our research sample). A few changes were made regarding the understandability and readability of the items. Items were scored on a 1–5 Likert scale, where 1 = strongly disagree and 5 = strongly agree.

Quantitative analyses of the questionnaire data was conducted within the software IBM SPSS Statistics 26. PCA analysis showed that the items did not cluster into the four pre-defined scales of Space science as a profession, Space science and my future, Positive attitudes to space science, Preparing for work in space science, in both the pre-test and post-test situation (see Appendix II). For example, some items from the scales Space science as a profession and Preparing for work in space science were clustered together, and items from Space science and my future and Positive attitudes to space science appeared together in one cluster in the post-test. However, we chose to stick to the original scales in order to be able to compare our results to previous results gathered by the Perceptions of space science survey (DeWitt & Bultitude, 2020). Another reason to stick to the original scales was that Cronbach's alpha was sufficient for most scales in the pre- and post-test (see Table 4). The scales showing a lower Cronbach's alpha (Preparing for work in space science, pre lesson series) were interpreted more carefully in our conclusions.

To compare pre- and post-test scores for each individual child, a paired-samples t-test was used. To compare boys and girls, we used multilevel analyses to correct for the fact that the children were part of three different schools and classes with different teachers. Multilevel analysis is a linear regression in which we applied a correction for the nested structure of the data (children are part of classes which are part of schools). Multilevel analysis corrects for the fact that the classes and schools may introduce extra variance in the data. Questionnaires with incidental missing items were included in analyses, causing the total number of children per analysed category to sometimes slightly deviate from the total of 65.

Interview design & analysis

Duo-interviews were conducted with 26 children (10 boys, 16 girls) who had followed the lesson series, one to three weeks after their last lesson (in the case of school 2, the

Table 4. Cronbach's alpha for each scale in the Perceptions of Space Science Questionnaire (PSSQ).

Scale	Space science as a profession		Space science and my future		Positive attitudes to space science		Preparing for work in space science	
	PRE	POST	PRE	POST	PRE	POST	PRE	POST
Cronbach's alpha	0.702	0.782	0.689	0.706	0.714	0.833	0.412	0.697

interviews were held after the Christmas break, so there was more time in between the end of the lesson series and the post-interviews). The questions in the interview were informed by literature on perceptions of space science (DeWitt & Bultitude, 2020) and sense of belonging (Aschbacher et al., 2014; Master et al., 2016; see Table A2 in Appendix I for an overview).

The interviews were first read several times by the first and fourth author to uncover main themes from the data. The main code categories were constructed using the framing of the interview questions (Table A3 in Appendix I). The interviews were coded in Atlas.ti version 8. After segments of text were assigned to a main code category, we aimed to find subcategories of these main codes using a conventional content analysis approach (Hsieh & Shannon, 2005). In the first round of coding, we stayed close to the original wording of the respondents (a method called *in vivo* coding – see King, 2008). These codes were then grouped into several meaningful clusters that were revised by the first and second author of this paper until consensus was reached. The codebook including code descriptions can be found in Table A3 in Appendix I.

Retention data

We also administered a short survey in June 2020 to the classes that had participated in the study in November-December 2019, approximately six months after the last lesson. Two out of the three classes responded by having the children fill out open questions in a written survey, resulting in 32 completed surveys. These data were handled as supportive, supplementary information, as they are not of sufficient quality to draw any strong conclusions.

Results

Children's perceptions of space science

Survey data

Analysis of the quantitative data from the Perceptions of Space Science Questionnaire showed that children overall had positive attitudes towards space science, but did not have any clear aspirations to work in space science themselves in the future (see Table 5 for the mean scores on each scale). Three of the four scales did not statistically differ in the pre- and post-test. The only scale that showed a significant increase was Space science as a profession ($p < 0.001$). This means that in the post-test, children were likely to agree more to statements like 'It is important that people from many different cultures work in space science'. The scale Attitudes towards space science already seemed quite positive in the pre-test ($M = 4.07$; $SD = 0.79$), indicating a general positive stance of children towards space science. The least positively scored scale was Space science and my future ($M = 2.9$; $SD = 0.91$), indicating that in general, students were not positive but also not very negative towards a future in space science. No significant differences between the perceptions of space science between boys and girls were found. Grade 5A from school 2 was the only class in which the scores of the children's aspirations for their future in space science in the PSSQ increased significantly after the lesson series.

Table 5. Pre and post scores on all four scales of the PSSQ of children from all three classes.

Scale	Number of students <i>n</i>	PRE		POST		Difference <i>p</i>
		mean	sd	mean	sd	
Professions in space science	53	3.61	0.70	4.09	0.66	0.000266
My future in space science	62	2.73	0.12	2.90	0.91	0.126
Positive attitudes to space science	64	4.07	0.79	4.02	0.81	0.58
Preparing for work in space science	63	3.82	0.79	3.81	0.85	0.966

Interview data

Qualitative data from interviews support the results from the PSSQ that children came to view space scientists as a more diverse, international group of people: ‘People from different cultures. And they are men and women’. Also, after following the lesson series the children could name a lot of different possible professions within space science, like ‘designing space suits’, ‘designing a rocket ship’, ‘an astronomer’, ‘a scientist’, ‘a mathematician’. Although children recognised that space science professionals could be different kinds of people, stereotypical perceptions were also still common in about half of the boys and girls who were interviewed: ‘they don’t have any hobbies outside of work’, ‘they wear glasses’. Children mentioned different skills and characteristics of space scientists, the most mentioned ones were that space scientists were smart, had to work hard, studied at university, and were good at working with others. Students also expressed their own affinity with different occupations in space science, mentioning that it would be fun to be an astronaut or to do experiments, or that it would be scary and exciting. Lastly, some students also talked about the impact the lesson series had on their perception of space scientists: ‘At first, I thought astronauts only went to space to do tricks. Now, I know that they do experiments’. An overview of all code categories can be found in Table A3 of Appendix I.

The interviewed children held mostly positive perceptions of space science after the lesson series. Children were asked about their dominant, first association with space science. Often, they associated space science with topics such as ‘universe’, ‘stars’, ‘planets’, ‘astronauts’ or ‘a rocketship’. Most children mentioned they perceived space science as ‘interesting’. We elicited the impact of the lesson series by asking children whether their opinion about space science had changed compared to their previous perceptions: ‘Before, I found space science boring. But now that I know a lot about it, it’s actually quite fun’. Most students stated that the lesson series had had a positive impact on their perception of space science: relatively more girls did so than boys. Children also mentioned different media that had an influence on their perception of space science: ‘Sometimes on TV, you see that people are talking very long when the topic is about space science, and then you find it boring’.

Children’s sense of belonging in space science

Negative belonging

Feelings of negative belonging (i.e. feeling that one does not belong) in space science could be attributed to a number of different reasons, appeared from the interviews. Firstly, children mentioned that they would not find it nice to work with ‘all people doing all different things’, they ‘don’t want to be distracted by others’, they ‘have different hobbies’, and they

'think differently than space scientists'. Secondly, children mentioned that they already have other career plans, and the most mentioned reason was that they 'would not like to go into space themselves'. Relatively more girls (44%) than boys (30%) mentioned at some point in the interview that they would not find space science fun. Thirdly, some children felt like they would not belong because they believed they could not succeed in space science. The fourth reason, mentioned by five children, was that they wanted to be with their family or friends, implying that they thought working in space science meant being away from your loved ones, or not being able to be with their friends: 'I would not feel at home, because I don't know the people [...] I would feel at home with friends'. Upon asking this pupil whether she thought that she could become friends with other space scientists if she was going to work there, she answered 'Yes I think I could. And then I would feel at home'. Relatively more boys (40%) than girls (13%) mentioned this reason. Lastly, there were children that could not imagine themselves doing space science, because they were not doing the same thing as space scientists at this moment in their lives.

Positive belonging

Positive feelings of belonging in space science were also related to a number of reasons mentioned in the interviews. Firstly, children stated that space scientists were similar to them, for example because they had similar skills or characteristics ('I think I am quite like space scientists, because they are curious and so am I'), similar hobbies ('I am quite like a space scientist, because the woman in the video also was a fashion designer, and that is also my hobby') or a similar background ('That girl, her father came from Curaçao, and her mother from the Netherlands. And my mother comes from Curaçao, and my father from The Netherlands'). Thirty percent of the interviewed boys mentioned this reason, and 81% of girls. Secondly, children stated one of the reasons to feel like they would belong is because they find space science fun or interesting, and they would like to discover things. Again relatively more girls (94%) than boys (70%) mentioned this reason. Thirdly, children expressed confidence in their ability to succeed in space science: 'I would really be at home in space science, because when I work there I will also learn more about it'. Girls more often expressed this confidence: 81% of girls thought of themselves as potentially capable, opposed to 60% of the boys. Within the fourth reason, children mentioned that being in space science would be cool and would earn them status. Lastly, children mentioned that they would like to work together with others: 'I especially like that you can work together that you can tell your ideas to each other'.

Retention data

The open survey, filled out after six months in Grade 5 in school 1 and Grade 5A in school 2, showed that most children still had positive perceptions of space science and stated they found it fun or interesting. Only in Grade 5A there were a few children (2 boys and 2 girls) who stated they found space science boring or not fun. A few of the children were still interested in a future in space science. Of the children who were not interested in space science, many answered that they were simply not interested, it was too hard for them, or not 'their thing'.

Discussion

With our study we gained insights into the impact of a lesson series about cutting-edge science designed with girls and underrepresented minorities in mind on children's perceptions of (professions in) space science and children's sense of belonging in space science.

Children's perceptions of space science

The results from the questionnaire and the interviews with the Grade 5 students in our study clearly showed that they perceived space science professionals as a more diverse group of people (in the sense of gender and culture) than before the lesson series. Showing children a wide array of examples of professionals working in space science and emphasising diversity in terms of gender, cultural background, educational background and hobbies worked to stimulate a more diverse perception of who can be a space scientist. However, children's attitudes towards space science in general did not seem to change after following the lesson series, as they were already quite positive to begin with. These positive attitudes towards space science in both boys and girls are similar to the findings of DeWitt and Bultitude (2020), who used a similar instrument to determine perceptions of space science among primary school children in eleven European countries. A finding that did not correspond with the results of DeWitt and Bultitude (2020), was that in our study there were no differences in future aspirations in space science between boys and girls. DeWitt and Bultitude (2020) found that in general, boys were more positive towards a possible future in space science, a finding that has been reflected by other studies about STEM (Archer & DeWitt, 2017; Buccheri et al., 2011). For the children in our sample, this was not the case. In our sample there was no significant difference between boys and girls related to future STEM aspirations. The qualitative data also did not reveal any differences between boys and girls regarding future aspirations in space science, even relatively more girls than boys mentioned to be interested in a space science career in their interviews. Possibly, the lesson series showed the children that both men and women can become space professionals. However children mentioned that intellectual attributes, like cleverness or smartness, as characteristics they associate most often with space scientists.

In the interviews, it was notable that after the lesson series in which children were encouraged to think about possible other professions in the space industry, the most mentioned profession was still 'astronaut'. This is apparently the first image that comes to mind when thinking about space scientists. Also, it was surprising that only one child mentioned the term 'black hole' as an association with space science, seeing as we asked this question after they had followed the lesson series. Perhaps images that first come to mind when children think about space in general are already quite consolidated in their minds, possibly through the media. They even brought this up themselves, mentioning for example television programmes or YouTube as a source of forming an image of (space) science. The way scientists are depicted by the media influences the way we perceive scientists (Cheryan et al., 2013). Since traditional media and even educational materials often depict scientists in a stereotypical way (Chimba & Kitzinger, 2010; Kerkhoven et al., 2016; Weingart et al., 2003), this could have an

influence on young children's perception of scientists. Our findings suggest that even children of 9–11 years old (or even younger; see for example Newton & Newton, 1992) already have consolidated images of (space) scientists, even though they might have never encountered one in real life.

Children's sense of belonging in space science

After following the lesson series, the interviewed children could state quite well the reasons whether they would or would not feel at home within space science. The lesson series gave them a clearer image and framework of what it is that space scientists do, and based on that information they could make the choice of whether or not it was something they aspired for themselves in the future. Quite some children also mentioned they felt they were similar to the professionals featured in the lesson series, because they had similar hobbies, like fashion or sports. This indicates that it is important to provide children with information about who a professional is as a whole person, professionally and privately, so that they can more easily identify with someone than if only someone's professional life was emphasised. It was a striking finding that in the interviews, 81% of the girls mentioned this similarity to the space science professionals, as opposed to only 30% of the boys. This could have to do with the fact that three out of the four professionals in the videos in the lesson series were female. We cannot know for certain whether this is the cause for this difference between boys and girls in our sample, but we do know that previous studies have found that a lessened sense of belonging of girls in STEM fields correlates with the presence of stereotypes (Good et al., 2012; Stout & Blaney, 2017). The results of this study are an encouraging sign of what it will mean for girls when we include more female role models in science education. It is also an encouraging finding that after the lesson series, almost all girls from the interview sample felt like they could be a space scientist if they wanted to, or found space science fun or interesting. A previous study of Walton and Cohen (2011) also described the positive effects of an intervention to increase Afro-American students' sense of belonging, along with positive impact on academic achievement and health.

Recommendations

Based on our results and on the process of co-creating the lesson series, we formulated a number of implications for interventions. First, schools and science educators and communicators should challenge the well-known stereotypes already with very young children, because students who hold stereotypical images of scientists may not aspire to pursue a scientific career (Archer & DeWitt, 2017; Gardner, 1980). Second, our study showed how a lesson series including diverse images of role models showing their lives as well as their profession may be able to increase a sense of belonging among all students, since this may have a substantial positive effect on involving girls and minority groups in science. Further research could focus on measuring the impact of such interventions through pre- and post-measures. Third, previous research (e.g. Dawson, 2018) has shown that including creative and active learning opportunities in science projects may also be beneficial, because if children see that this is also 'what counts' as science, it might help them to imagine a broader spectrum of people 'who count' in science as

well. Last, Vossen et al. (2019) and Brophy (2004) show that giving children autonomy within the boundaries of the design project in the lesson series may stimulate their own engagement, motivation and self-efficacy.

An intervention through a lesson series will likely not be able to change entire attitudes among children, since those are often too steady and robust. However they contribute to small increments in the shift of attitudes, so adding up different interventions like this one may have a long-term cumulative impact.

Notes

1. <https://www.cbs.nl/en-gb/background/2018/47/socioeconomic-status>
2. <https://echo-net.nl/>
3. <https://www.vhto.nl/>

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