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Interventions in education to prevent STEM pipeline leakage

Anniek van den Hurk, Martina Meelissen and Annemarie van Langen

Department OMD, University of Twente, Enschede, Netherlands; KBA Nijmegen, Nijmegen, Netherlands

ABSTRACT

The so-called leaking STEM pipeline (dropout in STEM education) has been the subject of many studies. The large interest of scholars in plausible causes of this leakage has resulted in a number of meta-reviews describing factors at system, school and student level related to interest and persistence in STEM education. The STEM pipeline discussion has also resulted in a large number of programmes aimed at enhancing STEM interest and persistence in STEM education. Although these programmes have been widely evaluated, there seems to be no consensus about which interventions are successful in raising interest in STEM or persistence in STEM education. This study reports the results of a systematic review of empirical studies in which the effectiveness of STEM-related interventions are assessed. Initially, 538 studies were found. The quality analyses showed that only a few of these evaluation studies are designed in such a way that it is likely that the found effects are caused by the intervention. Although some potentially effective interventions were found, this review shows that there is still a need for research into the effectiveness of those programmes, especially with regard to programmes preventing talented and initially motivated STEM students to drop out of STEM education.

INTRODUCTION

Despite several initiatives to increase the interest of Dutch students for STEM (Science, Technology, Engineering, and Mathematics), enrolment of students in STEM education in the Netherlands is still low compared to that of most other western countries (OECD, 2016, 2017). Recent data have shown that a substantial part of Dutch students who initially show talent and interest in STEM, eventually leave education with a non-STEM-related diploma or choose a non-STEM-related programme in tertiary education (TechniekPact & Platform Bèta Techniek, 2016).

Furthermore, in both the Netherlands and other western countries, there are still large gender differences in the participation in STEM education and STEM-related careers. Enrollment data regarding students at different levels of education show that in most western...
countries girls are no longer lagging behind boys in the attained educational level (OECD, 2015). In the Netherlands, on average girls attain a higher educational level at the end of their school career and show lower retention and dropout rates than boys (Van Langen, Driessen, & Dekkers, 2008). However, figures about the so-called horizontal participation in education demonstrate a very different picture. In all levels of education, female students are still underrepresented in Science, Technology, Engineering, and Mathematics (STEM) programmes (Microsoft, 2017; OECD, 2016; TechniekPact & Platform Bèta Techniek, 2016). Furthermore, more girls than boys drop out of STEM education during their educational careers (Miller & Wai, 2015; Van Langen, Elfering, & Hilkens, 2018).

This phenomenon is often referred to as ‘the leaking STEM pipeline’ (Alper, 1993; Berryman, 1983). It is a metaphor for the trajectory from early interest in STEM and enrollment in STEM programmes to the first steps into the labour market. During the educational career, there are several formal and informal choices to be made by students, offering the opportunity to switch educational programmes. These choices are often, especially among female students, to the detriment of STEM courses, hence the metaphor ‘the leaking STEM pipeline’. Some researchers recommend using different metaphors for example STEM trajectories or pathways (Cannady, Greenwald, & Harris, 2014). They argue that the pipeline metaphor suggests a linear and traditional process and does not justice to the multidimensionality of the process.

Another point of discussion is how to define STEM. Although the abbreviation clearly distinguishes what STEM is: Science, Technology, Engineering, and Mathematics, there seems to be no consensus about which more specific courses and professions are part of STEM. Most researches also place ICT-education and ICT-related jobs in the STEM category (Stoeger et al., 2016). Others suggest to include health sciences (e.g. Wallace, Perry, Ferguson, & Jackson, 2015) and even social sciences (e.g. Schultz et al., 2011). In line with the majority of studies, this study focuses on natural sciences – without health science – technological science, engineering, mathematics and ICT or combinations.

Recent data show that in the Netherlands the STEM pipeline is leaking even faster than in other western countries. The percentages of graduating girls in upper secondary vocational STEM-related programmes are below the OECD average (OECD, 2016). This is, even more, the case for the enrolment of girls in tertiary STEM education and the percentages of Dutch females leaving tertiary education with a STEM-related diploma (OECD, 2016). In today’s society where knowledge and skills in STEM could provide a secure future on individual, societal, and economical level, and where there is a shortage of STEM-trained professionals, it seems a waste that a part of the STEM potential, female and male, is ‘lost’ during the school career. Although this is specifically a problem in the Dutch context, other (western) countries also struggle to motivate young people for STEM education and careers. This emphasises the need for a broad search into existing research to determine what interventions can help to repair this persistent problem.

In the past few decades, there has been an extensive amount of research focusing on the enrolment, attainment and persistence in STEM education (Kelly, 2016; Wang & Degol, 2013). The majority of these studies is aimed at finding possible explanations for the low entry rates and dropout rates, specifically among girls, for STEM education. These studies have resulted in a number of meta-reviews and theoretical models describing factors at environmental, school and student level that are related with interest and persistence in STEM education (e.g. Wang & Degol, 2013). Insight in these factors is an
important prerequisite in repairing the leakage in the STEM pipeline, as it can be used for the development of interventions to raise interest and to prevent dropout of STEM courses and programmes. However, most studies and meta-reviews in this field offer suggestions for such interventions, but do not assess the effects of these interventions (e.g. Eccles & Wang, 2016). By conducting a systematic review of the literature, the aim of this study is to find interventions that have proved their effectiveness in raising interest and preventing students dropping out of STEM education. The research question of this study is: What kind of interventions are successful in raising interest and persistence in STEM education among girls and boys, according to the research literature?

This systematic review is based on the method described by Petticrew and Roberts (2006). For the description of the results of this review, a theoretical model was used, based on the outcomes of recent meta-reviews of studies focusing on factors influencing the interest in STEM and persistence of students to stay in the STEM field.

**Theoretical framework**

The low participation of especially females in STEM education has been subject of many studies in the past thirty years. This has resulted in a number of meta-reviews and theoretical models trying to explain the low interest and persistence in STEM education. Based on the outcomes of four recent and relevant meta-reviews, this section presents a theoretical framework to guide the systematic review. The meta-studies are published in the last twelve years and cover a wide range of research focusing on factors related to (gender differences in) the interests and persistence in STEM education (Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016; Wang, Eccles, & Kenny, 2013). The factors mentioned in these reviews can be categorised into three levels: environmental factors, factors at the school level and factors at the student level. Most scholars assume that these factors are not only correlating with the interest or persistence in STEM education but that they are also interrelated (Blickenstaff, 2005).

**Environmental factors**

Environmental factors steering students in or out of STEM education have been the subject of several studies. Stereotypes about gender and STEM not only influence the students themselves as well as their teachers and study advisors (see below), but also peers, family and future employers (Kelly, 2016). As a consequence, girls might experience less encouragement and support to excel or to choose STEM-related educational programmes and careers. Parental beliefs and behaviour can both promote and discourage students into STEM education (Kelly, 2016; Wang & Degol, 2013). The lack of female role models can also decrease the sense of belonging in STEM for STEM students and students considering STEM education (Blickenstaff, 2005). Cultural and societal beliefs, policy and economical and work-related developments should also be considered as an influence on students’ behaviour. As several large-scale studies state, the differences between countries in amount of students intending to pursue an education or career in STEM are visible (e.g. Microsoft, 2017). These cultural differences should also be taken into account in reviewing the interventions, while some interventions can be effective in one context and have no effect in others.
Factors at the school level

In the meta-reviews, empirical support was found for the assumption that the curriculum in STEM courses is particularly focused on ‘masculine’ subjects and is therefore less appealing to female students (Blickenstaff, 2005; Wang & Degol, 2013). Some studies conclude that the instructional approach of STEM teachers tends to be more in favour of boys. For example, girls are more likely to use cooperative techniques to learn and this is not often provided in STEM classrooms (Kelly, 2016; Wang & Degol, 2013). Last, STEM-gender stereotypes can influence teachers and study advisors to be (subconsciously or openly) prejudiced that women do not belong in the STEM world. This biased view can lead to less encouragement for girls to pursue a school career in STEM and a negative social atmosphere towards girls following STEM programmes. This so-called chilly climate has a negative influence on their sense of belonging and of competence (Eddy & Brownell, 2016; Kelly, 2016; Wang & Degol, 2013).

Factors at the student level

The student-related factors are covered in all meta-studies under review. These factors consist of cognitive characteristics, such as (academic) ability and achievement, background characteristics (e.g. gender, socioeconomic status), and affective characteristics, such as self-efficacy, motivation, belonging, and engagement (Eddy & Brownell, 2016).

The STEM ability or aptitude of students is probably the most discussed explanation of the gender gap in STEM education. The review studies by Blickenstaff (2005), Ceci and Williams (2010), Eddy and Brownell (2016), and M. T. Wang et al. (2013) hypothesise that the gender gap in participation in STEM education is caused by the lower performing rates of female students in STEM assessments compared to male students. However, in all four meta-reviews it is concluded this is not always the case, and that even if a gender gap in STEM ability is found, this difference is too small to have such an impact that it could explain the gender differences in STEM participation (Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016; Wang et al., 2013). Eddy and Brownell (2016) also conclude that the validity of the results in research on STEM ability is questionable. Different methods and measurements used in these studies make the data poorly comparable. For example, some studies base their statement about STEM ability on mathematics results and others on physics or biology results or a combination. In spite of these doubts, international large-scale studies show that the STEM ability of boys and girls in primary and secondary education is on average equal or slightly in favour of boys (Mullis, Martin, Foy, & Hooper, 2016; OECD, 2015). This observed difference in ability is too small to account for the large difference in STEM participation. However, studies have also shown that amongst the top performers in STEM subjects, boys are in the majority (Ceci & Williams, 2010; OECD, 2015), possibly explaining (part of) the gender gap in STEM participation.

Wang et al. (2013) have explored a totally different perspective on the relationship between gender differences in STEM ability and gender participation. They suggested that the underrepresentation of females in STEM education can be (partly) explained by the higher level of verbal ability of girls compared with that of boys. More girls than boys seem to show a combination of both a high STEM ability and a high verbal
ability. Large-scale international studies such as PIRLS and PISA show that on average girls outperform boys in reading literacy in most countries (Mullis, Martin, Foy, & Drucker, 2012; OECD, 2014). This means that talented girls in STEM have more options; they can choose from a wider range of educational programmes and professions (STEM- and non-STEM-related) than talented boys in STEM (Wang et al., 2013). Other factors explained below can make that these girls tend to choose non-STEM pathways.

Next to gender, other background characteristics are also related to the interest and persistence in STEM education. It is found that students from minority backgrounds and/or with low socioeconomic status (SES) are less likely to pursue a career in STEM education. Students with highly-educated parents and/or higher SES more often choose STEM courses and persist longer in STEM education (Eddy & Brownell, 2016; Wang & Degol, 2013; National Science Foundation, 2017). These factors underline the intertwining with the environmental factors, as explained by Blickenstaff (2005).

Eddy and Brownell (2016) explored in their meta-review the role of affective factors and engagement. Affective measures include self-efficacy, sense of belonging, and science identity. Wang and Degol (2013) added motivational beliefs, such as occupational and life values as an important part of the decision-making process to pursue STEM education or STEM-related careers. It is found that the self-efficacy, belonging, and science identity of girls tend to be lower than those of boys, influencing their choice whether or not to pursue STEM education (Eddy & Brownell, 2016; Kelly, 2016; Wang & Degol, 2013; OECD, 2015). Female students consistently perceive their STEM competences lower than male students (Wang & Degol, 2013). Furthermore, Blickenstaff (2005) and (Microsoft, 2017)found that these gender differences increase with age. Among primary school students, the difference in self-concept and science identity between boys and girls does not yet exist or is negligible.

**Theoretical models for participation or persistence in STEM**

Based on the outcomes of their review, both Wang and Degol (2013) and Eddy and Brownell (2016) developed a theoretical framework that shows potentially influencing factors on the participation in STEM education.

The meta-reviews (Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016; Wang et al., 2013) and the theoretical models offer an overview of factors that are related to or may explain (gender) differences in participation in STEM education. A distinction can be made between factors that are (to a certain extent) malleable such as school and environmental factors, and factors that are not malleable, such as SES or student aptitude. Insight in factors that could be influenced to increase the participation and persistence in STEM education and in factors that are not malleable but should be taken into account, is an important prerequisite in the development of interventions aiming at increasing the interest and persistence in STEM.

The focus of this study is to find successful (based on empirical evidence) interventions at the student, school or environmental level to raise interest in STEM or prevent dropout in the STEM pipeline. The outcomes of the meta-reviews (Blickenstaff, 2005; Ceci & Williams, 2010; Eddy & Brownell, 2016; Wang et al., 2013) and the existing models (Dekkers, 2007; Eddy & Brownell, 2016; Wang & Degol, 2013) were used to develop a framework to
guide the description of the results of this systematic review. The framework used in this study is presented below (Figure 1).

The framework is divided into several sets of factors mediating and moderating the process of making educational choices and persisting in STEM education. The arrows in the framework represent the assumed direction of influence of the sets of factors. The social context domain encompasses national, regional and cultural factors, such as the national educational policy, cultural environment (Blickenstaff, 2005), and economy. It is assumed that the social context influences the academic choices and persistence in STEM education by influencing the school context, social environment and/or student characteristics (Dekkers, 2007). Next, the school context refers to the educational policy on the school level, school climate and teaching pedagogy (Dekkers, 2007; Wang & Degol, 2013). The school context is assumed to influence the student characteristics. The social environment includes the parents (family) and peers. Both the support and view of parents and peers, and the background and socioeconomic status are taken into account (Wang & Degol, 2013). Then, in the student characteristics domain, the motivation, attitude, preferences, performances, and behaviour of the students are combined. Both the student characteristics and the academic ability and aptitude directly influence the educational outcomes (Eccles, 2009). These are the persistence in STEM education and educational choices. The latter describes the level of education attained, for example, vocational secondary education or university.

**Method**

Where many previous studies on the participation, dropout and gender gap in STEM education can be characterised as correlational or explorative research with suggestions for possible interventions, this review focused on the effectiveness of programmes aimed at increasing the interest and persistence in STEM. The research question that guided this systematic review is: What kind of interventions are successful in raising interest and persistence in STEM education among girls and boys, according to the research literature? A
systematic review is selected as a method to give a comprehensive view of the research on interventions in STEM education.

The systematic review is based on the method described by Petticrew and Roberts (2006). The review included an extensive search of different research databases, a selection of publications based on inclusion and exclusion criteria; a quality assessment; and a content analysis of the studies finally selected. First, the search process, inclusion criteria and review of the scientific quality will be explained.

**Search process**

The search for this systematic review was carried out in August 2017. First, an electronic search of four databases: ERIC, PsycINFO, Web of Science and Scopus, was conducted. Several combinations of search items were tested preparatory to the final search. It showed that these studies use a rich vocabulary. The search keys that seemed to yield the most relevant results were Science, Technology, Engineering, Mathematics (STEM), dropout, retention, persistence, motivation, attitude, intervention, programme, evaluation and combinations of these. These search keys were used for each database. Any possible differences in spelling (i.e. correct spelling) were also included in the search keys. The electronic search showed that a relatively large amount of intervention studies was reported in the *Journal of Science Education and Technology* and in the *Journal of STEM Education*. Therefore, also a manual search of these two journals was conducted. Finally, the reference sections of the studies that met the criteria for inclusion (see below) were explored. Despite this, it is still possible that relevant publications are missing in this review. However, the number of publications that met the inclusion criteria seems to be sufficient to report general trends and to be representative of this research field between 2005 and 2017.

Based on the electronic search, a pilot of the review was conducted to evaluate the usefulness of the systematic review, to assess the number of relevant studies and to evaluate the usefulness of the selection criteria (Petticrew & Roberts, 2006). The pilot also determined the final order of the criteria and was used to sharpen or broaden these criteria.

**Inclusion and exclusion criteria**

The possibly relevant publications were then analysed by reading the titles and abstracts. The following inclusion criteria were used to select or exclude the studies.

1. **The study was published after 2004.** This criterion was used to diminish the chance that interventions have become less applicable due to social and educational changes over time. For example, before 2005, the Dutch educational system in secondary education was quite different, resulting in different educational (STEM) pathways for students.

2. **The study focused on primary, secondary and/or tertiary education.** The interest of most studies in this research field lies with secondary and tertiary education. Blickenstaff (2005) found that the interest in STEM is often equal for boys and girls in primary education. However, this does not mean that interventions at an early age could not have an effect on the interest and persistence in STEM later on (Wang, 2013). For this reason, primary education was included in the review as well.
The study evaluated the effects of the intervention on the interest in STEM as a school subject or as a future career or evaluated the effects of the intervention on preventing dropout from STEM education. Studies evaluating the intervention by only assessing growth in STEM content knowledge or by evaluating experiences of students with the programme itself were excluded. Often, these studies argue that improving knowledge or positive experiences with the programme will increase interest or persistence in STEM. However, if these effects are not measured (for example by attitude questionnaires or retention data) it remains only an assumption. Studies which focused specifically on certain groups such as females, minorities or other underrepresented groups in STEM were included.

The data of at least 25 respondents (students) were analysed. The pilot showed that the number of respondents in some studies was very low. To increase the chance that the study was able to draw valid conclusions about the intervention effects, it was decided to exclude the smallest studies beforehand.

The study was published in a peer-reviewed academic journal. Finally, the study had to be published in a peer-reviewed academic journal, based on information provided by Ulrichs (see http://ulrichsweb.serialssolutions.com) to ensure a certain level of quality provided in the peer review publication process.

The selected studies that met all five criteria were categorised in type of intervention, research design and used instruments.

**Quality assessment**

The selected studies were assessed on quality with the use of a data extraction form (Pet-ticrew & Roberts, 2006). The data extraction form that was used for this study consists of several categories. The goal of this review was to find evidenced-based successful interventions. With this specific goal in mind, the quality of the study is determined to a large extent by its research design. In general, only ‘experimental studies’ or ‘quasi-experimental studies’ were considered appropriate to show that the effects were caused by the intervention. However, the pilot showed that most intervention studies used a ‘pre–post one sample design’, often for practical reasons. The lack of a control group prevents causal inference regarding the effects of the intervention. Pre- and post-scores could differ for reasons unrelated to the intervention such as regression to the mean, instrumentation, history, and maturation (Marsden & Torgerson, 2012; Shadish, Cook, & Campbell, 2002). If a pre–post study used a comparison group that is not comparable to the intervention group, the effect can also be caused by selection bias (often the intervention group is self-selected or selected by teachers), and it remains unclear whether these outcomes are a programme or a selection effect. This means that ‘post-test only’, ‘post-test only with comparison group’, ‘pre/post-test design without comparison group’ or a ‘pre/post-test design with a comparison group not comparable with the intervention group’ were classified as ‘weak causal evidence’.

The pilot also showed that some studies combine a ‘pre/post-test design’ with a ‘case study design’ (mixed method). Case studies (observations, interviews) can provide very useful in-depth information about how the programme is experienced by students, their behaviour during the programme or their perception of the influence of the programme
on their future educational (career). However, because these outcomes are perceptions of changes, they cannot provide evidence for actual changes in interest or persistence in STEM due to the programme. Therefore, such case studies or mixed method studies with a pre/post-test design were classified as ‘weak causal evidence’ as well.

Two reviewers assessed the quality of the studies independently. The research design was determined by reading the whole article. Publications, in which the design was not clear or the suitability of the comparison group was questionable, were discussed by the two reviewers. If the study design was categorised as ‘weak causal evidence’, the publication was excluded from further analysis.

**Results**

**Search results**

The electronic search yielded 918 studies in total. After removal of the duplicates, books, and reports, 538 possible relevant publications were selected. After application of the five inclusion criteria, 71 studies remained. The five inclusion criteria were also applied in the manual search of the two journals and the search in the reference sections of the selected publications. The manual search added 48 publications. This means that for quality analysis a total of 119 publications were reviewed (this list is presented in the supplementary materials). Although the systematic search followed the steps of Petticrew and Roberts (2006) carefully, there is always a risk of overlooking relevant studies. However, due to the large amount of studies that were initially found, it is expected that the studies are a sufficient representation.

Most (67%) of the publications found were aimed at evaluating the effects for students’ interest in STEM education and/or a STEM career. Only 26% of the interventions were targeted at preventing dropout in STEM and 7% focused on both interest and persistence in STEM. A small part of the evaluated interventions was directed to STEM in general, however, most interventions were aimed at one or two STEM fields. Engineering- and Science-related programmes seemed to be the most popular. Circa two-thirds of the studies reported the effects of Summer Camps, covering the largest group of interventions. Other interventions are for example changes in STEM pedagogy and mentoring programmes. Many publications focused specifically on underrepresented groups in STEM: female students, minority students and/or students in rural areas. The outcomes of the interventions were often measured by (a large diversity of) attitude questionnaires towards the STEM fields in general, towards STEM as school subjects or towards STEM careers. Some of the studies measured the effects of the interventions (also) by reporting retention or graduation rates.

**Quality assessment**

As described in the method section, the quality of the publications was reviewed with the use of data extraction forms. However, the first step in the quality assessment was to describe the research design of each study.

The quality assessment showed that the majority of the studies used a pre/post-test design without control or comparison group. Many of those studies describe the
evaluation of a summer science camp. Participants were asked to fill in an attitude survey before or at the start of the summer camp and after or at the end of the summer camp. Based on the growth in the attitude of the participants, the researchers concluded the summer camp to be effective. Because of the absence of a control group or comparison group, there is a risk of several biases; for example, maturation and history. Therefore, those designs were not considered to be able to draw reliable conclusions.

In total, 25% of the studies were considered evaluation studies using a quasi-experimental or experimental design, which makes them able to draw those conclusions. These thirty studies were assessed on the quality of the design based on the following criteria: trustworthiness of the executed design, sampling and assignment of the intervention group and control group, and instrumentation used to measure the dependent variable. Only nine studies met the standards such that solid conclusions could be drawn about the effectiveness of the intervention. Most of the excluded studies lacked information about the sampling and/or the assignment of the control group and intervention group. Or the sampling design was considered as weak. For example, by purposeful choice of participants by teachers, or the choice of an existing group as a control group without controlling for group characteristics such as gender, ability and/or motivation, causing possibly unequal groups (internal threat of selection). Unequal groups make it impossible to compare results and to draw reliable conclusions about causality. The results from studies using such designs were therefore considered not convincing and were excluded from the final group.

**Content analysis**

The nine selected studies are summarised and sorted into the categories used in the theoretical framework (Figure 1). The results are presented in this paragraph.

**Social context**

Studies were categorised in the social context when the interventions were aimed at altering educational policy and/or cultural and social views. Two of the selected studies in this review were aimed at altering the social context, both attempting to influence the student characteristics (Stoeger et al., 2016; Stout, Dasgupta, Hunsinger, & McManus, 2011). Both studies were aimed at enhancing women’s motivation and attitude by providing them with female role models (as mentors). Both interventions had a positive effect on the dependent variables.

**School context**

Studies in the school context encompass interventions in pedagogy, school climate, and school-level educational policies aiming to increase retention of students in STEM education and/or increase the STEM attitude. In total, six studies were considered as evaluation studies of interventions in the school context domain. In this domain, four interventions were found to focus on improving or renewing the STEM pedagogy: Gaspard et al. (2015), Kara and Yesilyurt (2008), Lee and Erdogan (2007), and Prokop, Tuncer, and Kvasnicak (2007). For example, by using (more) ICT (Kara & Yesilyurt, 2008) or more hands-on experiences inside and outside the classroom (Lee & Erdogan, 2007; Prokop et al., 2007). Two other studies provided an (online) training programme for women and minorities aimed at retaining the participants in STEM (Bekki, Smith,
Bernstein, & Harrison, 2013; Schultz et al., 2011). Gaspard et al. (2015) focused in their 90-minute lessons on the relevance of STEM to raise awareness amongst students. All studies reported a positive effect of the intervention on students’ attitudes or intentions to pursue a career in STEM. However, one study reported an overall decline in student interest over the years albeit less for the intervention group (Schultz et al., 2011).

**Social environment**

The social environment of students includes both the familial environment, such as parents and siblings, as well as the students’ peers. It is expected that this environment influences students’ motivation and behaviour to pursue a (educational) career in STEM (Wang & Degol, 2013). One of the selected studies in this review was aimed at interventions in the social environment.

Harackiewicz, Rozek, Hulleman, and Hyde (2012) focused on the expected influence of parents in their randomised experiment. They informed parents about the positive aspects of choosing STEM courses in upper high school by providing brochures and a website, hereby attempting to enhance parents’ view of STEM and increase the communication on this subject between parents and adolescents. It was concluded that the interventions positively influence both the mothers’ perception of the value of STEM courses, the conversations about the value of STEM courses and the number of STEM courses chosen by the adolescents (p. 904). Subsequently, Harackiewicz et al. (2012) found that students’ gender did not have a significant effect and parents’ educational level was a predictor for the number of STEM courses taken by the children. The authors used the same data in a follow-up analysis to elaborate on the absence of an effect of gender on the effectiveness of the intervention (Rozek, S. Hyde, Svoboda, Hulleman, & Harackiewicz, 2014). These analyses confirmed the positive effect of the intervention on the number of STEM courses taken by the adolescents.

**Conclusion**

The leaking STEM pipeline is a significant subject in educational research for several reasons, one of which is the shortage of STEM professionals in the labour market. This phenomenon is a problem in the Netherlands as well as in many western countries. It has resulted in a large number of studies exploring the reasons for this leakage, the tendency to follow pathways outside STEM education and gender differences. Most of these studies have used a correlational design to identify malleable and non-malleable factors related to (gender differences in) enrolment and persistence in STEM education. Meta-reviews have demonstrated that these factors can be found in social context, school context, social environment, and student characteristics, and that they are often interrelated (Blickenstaff, 2005). These factors can be taken into account when interventions to address this problem are developed. However, it seems that despite the large interest of scholars in the leaking STEM pipeline, not many robust studies assessing the effects of interventions are available. The main purpose of this study was to find promising programmes aimed at increasing the interest and persistence in STEM. The study focused on the question: *What kind of interventions are successful in raising interest and persistence in STEM education among girls and boys, according to the research literature?* This research question was answered by using a systematic review of publications about the effects of
interventions aimed at increasing the participation in STEM education and preventing students from dropping out of STEM-related educational programmes. The results of the search of the literature revealed that very few published studies (n = 9) examined the effects of interventions in such a way that causal effects could be determined.

It is important to note that a systematic review always suffers from publication bias (Petticrew & Roberts, 2006). Studies with negative effects or no effects have a much smaller chance to be published, despite the fact that information about what does not work can also be important for the development of effective interventions. The data extraction form showed that the results of an even lower number of the peer-reviewed studies were convincing in terms of internal validity. Furthermore, the heterogeneity of these studies made it difficult to compare the results of the studies (Petticrew & Roberts, 2006). For example, different scales were used to measure attitude. Others used motivation, career aspirations or perceived compatibility as predictors or outcome variables. None of the studies under review were longitudinal and examined the effects for potential dropout moments, such as the transition from secondary to tertiary education or from tertiary education to the labour market. The results were also difficult to generalise because many of the studies used a convenience sample, were aimed at a specific group of students (e.g., minorities) or took place in a very specific context.

Despite all these limitations, it seems that programmes focusing on knowledge, ability, motivation and feelings of belonging could increase the interest and persistence in STEM education. These interventions can be found in a school context: change of the pedagogical approach of teaching STEM, or a support programme in a STEM programme. Other interventions focused on science mentors as ‘role models’ for potential science students to enhance their motivation and belonging in STEM, STEM oriented summer camps or involved raising awareness about the importance of STEM education among students and parents. However, the number of successful interventions and the limitations mentioned above, make it difficult to draw any general conclusions about what seems to work, or about which characteristics of an intervention are specifically effective. All studies, both selected for this review as well as those who were found to be insufficiently able to prove causal effect, reported generally (small) positive results. This confirms the importance of persisting in evaluation studies in STEM education aiming at motivating students and helping them to persist in STEM. Some remarks for further research will be given in the next section.

**Implications for further research**

The results of the meta-reviews in this research field as well as this systematic review stress the need for more empirical experimental research, specifically aimed at the effectiveness of interventions focussed on directly or indirectly increasing the interest in STEM and preventing dropout from STEM, on the short-term as well as the long-term. The amount of research that was not able to draw conclusions about causal relations on, for example, STEM interest is of such a proportion that there should be more attention towards research methodology when evaluating a potentially successful intervention. For example summer camps, being the subject of a large part of the evaluation studies that were found in this systematic review, are quite difficult to evaluate. In these studies, students are not randomly selected to be part of the intervention. Students choose to join and are therefore probably more motivated than
the students who did not decide to enrol. These studies often also lack a control group. To strengthen the evaluation method for the effectiveness of summer camps, the research design applied by Stoeger et al. (2016) could be useful. They invited students to join their mentor programme and randomly selected the participants from the register list. The rest of the students were told that they could join the programme next year, but functioned as a waiting list-control group (under the condition that they did not enrol in another STEM-related summer camp). The purpose was to have equally motivated students in both the experimental group and the control group.

Besides the relevance of more attention to research methodology (before starting the intervention) in order to draw more reliable conclusions, the definition issue should prioritised as well. Interventions are often focused on one school subject or university study or the focus is not specified enough. Therefore conclusions about STEM-interventions are more difficult to draw, although some researchers do extrapolate the effect of an intervention on one specific subject to STEM as a large group of subjects.

Also, results of several studies have indicated that students from a minority background are also more likely to drop out of STEM education and can therefore be an interesting topic for further research (e.g. Schultz et al., 2011). Another group that could profit from more attention in this research field are the (female) top performers in STEM. PISA data showed that there is a difference in achievement between high-performing male and female mathematics and science students (OECD, 2016). Whether this is caused by gender differences in ability, learning needs or other reasons such as lower interest due to the lack of role models, is not clear. It would also be interesting to explore whether an early positive exposure to STEM and more knowledge of STEM-related education and profession among parents have positive effects on the long term, especially for girls in STEM education.

Research in the past thirty years has resulted in a lot of knowledge about why many (female) students are less interested and less persistent in STEM education than in other fields of education. However, this knowledge can be more useful for the field of education if it results in actions focusing on increasing the interest and persistence in STEM education and STEM-related professions. In future studies, a comprehensive view using the various aspects of the conceptual framework should be the basis for the design of programmes and experiments with them to prevent talented boys and girls from dropping out of STEM education.

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**ORCID**

Anniek van den Hurk http://orcid.org/0000-0002-0673-6073
Annemarie van Langen http://orcid.org/0000-0001-7576-9816
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