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Study choice and career development in STEM fields: an overview and integration of the research

Cathy van Tuijl[1] · **Juliette H. Walma van der Molen**[2]

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Abstract Although science, technology, engineering and mathematics (STEM) study paths and STEM work fields may be relatively difficult and therefore not appropriate for everyone, too many children prematurely exclude STEM-related study and work options, based on negative images of the field or negative ability beliefs. In the present article, we provide an overview of the literature from different research perspectives that shows that study choice and career decisions made by young adults have their roots in earlier in childhood. In our view, the literature reviewed points to three interrelated factors that are important in the study choice and career development of children aged 8–16: knowledge, affective value, and ability beliefs and self-efficacy building. Based on this review, we argue that knowledge of the STEM field, and of the self in STEM activities, and parents' and teachers' knowledge of the early circumscription processes of children aged 8–16 needs to be broadened. Also, negative and often-stereotypical affective values adhered to STEM study choices or careers among parents and teachers need to be countered. With regard to ability beliefs, we argue that we should focus more attention on turning pupils' entity beliefs into incremental ones.

Keywords Career development · Study choice · STEM · Stereotypes · Childhood

Introduction

Several Western countries are faced with a lack of students and workers in the so-called STEM field, i.e., the field of science, technology, engineering and mathematics (STEM). Especially the underrepresentation of women, disadvantaged youngsters and ethnic

✉ Cathy van Tuijl
C.vanTuijl@saxion.nl

[1] Saxion Applied University, Enschede, The Netherlands

[2] University of Twente, Enschede, The Netherlands

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minorities in this field is cause for concern (OECD 2008; Watt et al. 2012). Although the STEM-field is broad, and not all disciplines in the STEM-field are confronted with low enrollment to the same extent, there is cause for concern in engineering, physics and mathematics studies, especially in OECD countries (Bøe et al. 2011). A variety of factors seems to contribute to the lack of interest in studies and work in these STEM fields: sociological factors related to resources for career choice, psychological factors related to motivation and interest (e.g., Chow et al. 2012; Lent et al. 1994), educational factors (e.g., Osborne et al. 2003), socio-cultural factors (e.g., Archer et al. 2014) and socio-historical factors (e.g., Schoon and Parsons 2002). These factors come from a range of disciplines and theories. To our knowledge, thus far, these different factors have not been integrated. Therefore, in the present article, we aim to provide an overview of the results from different research disciplines and attempt to integrate the factors that may contribute to STEM study and career choices.

The low interest of students in STEM related studies and work is a complex problem that needs to be solved. A substantial body of literature is available in this domain, but most scientific studies have a narrow focus or are limited to one sphere of influence (such as family, level of education, or peer groups) or to one underlying personal factor (e.g., gender or self-efficacy). Moreover, disciplines are delineated in such a way that insights from one discipline often remain unnoticed in others, e.g., through the specific scientific journals that belong to a specific domain, resulting in a fragmented body of research. Since in real-life the choice of study and work is affected by various factors, both objective and subjective, conscious and unconscious, in several spheres, it is important to integrate insights from the variety of theoretical frameworks to get a better overview of what could be done to remedy the lack of interest in STEM study or career choices. Therefore, the aim of the present article is to integrate findings from different disciplines (such as gender studies, developmental psychology, sociology) and different theories regarding career development, in order to track mechanisms that play a pivotal role in this development. Apart from our scientific interest in combining these different literature sets, it is our strong opinion that more insight into the *joint* mechanisms that may affect STEM choices is essential for educational practices that aim to promote a more positive orientation towards STEM related studies or career paths.

Studies on career choice have traditionally focused on youngsters, typically age 16 and older. However, research shows that already at an early age children may develop awareness and (stereotypical) images of and attitudes towards work environments (Gottfredson 1981, 1996; Hartung et al. 2005; Watson and McMahon 2005). These images and attitudes may have a clear impact on their career choice: they may narrow their options and especially STEM related fields might get excluded. Therefore, incorporating research with younger children into our overview was deemed important. As will be discussed in more detail below, focusing on younger children also implies that we need to broaden our view from career *choice* (something that is typically done at an older age) to career *development* (which happens at both younger and older ages). Thus, this paper aims to bridge several disciplines, each with their own restricted body of knowledge and their own readers, who may be unaware of each other's perspectives. For presentation purposes, in the present article, we identify six different theoretical and research perspectives and the major contributions of these six perspectives will be described below. Thereafter, we will attempt to integrate the findings from these perspectives, thus aiming to inform our readers about the various factors that may influence study and career choice processes of youngsters early in life and to look for better solutions to affect children's career development in a positive manner.

Study or career choice refers to a relatively restricted set of activities, such as orienting, planning and decision-making (cf. Hirschi et al. 2011) and a restricted period of time

(usually middle to late adolescence) in which choices and decisions regarding education and/or work are made. In contrast, career development refers to a longer lasting, a more comprehensive and a more dynamic view on how career exploration, awareness, interests, aspirations and expectations develop and how they are affected by societal, socio-economic, educational and family influences (Hartung et al. 2005). From a developmental framework, such as Havighurst's developmental task perspective (Havighurst 1972) or Gottfredson's (1981, 1996) circumscription and compromise model, career development is believed to start at a young age and to follow a specified order (Watson and McMahon 2005). In addition, educational aspirations and achievements before age 14 are viewed as important precursors of educational choices and occupational aspirations and attainment in adolescence (Rojewski and Kim 2003). As Pinxten et al. (2012) emphasize, the dynamic nature of career development is important because not only do interests, aspirations and expectations of children in- or decrease in the early years, but children themselves are also developing, acquiring more knowledge of the world and becoming more stable and realistic in their self-perceptions. These developments in awareness and knowledge of the world and the 'self', may set the stage for orientation, exploration, perceptions and attitudes and may steer individuals toward or away from STEM related activities, subjects, studies, and work. Therefore, in this paper the focus was broadened to important career development processes occurring before adolescence.

Factors influencing career development are broad and are often distinguished as being intrapersonal or contextual. However, such a distinction does not fit recent conceptualizations in which societal or more proximal external (family) influences are believed to become internalized by individuals. Thus, more important than a mere distinction between contextual or intrapersonal factors is the need to unravel processes through which contextual and intrapersonal factors may impact career development. The environment may influence the career development of children in a variety of ways: from biological influences (Beltz et al. 2011; Halpern et al. 2007), parenting influences (both structural factors like educational and income level, as well as process factors like role modeling and having high expectations of children) (Bryant et al. 2006), to socio-cultural and socio-historical influences (e.g., Ceci et al. 2009; Schoon et al. 2007). In addition, intrapersonal factors, such as attitudes and individual agency variables, may influence several aspects of career development. With regard to STEM, studies have focused mainly on three intrapersonal factors: interest (Nye et al. 2012), motivation (e.g., subjective task values: Watt et al. 2012), and ability beliefs (such as self-efficacy: Lent et al. 1994). In this paper, we attempt to summarize the research into the central factors from different research disciplines and perspectives. It should be noted, that our aim was *not* to conduct a meta-analysis or vote-counting review of the body of literature, since the different sets of literature and research traditions are too diverse. Rather, we set out to provide an overview of the main results from the different research disciplines, in order to gain more insight into the potential interplay of different factors affecting STEM career development processes.

Method

Search strategy

In order to arrive at a broad set of both empirical and review studies in the various research fields, two search-waves were conducted. We chose to use the two largest databases with

high impact articles: Psychinfo and Web of Science. First, a multi field search in Psychinfo was executed with broad key words, such as 'occupational interest or preference', 'occupational choice', or 'occupational attitudes'. Three restrictions were added to this search. First, since we wanted to present an updated overview of the diverse research fields, we searched for publications from the last 2 decades. Second, the focus was on study and career choice processes and career development, and therefore the search was restricted to children and adolescents. In Psychinfo we chose to search for articles that included children and adolescents between the ages 6–12 and 13–17. Finally, in order to enhance the quality of the overview, the type of publication was restricted to peer-reviewed journals. A second literature search was conducted within Web of Science with key words: 'occupational interest', 'vocational interest', 'occupational preference', 'career preference', 'vocational preference', 'occupational choice', 'career choice', 'vocational choice', 'career development', 'occupational attitude', or 'occupational aspiration', in combination with child* or adolescent*. Third, several key-review studies were used to trace relevant papers. Finally, Ovid auto alerts of Psychinfo and the Web of Knowledge search alerts were used to keep updates during our research. This search process resulted in over 2000 references. These references were saved in a Refworks data file.

In order to reduce the number of publications, additional searches within this large data file were conducted with more specific key words: 'aspiration', 'expectation', 'gender', 'stereotype', 'longitudinal', 'family', 'STEM', 'STEM interest' and 'STEM choice'. This resulted in a significant decrease of publications (to around 340). Next, several inclusion criteria were formulated. With regard to location, we included publications from the Western world including large developing countries, such as Brazil, China and Taiwan. With regard to the sample, we focused on normal developing children and adolescents in the age range 6–17 years. Special groups, such as students with visual disabilities or handicaps were excluded. Also, research conducted in specific work fields or studies (such as medicine or nursing) were excluded.

Finally, about 100 of the remaining references were used to ensure that our inclusion criteria were valid and to check the reliability of the use of these criteria by different reviewers. The main researcher and an assistant evaluated the references. There was a large amount of consensus (90 %) on whether the papers met the inclusion criteria. In the following, researchers autonomously coded the rest of the 340 papers for inclusion and only in case of doubt consulted each other until they arrived consensus. This resulted in a final body of 160 publications that met our inclusion criteria.

The 160 papers that met our inclusion criteria were coded on type of publication and, in case of empirical studies, also on research design, number of participants, age range and other characteristics. Due to a considerable overlap between articles, of these 160 publications 95 are used in our overview and approximately 80 were used to summarize in the perspectives section, together with one review study published before 1993 because of its relevance to the field, for which we did not find a more updated version, and two theoretical papers that form the basis of an often investigated theoretical model. For each of the below-described perspectives, a comparable set of publications was used, containing at least one review study or meta-analysis, including both cross-sectional and longitudinal empirical studies and covering both US and other Western samples.

Perspectives on study choice and career development

In the next section, we elaborate on the different perspectives about study choice and career development. To limit the length of the article, below we will focus on summaries of the main findings for each perspective. Additional details of the reviewed studies are presented for each perspective in separate tables in the "Appendix".

Sociological perspective

From a sociological perspective, the influence of socio-economic status (SES), together (or sometimes confounded) with race or ethnicity, on achievement and career development has been a central topic. Some groups have less cultural and social capital and children from these groups therefore have less access to (quality) education, less role-models and supporting networks, lower achievements and educational qualifications, and less knowledge of educational and vocational trajectories.

Some conceptualizations of this inequality in resources, such as Bourdieu's, stress the way external influences are being internalized as mental schemata by individuals, creating a 'socialized subjectivity' (Bourdieu and Wacquant 1992). Even though individuals are active agents in their career development, this absorption of mental schemata, transferred by social referencing groups, may restrict individuals' options in career development. Research from the sociological perspective (e.g., Vilhjalmsdottir and Arnkelsson 2003) shows that some careers are being perceived as inappropriate or inaccessible by and for certain groups (women, ethnic minorities or children from disadvantaged families). Numerous studies from a broad range of other disciplines (e.g., Rojewski and Yang 1997) also indicated that SES is significantly related to the vocational aspirations of adolescents (age 14–18). "Structural coefficients for the social demographic variables of gender, race/ethnicity, and SES indicated significant effects on adolescents' aspirations, primarily for SES" (Rojewski and Yang 1997, p. 403). More recently, Archer et al. (2014) indicated that at age 12 to13, children's aspirations are affected by social structures, such as SES and ethnicity. Cook et al. (1996) revealed that even at a younger age (8–14) inner-city boys already may have lower educational and vocational expectations and see more barriers to vocational success than their middle class peers. Educational and occupational aspirations and expectations are important motivational forces: research has shown that they are related reciprocally and may affect educational and vocational attainment later in life (Beal and Crockett 2013). With STEM related studies and vocations being considered as difficult or 'tough' (Osborne et al. 2003), it seems reasonable to assume that this may be a reason why youngsters from disadvantaged backgrounds are underrepresented in STEM studies and vocations.

Apart from sociology, various other disciplines have included SES or SES-differences in their views of career development. A model that explicitly starts from SES, but also includes a developmental approach, can be found in the work of Schoon and colleagues. Their social reproduction model refers to the transfer of resources over generations (Schoon et al. 2007) via the proximal family environment, leading children from disadvantaged homes to have uncertain career aspirations in adolescence and attain less prestigious occupations in adulthood. Starting from this contextual developmental model, Ashby and Schoon (2010) were able to show in a British 18-year follow-up study that social origin and individual agency factors of adolescents, such as career aspiration and ambition value, interacted to influence social status attainment. They also found that this

reproduction could to some extent be countered, for instance if low-income parents had high aspirations for their children. Numerous studies have shown that factors in the proximal family environment (parental beliefs, expectations and aspirations, occupational knowledge, and parenting values such as valuing self-direction versus conformity in children) can mediate the relation between SES and career trajectory outcomes, such as self-efficacy, aspirations, or occupational attainment status (e.g., Archer et al. 2012a; Bandura et al. 2001; Gutman et al. 2012; Schulenberg et al. 1984; Watson and McMahon 2005). Thus, we may conclude that the influence of SES on career development is not always direct or explicit but that it is related to family and individual agency factors and therefore should be taken into account in STEM enhancement studies or projects.

Vocational psychology

Vocational psychology has emphasized the match between individual interest profiles and type of work environment as a predictor of work-related choices. In this field, research is mainly focused on adolescents and adults, with Holland's RIASEC model as the most researched model (Spokane et al. 2000): "A dozen literary reviews and two meta-analyses of congruence research, operationally defined using John Holland's (1959) theory, continue to reveal a mixture of significant and non-significant relations between congruence and a variety of work-related behaviors" (p. 137). The RIASEC model describes six categories (Realistic, Investigative, Artistic, Social, Entrepreneurial and Conventional), which can be used to categorize both people's personality types and their vocational aspirations. Holland's RIASEC model is theoretically based on selective orientations toward social environment (People) versus the physical environment (Things) and toward Data versus Ideas. These orientations have their impact on motivation and on the development and expression of personal interests in cognitive and social activities.

Graziano et al. (2012) compared the People-Things orientation of university students in STEM and non-STEM majors and found no evidence for differences in People-orientation. However, STEM majors and men were higher in Things-orientation than non-STEM majors and women. In addition, since STEM interests decline in middle childhood, they compared the People-Things orientation in 3rd and 6th Grade children using an abbreviated self-report and a teacher report. Teachers rated boys higher in Things-orientation, as did boys in their self-report. Teachers rated girls higher in People-orientation, as did girls in their self-report. Third Grade children differed in People-orientation from sixth Graders but not in Things-orientation, although girls were lower in Things-orientation in 6th than in 3rd Grade. The authors conclude that Things-orientation of university students is more predictive for educational choices and persistence than the People-orientation. For elementary school children, Things-orientation probably contributes to (gender-typical) educational and recreational niche-picking, affecting study and career choice. Although the orientation on People versus Things has received much attention as a psychological model of career choice, its roots seem partly biological as was suggested in a study by Beltz et al. (2011) on prenatal androgens.

Although most studies in the field of vocational psychology are aimed at older adolescents and adults, some research has focused on young children's vocational development. For example, Helwig (2003) was able to follow 103 children longitudinally from age 7 to 17 and to report on the stability of the Holland codes for 65 children. The distribution of aspirations over the six Holland categories remained roughly the same from second to twelfth Grade but the majority of children had changing occupational aspirations. About a quarter of the sample had relatively stable codes over this ten-year period. By Grade 10 and

12, the majority became more stable and consistent in their choice of Holland codes. Helwig's research offers important insights into the stability and changeability of vocational aspirations in childhood, insights that can be useful if we want to modify children's vocational aspirations in favor of STEM-related vocations.

The use of Holland codes with children has been subject of critique, however. Since children's knowledge of occupations is limited, the question is whether the structure of interests in elementary school children can be appropriately assessed through occupational choices. Tracey and colleagues (1998, 2002) showed that the structure of interest was age-related: i.e., it differed for children in elementary school from those in middle and high school. They therefore developed a more age-appropriate instrument, the Inventory of Children's Activities—Revised (ICA-R), which assesses interests in activities.

The matching of personality and work fields still is an important perspective on career choice and is therefore relevant for career development. However, with regard to STEM the question is in which RIASEC categories to situate STEM vocations? Are STEM vocations considered as mainly scientific or should the field of STEM-related occupations be considered more broadly, such as also including entrepreneurial occupations such as sales manager, the hard-core scientific physics as well as artistic web design? Moreover, especially in the younger age groups (8–16), the matching of interest and personality with work fields should be viewed as a dynamic process, since interests and personality are still developing (Pinxten et al. 2012). In sum, vocational psychology has contributed with the RIASEC model and its underlying orientations on People-Things and Data-Ideas to the domain of vocational choice. Studies show that already at an early age children develop preferences toward these orientations. However, a more dynamic and age-appropriate approach is needed in the study of vocational development in childhood and early adolescence.

Psychological approaches

As mentioned in our introduction, important aspects of career development are motivational forces such as interest, enjoyment, value, and perceived competence or self-efficacy. Two psychological models in this domain have received much attention and have been extensively examined: the Social Cognitive Career Theory (Lent et al. 1994) and the Expectancy-Value Model of Motivation of Eccles (1983). Both models are important with regard to the STEM-domain since they point to core variables and mechanisms that seem to explain educational and occupational choices.

The Social Cognitive Career Theory (SCCT) is an extension of Bandura's more general social cognitive theory (Bandura 1986, 2001) and his application of this theory to career development (Bandura et al. 2001). SCCT is used to explain processes, by which people develop interests, make choices, achieve and persist in performances and experience satisfaction in educational and career-relevant contexts (Lent and Brown 2013). The core concepts in SCCT are: self-efficacy (perceived capabilities), outcome expectations (beliefs about the outcomes of certain efforts), and goals (the determination to engage in a particular activity or to strive for a particular future outcome) (Lent et al. 1994). Well-being and satisfaction were later added to the theory as the fourth component. This framework assumes self-efficacy to influence outcome expectations. Interests are assumed to develop mainly based on self-efficacy beliefs and outcome expectations. Furthermore, interests mediate the relationship between self-efficacy and outcome expectations on the one hand and goals on the other hand.

Self-efficacy is mainly determined by four sources: personal accomplishments, vicarious learning, social persuasion, and physiological states and reactions (such as anxiety) (Lent et al. 1994). According to Lent and colleagues, physiological states and reactions can filter the processing of efficacy information; i.e., people with a negative affective predisposition may pay more attention to failure than to success and despite an equal ratio of successes and failures may perceive and experience less self-efficacy than people with a positive affective predisposition.

Although the central variables in SCCT are intrapersonal and many studies use the Holland's RIASEC themes, the theory is not restricted to intrapersonal concepts. Environmental variables in SCCT include (perceptions of) distal or proximal social supports and barriers in choice options. Moreover, environmental variables may influence the development and revision of self-efficacy and outcome expectations over time. "An important point to highlight is that person inputs, such as gender, ethnicity, social class, and sexual orientation, are seen as affecting the exercise of career agentic behaviors largely indirectly, for example, via cultural socialization experiences that convey information about self-efficacy (e.g., one's capabilities to perform particular behaviors) and outcome expectations (e.g., which values are important to pursue, what can be expected if one chooses to pursue them)" (Lent and Brown 2013, p. 7). In addition, the SCCT includes a developmental notion in that variables are assumed to have differential causal weight at any given point in time.

Since the SCCT is an elaborate theory that includes several influencing factors, process variables and their interrelations, most research has tested only part of the theory and its assumptions, e.g., the mediating effect of interest on the relationship between self-efficacy and goals, or the effect of achievement or social support on self-efficacy. Overall, most of the SCCT-assumptions have been empirically supported by numerous studies, including longitudinal (e.g., Lent et al. 2008) and cross-cultural studies (e.g., Lent et al. (2003). Most studies on SCCT, however, examined samples in late adolescence: especially college students (Sheu et al. 2010). Only a few studies have included early adolescents (e.g., Ali and Saunders 2009; Fouad and Smith 1996; Jantzer et al. 2009; Turner and Lapan 2003) and therefore, information on early precursors or predictors in career development within this framework is limited.

The Expectancy-Value Model of Motivation focuses on subjective values that individuals assign to tasks or school subjects and on ability beliefs (Jodl et al. 2001; Watt et al. 2012). Eccles describes four types of values: intrinsic values (expected enjoyment or interest in a specific activity or task), attainment value (perceived importance to be competent at a task), utility values (perceived usefulness of a task in obtaining rewards or facilitating the achievement of goals) and perceived cost (in terms of effort and evoked emotions, such as fear of failure). Together, these values form intra-individual hierarchical patterns that may predict subsequent educational and occupational preferences and choices (Chow et al. 2012). In addition to the values, ability beliefs may predict educational and occupational choices (Watt et al. 2012). Ability beliefs (Durik et al. 2006) are sometimes referred to as success expectancies (Watt et al. 2012) or self-concept (Jodl et al. 2001) but those definitions are, in fact, the same as that of self-efficacy.

Research inspired by the expectancy-value model of motivation has illustrated how ability beliefs and values can predict achievement in several domains, including STEM (Eccles and Wigfield 2002). Several studies (e.g., Chow et al. 2012; Robnett and Leaper 2013; Watt et al. 2012) concentrated on STEM or math-related motivations in middle to late adolescence. Comparisons among Australian, Canadian and US samples resulted in somewhat different outcomes with regard to the predictive value of both (intrinsic and

utility) values and ability beliefs for math course choice among each of the samples (Watt et al. 2012). Adopting a person-centred approach and using a latent profile analysis, Chow et al. (2012) were able to show that task value membership predicted subsequent aspirations towards physical and IT-related sciences both in a U.S. and a Finnish sample of 16–18 year old adolescents. Task value research often finds gender differences in task values of STEM-related domains but in international comparisons these differences are not consistent (Watt et al. 2012). Nevertheless, the expectancy-value model has added to the body of literature of STEM-related educational and occupational preferences and choices, especially in pointing to the affective dimension of motivation. With regard to STEM-subjects, Eccles' dimension of costs or efforts is especially relevant since many pupils consider these school subjects as difficult.

Studies of gender

The lack of women in STEM related studies and fields has changed positively over the last decades but nevertheless, especially in OECD countries, women are still underrepresented in several STEM fields. In this context, gender and gender stereotyping have evoked much research and discussion. In addition to gender studies, those studies in which gender was a central variable are summarized here.

As Hartung et al. (2005) pointed out in their review, preadolescent girls have more restricted aspirations and engage less in career exploration than preadolescent boys do. One of the explanations for this finding points to gender stereotyping. Gender stereotyping reflects societal norms of personal characteristics, activities, studies, occupations and life styles (e.g., work-family balance) that are deemed appropriate for men or women. Gender stereotyping is transferred, implicitly and explicitly, through parenting, education, and the media. Research of the socio-historical context (e.g., Schoon and Parsons 2002; Schoon et al. 2007) has shown a decline in the gender stereotyping of occupations over the last decades, with an increase in women in neutral and male-dominated fields. However, gender stereotyping of work is still present, even in the young generation (e.g., Fuller et al. 2005). Miller and Hayward (2006) reported that in the UK both boys and girls (age 14–18) perceived jobs as gender segregated: i.e., jobs as either male or female-dominated. Girls perceived jobs as being more gender-segregated than males did. Both males and females preferred jobs that they saw as stereotypically gender-appropriate and dominated by their own sex. Some researchers explored the role of language in job titles as a means of creating and maintaining stereotypes in primary school children (e.g., Liben et al. 2002; Vervecken et al. 2013). Gender specific job titles are exclusionary, whereas the naming of occupations in both a male and female form seems to increase the mental accessibility of female jobholders and strengthens their interest in stereotypically male occupations. "From the perspective of trying to understand how children's gender-related beliefs about occupations develop, a particularly important need is for future work to address the question of whether language can itself create gendered beliefs about occupations." (Liben et al. 2002, p. 825).

Another line of research has emphasized values such as money, power, helping other people or family. According to Weisgram et al. (2010), work fulfills personal values and these affect occupational interests both for children, adolescents and adults. Values differ between men and women, with men valuing money and power more and women valuing family and helping others more. Analogous to this study on work values are the studies on subjective task values (Eccles 1983; Watt et al. 2012; see section on expectancy-value model of motivation) and ambition value, defined by Ashby and Schoon (2010) as: "the importance placed on getting ahead, being promoted and being challenged." (p. 352). Like

Weisgram and colleagues, Watt et al. and Ashby and Schoon reported gender differences in these values. Women often prefer jobs that leave room for time with their family.

Using both an Implicit Association Test and self-reports, Cvencek et al. (2011) were able to show math-gender stereotypes ('math is for boys') as early as the second Grade. Boys also identified with math more strongly than girls did, and this is assumed to affect math self-concepts early in the school career. With regard to the underrepresentation of women in science, a question has been whether biological (brain structure and hormonal differences) and/or sociocultural factors account for this underrepresentation. In their extensive review, Ceci et al. (2009) show that biological evidence is contradictory and inconclusive. Among the sociocultural variables, the most powerful explanatory factor is women's preferences, reflecting free and constrained choices. Math-proficient women disproportionately prefer careers in other areas than the math-intensive job areas and, because of higher verbal competence, have more choice options than math-proficient men. Among the choices are lifestyle preferences (with women having a greater preference for a home-centered lifestyle) and interest in and valuing of people-oriented jobs.

From a SCTT perspective, Fulcher (2011) examined the influence of parent traditionality on gendered occupational aspirations among 7–12 year old children. She describes two ways in which parenting may influence gender stereotypes: through parents as role models and through building efficacy for gendered skills. Fulcher found that mothers who reported non-traditional attitudes had children with non-traditional occupational aspirations and that this association was mediated by children's efficacy for non-traditional tasks. Novakovic and Fouad (2012) in their study on adolescent girls (mean age 16) also found that background variables, such as SES and ethnicity, contributed to gender-traditionality of career choice. This gender stereotyping has been shown to be more prominent in low SES than high SES families, resulting in more restricted choice options for children and youngsters in low SES families.

Interesting insights come from Archer et al. (2012b). Using a feminist poststructuralist theoretical lens, Archer and colleagues investigated children's identification with science and how girls combine their science aspiration with gendered identity performances. Archer and colleagues interviewed a group of girls who, unlike most peers, did identify with science and who expressed science aspirations at age 10/11. This group of girls was derived from a larger research sample. The interviews were qualitatively analyzed. The researchers described two groups of girls. The first group, called 'feminine scientists', coped with the tension between science being clever and masculine versus being a girl by balancing their performances in the 'clever' (achievements) and 'girly' (socially competent, interest in fashion and sports) domain. They were successful in managing both sides of their identities. A second group, called 'bluestocking scientists', were described by their parents as 'non-girly' and extremely focused on achievement and academic success. "We suggest that the development and cultivation of science aspirations requires girls to engage in considerable identity work, not least to navigate dominant associations of science with "cleverness" and masculinity, which construct science as an elite field which is only open to women within certain narrow parameters. That is, girls have to identify with, and be able to occupy, a "clever" learner identity and negotiate a socially acceptable performance of femininity that can balance their engagement with the aspects of science that are perceived to be "masculine" (and masculine notions of "achievement") if science is to be a "thinkable" aspiration." (Archer et al. 2012b, p. 983). This research shows at a micro level how stereotypical notions and peer pressure in children's environment may color their science activities and experiences.

Educational studies

Finally, educational studies have provided a lens on study choice and career development, especially with regard to STEM related subjects. One line of research in educational studies has typically invested in research on curriculum content, design and innovation. Studies in this line of research suggest that dissatisfaction with the school (science) curriculum contributes to the lack of choice for STEM subjects and studies. According to the review study of Osborne et al. (2003), there is a need for meaningful activities in science education: activities that relate subject matter to real life experiences of adolescents. Cleaves (2005), however, suggests that dissatisfaction with the science curriculum might reflect the view of only a subgroup of students, namely those who lack confidence in their own abilities. She therefore warns not to change the curriculum solely on the basis of the perception of certain subgroups of students.

Curriculum-innovative studies in the STEM fields have focused on grouping (e.g., small groups or single-sex groups: Hoffman 2002), special schools for gifted students (e.g., Olszewski-Kubilius 2010), or collaborative and authentic learning (e.g., Meluso et al. 2012). Despite some good exceptions, such as the study by House (2009) on classroom instructional strategies and science interest in early adolescence, many of these studies are flawed in the sense that the school context is viewed as an isolated system in which other influential factors on career development (SES, gender, self-efficacy) need not be included in the designs (cf. Halpern and colleagues 2011). In addition, international research has shown that many countries face the same leaking STEM-pipeline, despite differences in curriculum design and school contexts (e.g., Rasinen et al. 2009). Therefore, curriculum-innovative studies do not provide a very promising avenue.

Teachers are assumed to have an important role in the career development of children, not only as a role model and by providing career guidance, but also as the ones who can create and stimulate interest in certain subjects and topics (Krapp and Prenzel 2011; OECD 2008). Not surprisingly, a second line of research in education focuses on teachers, teachers' beliefs, teacher–pupil interaction, training and qualifications. Research on pre- and in-service primary teachers' attitudes showed a negative attitude towards science and technology (Van Aalderen-Smeets et al. 2012). In elementary education, the fact that many (female) teachers feel uncertain and lack self-efficacy in STEM related activities may lead to stricter learning formats, which hamper exploration, pleasure, interest and deeper learning in STEM fields by students (Appleton and Kindt 1999; Harlen and Holroyd 1997; OECD 2008). "The teachers' feelings about how confident they were in teaching science, and their interest in teaching it, seemed to determine how often each teacher taught it and how he/she went about teaching it" (Appleton and Kindt 1999, p. 160). Moreover, this research line illuminated how, depending on gender and social status of the student, stereotypical beliefs in teachers may affect the opportunities, instruction and feedback these teachers offer to students (Archer et al. 2012b; Li 1999). Primary schools and their teachers therefore are assumed to play a crucial role in determining the attitudes and images of students towards science and improving primary teachers' attitudes towards science and technology is one of the major challenges in today's science education (Haney et al. 1996; Osborne et al. 2003). Professional development should therefore pay explicit attention to improving the attitude of (pre-service) primary teachers towards science and technology.

A third research line in education is on career education, guidance and counselling. Since career guidance and counselling starts in school, the timing, content and

effectiveness of these processes have been studied. In a meta-analytic study of a diverse group of school interventions, Whiston et al. (2011) found a small positive effect of career guidance. Investigating the effects of a 9-week career education program for 15-year olds, McWhirter et al. (2000) reported increased self-efficacy in career decision-making vocational skills, and short-term gains in outcome expectations. However, the educational barriers these youngsters perceived were not affected. Researchers using a developmental approach (e.g., Auger et al. 2005; Harkins 2001; Hartung et al. 2005) have emphasized the need for early career education. Career guidance is still focused on youngsters in middle adolescence, which, from a developmental approach, is too late. "Vocational development begins much earlier in the life span than generally assumed, and what children learn about work and occupations has a profound effect on the choices they make as adolescents and young adults, and ultimately, on their occupational careers" (Hartung et al. 2005, p. 412). In a relatively young group of children (Grade 4 to 7), Schmitt-Wilson and Welsh (2012) found that vocational knowledge significantly predicted vocational aspirations and expectations. However, in general, students, teachers as well as parents and school counselors seem ill-informed with regard to the opportunities and chances that further education in the STEM-field may offer (OECD 2008).

Towards a synthesis of the literature

Overall, the above-mentioned disciplines have all contributed conceptually and empirically to the field of career development. There is abundant evidence for the impact of SES on educational and occupational attainment and its mediating mechanisms (i.e., parental beliefs, parental expectations and aspirations, which seem to interact with individual agency factors, such as self-efficacy and youngsters' values). The match between perceived personality type and work environment, as measured with Holland's RIASEC model, is applicable to middle and late adolescents but seems less appropriate for children and early adolescents who are still developing views of the world or of work and the self. Ability beliefs or self-efficacy and subjective task values have been shown to influence educational and occupational choices. Gender differences in career development have received much attention with biological, (socio-) cultural and historical explanations. Several studies have shown that early developments in central variables such as self-concept or self-efficacy together with early environmental impacts may influence career choices later in life. Thus, a developmental framework is needed to grasp how early career development affects later choices. More specifically, the question is how children's preferences, their self-efficacy, and other career choice-related aspects develop and how children, already at a young age, come to perceive STEM-related study or career options as less attractive than other possibilities.

Life-span and developmental approaches

Life-span approaches of career development and developmental psychological theories have underscored that career development is a lifelong process in which children learn about the vocational world and the society at large and themselves in that world (Auger et al. 2005; Hartung et al. 2005; Vondracek et al. 1999). This approach emphasizes childhood as a formative period for career development. Learning about the world of work and the self is both conscious and unconscious and is fed by a wide range of experiences

and activities in several spheres: the family, school, leisure time and media (OECD 2008). Vocational or career development approaches nowadays acknowledge the fact that already early in childhood, parallel to their cognitive development, children learn about and form images of the world of work. Central concepts are aspirations and expectations. Aspirations are typically operationalized by the question: What do you want to be when you grow up? Whereas expectations are based on the question: What do you think you really will be when you grow up? Thus, aspirations refer to preferences about work under ideal circumstances whereas expectations take into account a child's perceived barriers and limitations. Aspirations are thought to reflect information about self-concept, perceived opportunities, interests, and hopes. One of the leading models using a developmental approach is Gottfredson's model of circumscription and compromise. Especially with regard to STEM related subjects and work domains, this model sheds light on how already in their elementary school period, children and youngsters restrict their preferences and choices based on experiences, (stereotypical) perceptions and attitudes.

A comprehensive developmental approach: the circumscription and compromise model

Gottfredson, a sociologist who worked with Holland, posited a developmental model in which the sociological and psychological perspectives are combined. According to Gottfredson (1981, 1996), career development is a dynamic interactive learning process, in which the cognitive development of children sets the pace for career development. In her developmental model, children's career choice is influenced by gender (preference for same-sex or neutral occupations), by prestige or status of occupations (preference for occupations that tune in with the social valuation in their family and environment and with their intelligence), and by personal interests in certain fields of work. Gottfredson described four phases in career development, which, depending on the cognitive development of children, can be related to age.

In the preschool and kindergarten period (age 3–5) children are focused on size and power: they perceive themselves and others in terms of little versus big, and learn that having a vocation belongs to the adult roles. Their thinking and learning in this stage is intuitive, magical. In the second, early elementary school stage (age 6–8), children's thinking develops from intuitive to concrete: i.e., they are able to define themselves and the world around them in terms of concrete and external characteristics, such as gender. In this stage, children incorporate traditional sex roles in their knowledge of vocations and hold to them in a strict, sometimes absolute, way. During the older elementary school period (around age 9–13), thinking about the self and vocations becomes less concrete. In this third stage, children become aware of and learn about social class and intelligence. They now understand that vocations can differ in prestige or social value as well as in requirements, in terms of ability and education. It is in this period that children start to delineate vocations for themselves. In the final phase, 14 years and older, youngsters make a shift to more abstract and more complex thinking. Adolescents become aware of and explore unique personal interests, values and competencies. They develop a notion of work fields and how their self-concept is related to these work fields.

Central in Gottfredson's model is the idea that development of self-concept and preferences becomes more complex but also more clearly delineated. Circumscription refers to children's or adolescents' narrowing of choices based on compatibility or suitability of occupations with images of themselves, whereas compromise refers to changes in preferences based on perceived accessibility: more accessible options replace inaccessible

occupations. Finally, in adolescence, occupational aspirations represent the joint product of an individual's assessment of job compatibility and accessibility. Evidence for the circumscription and compromise model is substantial, both in longitudinal studies spanning 10 years or more (e.g., Helwig 2008; Lee and Rojewski 2009) and in shorter longitudinal studies (e.g., Armstrong and Crombie 2000). Some stages, however, seem more prolonged than depicted by Gottfredson, especially for boys (Helwig 1998a), and the evidence for children to think more gender-stereotypical with age is inconsistent (Helwig 1998b).

According to Gottfredson (1981, 1996), circumscription, or elimination of alternatives, is irreversible: once rejected, options will not be reconsidered spontaneously. Especially in stage three, both vocations that are perceived as too difficult and those that are considered to be too low in status are excluded. In this process of circumscription, the boundaries are determined by self-evaluations of abilities and motivations together with what is defined as success in one's community, expectations of other people and personal factors, such as interests and values. Depending on traditionality of values, children incorporate mainly same-sex or gender neutral vocations, although research shows that boys restrict their choice more than girls to same-sex dominated fields. In this way, children create a self-defined social space that consists of acceptable alternatives. This social space will be the starting point for the next stage. It should be noted that early in life, children not always have sufficient or valid information about their abilities and talents or of the working world. Evaluating the match between images of oneself and occupational images is even more cognitively demanding. Therefore, exclusion of options is premature, but nevertheless occurs. According to Gottfredson, this elimination process is gradual and implicit; i.e., difficult to report spontaneously although it affects beliefs and behaviors.

Stereotypes and images of the STEM field

Gender stereotypes have received much attention (see our section on studies on gender). "An occupational image may potentially include many types of generalizations about an occupation; for example, the personalities of people in those jobs, the type of work they do, the type of lives they lead, the rewards and conditions of the work, and the appropriateness of the job for different types of people. Like self-concepts, occupational images can be characterized by their complexity and differentiation, and their comprehensiveness and specificity" (Gottfredson 1981, p. 547). Gottfredson assumed images of occupations, 'occupational stereotypes', to affect the narrowing of choice options. Occupational images are not limited to the activities or work environment characteristic of an occupation, but also refer to the perceived status or personality of the average worker in a particular field. Images of occupations as (fe)male dominated may result in rejection by cross-sex individuals with a traditional role view. In the same way, images of occupations may be rejected as incompatible or inaccessible in status or perceived difficulty. In some fields, occupational stereotypes are more pronounced, as is the case in the STEM-field.

According to the OECD report (2008), the image of science and technology professions is one of the main determinants of students' study and career choice, that is, of excluding these STEM professions from choice options. Although the general view of science and technology is positive, and young children are interested in science and technology up to about age 10, from around age 11 or 12 many adolescents in Western countries indicate that a study path or profession in a STEM-field is 'not for me' (DeWitt et al. 2013; Jenkins and Nelson 2010; OECD 2008). This is in contrast to developing countries where both boys and girls are more attracted to STEM fields, emphasizing how culturally dependent these stereotypes may be.

In Western countries, the image of work in the STEM field is limited in the sense that children and adolescents have only vague ideas about the daily activities that work in this field encompass (OECD 2008). Occupational images of the STEM field are static (e.g., Lang 2012), especially for girls (e.g., Archer et al. 2012b; Perez-Felkner et al. 2012), or for children from certain ethnic or socioeconomic backgrounds (Hughes 2011). The image of workers in this field is also stereotypically negative: workers in this field are considered dull and unsociable. "Young people, like their elders, have a stereotyped image that swings between the two visions of a man in a white lab coat staring intelligently at some exotic glassware full of scientific-looking liquid, or of a wild-haired eccentric solving mile-long equations but incapable of posting a letter" (OECD 2008, pp. 55–56). The perception of work environments, lifestyles and careers in STEM fields suffers from stereotypes as being isolated, with little time for family, unattractive in terms of rewards, inflexible, and having little career opportunities.

Occupational images seem to be primarily influenced by parents, other significant adults such as teachers, and the media. As with gender stereotypes and parent traditionality, images of STEM differ between low- and high-educated parents, with high-educated parents having a more positive attitude towards STEM than low-educated parents. Having parents who work in the STEM field increases the chance that students will opt for a STEM career. Probably having more knowledge of and being familiar with STEM work (and workers), activities and work environments in this field dismantles stereotypes or emphasizes opportunities. According to Cleaves (2005), there is an interplay between self-perception with respect to science, occupational images of working scientists, relationship with significant adults, and perceptions of school science. Teachers, as part of society, respond to mainly the same stereotypes as are prevalent in the general population, and therefore act on these stereotypes by reinforcing and motivating boys and demotivating girls in STEM related activities (see our section on educational studies). The stereotypes of parents, teachers and the media are deeply embedded in society and therefore not easy to change.

Related to the occupational stereotypes is the lack of knowledge of STEM studies and work. Children are still in the process of acquiring information of the world. Moreover, since teachers and career counsellors are usually not acquainted with STEM fields, they may suffer from lack of knowledge on work and workers in these fields. Especially in countries where children are tracked in educational trajectories from an early age (as in The Netherlands: age 12), essential steps in career development, such as educational profiling choices, have to be taken early, thereby risking premature and unfitting choice options.

Towards a possible solution

The problem of a lack of interest in studies and work in STEM fields is a complex problem that needs to be solved, especially if children opt for non-STEM studies and careers for the wrong reasons. One problem is the fact that knowledge of STEM choice processes is spread over several barely connected disciplines. If we really want to apply the knowledge from these disciplines to depict the *joint* factors that contribute to choice processes of real-life children, we need to connect the research outcomes of these different disciplines. In our view, only with such an approach, we may find ways to influence study and career choice processes and might be able to convince more youngsters that STEM related studies

(such as technology or design education) and vocations could be an attractive option for them.

Although STEM related studies and work fields may be relatively difficult and therefore not appropriate for everyone, too many individual children prematurely exclude STEM related options, studies and work. The synthesis of the literature, especially the literature from a developmental approach, shows that career decisions made by young adults may have their roots in early childhood. In our view, with regard to the 'leaking pipeline', the literature reviewed here seems to point to three interrelated underlying factors that are important early in the career development of children. The first factor concerns *knowledge*. Parents', teachers', and children's knowledge of the STEM field, children's knowledge of the self in STEM activities, and parents' and teachers' knowledge of the early circumscription processes between the age of 8 to 16 needs to be broadened. Students, parents and teachers should be made more aware of the broad range of vocations, activities and opportunities that the STEM field offers. In addition, children's experiences with STEM activities in primary school should be made more suitable to explore and inform them about their own interests and abilities in the STEM field. In the elementary school, from Grade 4, children start to define their social space in terms of their selves in the world of work, and parents and the educational system should be made more aware of these early circumscription processes and their impact on exploration, aspirations and expectations.

The second underlying factor that is important to tackle early in children's development concerns the *affective value* that is adhered to STEM study paths or careers. Our overview of the literature illustrates that the STEM field suffers from a negative affective value derived from the (false) idea that studies and occupations in STEM fields are predominantly 'things- and male-oriented' and form a threat to more feminine lifestyles or to a good family-work balance. This affective value component seeps in in several ways: by stereotyping activities and interests as only for boys/girls or for nerds, by attainment and utility values in education, by success expectancy or costs of efforts, and by personal values. Together with language use (e.g., occupational titles), deeply-embedded traditions in society (e.g., division of family tasks), and stereotypical feedback from parents, teachers and peers on children's activities and accomplishments the stage could be set for a negative affective perception of further education or work in the STEM field. From experimental studies (Liben et al. 2002) and socio-historical studies (Schoon and Parsons 2002), it has become clear that such perceived barriers can be overcome. Thus, we should strive towards awareness of these negative and often stereotypical affective values among parents and teachers and counter them with positive values and positive images of men and women in STEM-related work fields.

The third factor that we derive from our literature overview concerns the individual agency aspect of *ability beliefs and self-efficacy building*. Ability beliefs may influence interest, exploration and choice and, in the case of STEM-related study paths or career options, ability beliefs may be hampered by a stereotypical perception of reality. In this stereotypical perception of reality, implicit assumptions play a central role. Implicit assumptions with regard to gender and status, but also with regard to the concept of the self, such as Dweck's idea of a fixed or growth mindset (e.g., Dweck 2006). Research by Dweck and colleagues postulates that differences in responses to challenges that are observed among children, adolescents, and adults may be explained by the implicit theories that people hold regarding the flexibility of their own intelligence. The core implicit beliefs described by Dweck's motivational model can be divided into two categories: entity and incremental theories. People holding an implicit entity theory believe that their

competencies in a given area are a fixed and unchangeable entity; they implicitly believe that they are born with a certain amount of competence in a given area and cannot do much to develop this. Students with such an 'entity mindset' attribute success to their 'natural ability' and failure to a lack of this ability. On the other hand, students holding an implicit incremental theory (growth mindset) think of intelligence, or their competencies in a given area, as a quality that can be developed through effort and they attribute success to hard work and failure to a lack of effort. These implicit assumptions are transferred from an early age to children by parents, teachers and the media. In the minds of children, barriers may thus be formed against expected failures and other educational challenges, and also against incompatible and, therefore, inappropriate identity options. However, if we want to prevent students from dropping STEM subjects at school for the wrong reasons, we should focus more attention on turning their entity beliefs into incremental ones. We expect that especially those students who regard STEM subjects as complex and something you need to put a lot of effort into and who also hold an entity theory of intelligence be at risk of leaking out of the STEM pipeline.

These three aspects, knowledge, affective value and ability beliefs, seem to be interrelated, especially in education. Although we do not yet know how they are precisely related, what we do know is that primary teachers' knowledge of study or career paths in the STEM field is limited and highly affected by gender and occupational stereotypical beliefs and that this colored knowledge is accompanied by a lack of self-efficacy and insufficient training in the STEM field (for a review, see Van Aalderen-Smeets et al. 2012). Together, these aspects may lead to insufficient fostering of children's enjoyment, interest and deep learning in STEM subjects during primary education. Consequently, it could be that STEM related activities and subjects are not (or no longer) explored or chosen by children from age 11 because they are thought to be incompatible ('unthinkable') with the self-concept, thereby disabling self-efficacy building (DeWitt et al. 2013). The mechanism behind such career choice processes seems to be led by a perception of reality that is ill-informed, devalued, and stereotyped. The third dimension, ability beliefs, seems crucial since it points to recursive processes in which self-perceptions are reinforced and encouraged by the environment, or not (Van Aalderen-Smeets et al. 2015). These recursive processes, the interaction between environmental and intrapersonal variables over time, may put individuals on trajectories leading away from STEM fields. Therefore, taking into account parents', teachers' and children's perceptions of reality and the consequences of those perceptions on study or career development during the elementary years is essential to effectively eliminate barriers to STEM related study choices. Perceptions may be distorted with regard to gender, status or ability beliefs. Since those children who prematurely exclude STEM studies and careers are a heterogeneous group, interventions need to be targeted towards specific populations such as boys or girls, children from high versus low SES (e.g., Beal and Crockett 2013), or high risk populations (e.g., Doren et al. 2013; O'Brien et al. 1999).

Although the first problem, insufficient knowledge of the STEM field, seems relatively easy to solve, this will only be the case if the stereotypes and negative affective values that are connected to the STEM field are tackled. Since stereotypes and negative values are transferred from various 'spheres', such as the family, teachers, and the media and are partly implicit processes, Archer et al. (2012b) advocate to provide students and teachers with the tools to question and challenge taken-for-granted assumptions around STEM stereotypes, such as 'who does science' and 'what does doing science mean'. These spheres and their actions have to work together in order to be effective. It is probably not enough to tackle dissatisfaction with the school science curriculum (or any other isolated

factor) by bringing in fun activities if children associate these activities with nerds and do not relate these activities with a potential pleasure of working in STEM fields.

In our view, parents and teachers may play a crucial role in self-efficacy building, by exposing children to a wide range of activities and environments, providing opportunities for task and role model exposure, using a growth mindset as model, helping to build knowledge and competence in both girls and boys, and by questioning and discussing stereotypical notions surrounding the STEM field. That will not be easy. On the other hand, the field has been successful earlier: As discussed earlier in this article, intervention studies of high-risk youth have shown that children and youngsters can be supported in optimizing their aspirations and expectations and in broadening their horizons. And gender-related interventions have shown that using male and female forms of vocational titles may open up vocational opportunities for girls. In addition, socio-historical research has shown that societies are changing, e.g., the number of women nowadays working has risen the last decades, resulting not only in role models in families for both daughters and sons, but also in rising numbers of females choosing STEM studies. To speed up this process, the first step is to question and discuss stereotypes and to provide alternatives; only then can next steps, such as improving career education knowledge in parents and teachers, together with teacher training, be truly effective.

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Appendix: details of the studies that were used in our overview

References	Publication type	Design empirical study	N	Country	Age range
Sociological themes (SES, cultural capital, family beliefs)					
Schulenberg et al. (1984)	Review				
Bourdieu and Wacquant (1992)	Theoretical				
Cook et al. (1996)	Empirical	Cross-sectional	220	US	8, 10, 12.5 and 14.5
Rojewski and Yang (1997)	Empirical	Longitudinal	18311	US	14–18
O'Brien et al. (1999)	Empirical	Experimental	57	US	11–14
Vilhjalmsdottir and Arnkelsson (2003)	Empirical	Cross-sectional	911	Iceland	15–16
Watson and McMahon (2005)	Review				13 or younger
Archer et al. (2012a)	Empirical	Qualitative, first wave longitudinal	92	UK	10
Gutman et al. (2012)	Empirical	Longitudinal	21000	UK	14–18
Beal and Crockett (2013)	Empirical	Longitudinal	636	US	14–16
Doren et al. (2013)	Empirical	Experimental	111	US	14–17

References	Publication type	Design empirical study	N	Country	Age range
Archer et al. (2014)	Empirical	Cohort study, partly longitudinal	5634/85	UK	12–13
Vocational psychology					
Tracey and Ward (1998)	Empirical	Cross-sectional	739	US	10–14
Spokane et al. (2000)	Review				
Tracey (2002)	Empirical	Longitudinal	348	US	10–12
Helwig (2003)	Empirical	Longitudinal	208	US	7–17
Graziano et al. (2012)	Empirical	Cross-sectional	233	US	Study 2: 9 and 12
Pinxten et al. (2012)	Empirical	Cross-sectional	2518	Belgium (Flanders)	15
Psychological themes (interest, motivation, task value)					
Eccles (1983)	Theoretical				
Lent et al. (1994)	Theoretical and meta-analysis				
Fouad and Smith (1996)	Empirical	Cross-sectional	380	US	12–15
Jodl et al. (2001)	Empirical	Cross-sectional	444	US	14–15
Eccles and Wigfield (2002)	Review				
Lent et al. (2003)	Empirical	Cross-sectional	796	Italy	14–18
Turner and Lapan (2003)	Empirical	Cross-sectional	254	US	13–14
Durik et al. (2006)	Empirical	Longitudinal	606	US	10 and 16
Lent et al. (2008)	Empirical	Longitudinal	209	US	17–18
Ali and Saunders (2009)	Empirical	Cross-sectional	63	US	14–18
Jantzer et al. (2009)	Empirical	Cross-sectional	820	US	14
Sheu et al. (2010)	Meta-analysis				>14
Fulcher (2011)	Empirical	Cross-sectional	150	US	7–12
Chow et al. (2012)	Empirical	Longitudinal	600	US and Finland	14–18
Watt et al. (2012)	Empirical	Longitudinal	1247	Australia, Canada, US	15–16, 17–18
Lent and Brown (2013)	Theoretical				
Robnett and Leaper (2013)	Empirical	Cross-sectional	468	US	13–18
Gender					
Helwig (1998b)	Empirical	Longitudinal	208	US	7–11
Liben et al. (2002)	Empirical	Cross-sectional	64 and 51	US	6–11 and 6–10
Schoon and Parsons (2002)	Empirical	Cohort studies, cross-sectional	11016 and 6417	UK	16
Fuller et al. (2005)	Empirical	Cross-sectional and qualitative	1281 and 73	UK	14–15
Miller and Hayward (2006)	Empirical	cross-sectional	508	UK	14–18
Ceci et al. (2009)	Review				

References	Publication type	Design empirical study	N	Country	Age range
Weisgram et al. (2010)	Empirical	Cross-sectional and experimental	313 and 240	US	5–10 and 11–17
Beltz et al. (2011)	Empirical	Cross-sectional	125	US	9–26
Cvencek et al. (2011)	Empirical	Cross-sectional	247	US	6–10
Novakovic and Fouad (2012)	Empirical	Cross-sectional	217	US	14–19
Vervecken et al. (2013)	Empirical	Experimental	352	Germany and Belgium	6–12 and 6–16
Educational studies (curriculum, teachers, career guidance)					
Haney et al. (1996)	Empirical	Cross-sectional	800	US	(teachers)
Harlen and Holroyd (1997)	Empirical	Qualitative	60	UK	(teachers)
Appleton and Kindt (1999)	Empirical	Qualitative	9	Australia	(teachers)
Li (1999)	Review				
McWhirter et al. (2000)	Empirical	Experimental	166	US	15
Harkins (2001)	Review				6–12
Hoffman (2002)	Empirical	Experimental	456	Germany	13
Cleaves (2005)	Empirical	Longitudinal, qualitative	21/4	UK	13–17
Rasinen et al. (2009)	Descriptive			Finland and Germany	
Olszewski-Kubilius (2010)	Descriptive			US	
Halpern et al. (2011)	Descriptive			US	
Krapp and Prenzel (2011)	Overview				
Whiston et al. (2011)	Meta-analysis		16296		8–20
Van Aalderen-Smeets et al. (2012)	Theoretical				
Meluso et al. (2012)	Empirical	Experimental	100	US	9
Schmitt-Wilson and Welsh (2012)	Empirical	Cross-sectional	132	US	10–13
Life-span or developmental studies					
Gottfredson (1981)	Theoretical				
Gottfredson (1996)	Theoretical				
Helwig (1998a)	Empirical	Longitudinal	208	US	7–11
Vondracek et al. (1999)	Empirical	Cross-sectional	685	Germany	10–13
Armstrong and Crombie (2000)	Empirical	Longitudinal	502	Canada	14, 15
Helwig (2008)	Empirical	Longitudinal	208	US	7–23
Lee and Rojewski (2009)	Empirical	Longitudinal	26432	US	14, 16, 18, 20, 26
Jenkins and Nelson (2010)	Empirical	Cross-sectional	1277	UK	13–17
Hughes (2011)	Empirical	Experimental	46	US	10–13
Lang (2012)	Empirical	Cross-sectional	113	Australia	8–12
Perez-Felkner et al. (2012)	Empirical	Longitudinal	2990	US	16

References	Publication type	Design empirical study	N	Country	Age range
DeWitt et al. (2013)	Empirical	Cross-sectional, part of longitudinal	9319	UK	10–14
Mixed					
Bandura et al. (2001)	Empirical	Cross-sectional (first wave longitudinal)	272	Italy	12–15
Osborne et al. (2003)	Review				
Auger et al. (2005)	Empirical	Cross-sectional	123	US	6–10
Hartung et al. (2005)	Review				3–14
Schoon et al. (2007)	Empirical	Longitudinal	21294	UK	0, 16, (30, 33)
Organisation for Economic Co-operation and Development (OECD) (2008)	Empirical	Cohort study	Unknown	15 countries	15–19
Ashby and Schoon (2010)	Empirical	Longitudinal	3675	UK	16
Archer et al. (2012b)	Empirical	Qualitative, first wave longitudinal	92/17	UK	10–11

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