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Gendered study choice: a literature review. A review of theory and research into the unequal representation of male and female students in mathematics, science, and technology

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This article presents an overview of the recent literature on gendered patterns of academic choice in mathematics, science, and technology. It distinguishes in this literature micro-level, macro-level, and institutional explanations. Micro-level explanations focus primarily on psychological constructs, that is, variables at the level of the individual students. Macro-level explanations focus primarily on socioeconomic conditions and cultural understandings of gender roles. Institutional explanations focus on design characteristics of (national) education systems. After a presentation of these perspectives and of recent research progress that has been made, the authors critically discuss the lacunae that still exist in explaining cross-national variety, and provide suggestions for designing future research in this field.

Keywords: gender; education; academic choice; mathematics; science and technology

Introduction

Female participation in higher tertiary education has increased rapidly over the past decades.[1] Currently, about 56% of all students in the European Union are women, and this figure is still rising (Eurostat, 2010). Yet, this increase in female student participation does not apply to all academic fields. In mathematics, science, and technology (MST), where women have always been underrepresented, their participation rate has actually decreased over the last years, from 41% at the end of the 1990s, to 38% in 2010 (Eurostat, 2010). The relative decline of women in MST is generally regarded as undesirable as it contrasts with European ambitions of achieving gender equality and a highly skilled, innovative society (European Commission, 2007, 2008, 2009a, 2009b, 2010a, 2010b, 2012; Organisation for Economic Co-operation and Development [OECD], 2006a).

Where in the past the unequal representation of female students in mathematics, science, and technology used to be explained as a result of a lesser aptitude of women for these subjects, thorough research in primary and secondary education shows that there is little empirical support for this claim (Barres, 2006; Ceci, Williams, & Barnett, 2009; Guiso, Monte, Sapienza, & Zingales, 2008; Haworth, Dale, & Plomin, 2008; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Lynch & Feeley, 2009; OECD, 2009, 2010; Spelke,

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2005). Moreover, this explanation of presumed lesser aptitude cannot be used to explain the vast differences in female participation rates that exist between countries.

Fortunately, in recent years, progress has been made in explaining gender differences in academic choice patterns along more sophisticated theoretical lines, and with new empirical methods. Especially the availability of new comparative international data sets such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS) have opened new opportunities for research into cross-national variation, and additional avenues for explaining gendered study choice have been explored. The aim of this article is to present an overview of this recent literature, to describe the state of the art in explaining gendered study choice patterns, and to critically assess recent scientific progress in this field. For this reason, we focus on research as published from 2005 onwards. The central question we will try to answer is: Which types of explanations are currently given for gendered choice patterns in mathematics, science, and technology and what are the implications of these types of explanations for designing further research in this field?

To answer this question, the structure of the article is as follows. First, we present the method of literature search and selection. Second, we distinguish three main strands in the literature, based on micro-level, macro-level, and institutional perspectives. For each perspective, we present a summarized overview of the main theoretical frameworks on which recent studies have been based, as well as the results of these recent studies. Next, we critically discuss the evidence provided from each perspective, but we also point out some inconsistencies and lacunae. This discussion then leads to the formulation of recommendations for a more integrative approach. The contribution ends with a brief conclusion.

Review method

The method used for this literature review consisted of six stages. Stage 1 consisted of a broad search in electronic databases that were expected to contain (references to) academic publications on the topic. The databases included in the search were Web of Knowledge, ScienceDirect, International Bibliography of the Social Sciences (IBSS), Education Resources Information Center (ERIC), and also Google Scholar. The databases were searched using combinations of key search terms such as gender, education, choice, science, mathematics, and technology.

Stage 2 was to select articles from the search results on the basis of their timeline and their status. With regard to the timeline, articles published or accepted for publication from 2005 onwards were selected in order to provide a state-of-the-art review. With regard to status, articles were selected which had appeared or had been accepted to appear in peer-reviewed journals.

Stage 3 consisted of a further selection of the articles based on their titles, abstracts, and keywords. If it was unclear from the title, abstract, and keywords whether a study conformed to the screening criteria, it was included so that it could be subject to a detailed assessment in the next stage. This resulted in the selection of 331 studies.

Stage 4 assessed the quality of each of these 331 studies by examining the full text of the paper. The quality was mainly assessed using two criteria: rigor and credibility. With respect to rigor, we examined the research design, the method of data collection, and the method of analysis, thereby respecting quantitative, qualitative research and also mixed-method designs. With respect to credibility, we examined the presentation of the data, discussion

of the evidence, description of the limitations of the study, and justification of the conclusions on the basis of the results.

During Stage 5, a grouping of the 155 remaining articles was made. This eventually resulted in a distinction of three main analytical foci, applied in these recent studies:

- a micro-level focus, especially applied in the field of educational psychology, in which gendered choice patterns are explained using psychological constructs, that is, variables at the level of the individual student;
- a macro-level focus, especially applied in the fields of educational sociology and gender studies, in which gendered choice patterns are explained as a result of societal characteristics;
- an institutional focus, in which gendered choice patterns are explained as a result of characteristics of (national) education policies and system characteristics.

In the remainder of this article, we refer to the distinction between these three types of studies as micro-level, macro-level, and institutional studies.

Finally, in Stage 6, the three perspectives were subjected to an additional literature study, to come to a more fundamental understanding of their conceptual cores. For this purpose, we included books, articles, proceedings, and research reports of international organizations from earlier publication years as well. This also included references to the key literatures which formed the foundations of current research, for example, for micro-level studies Bandura's work on social cognitive theory (1977, 1978, 1982, 1986, 2001; Bussey & Bandura, 1999). Including these additional materials enabled us to place the more recent research findings in the context of the literatures they referred to.

This whole process resulted in three separate overviews, which are presented in the next three sections. For each perspective, we will first expound the broader theoretical foundations, after which we present the main research findings of recent studies conducted from that perspective.

Micro-level studies: the psychology of individual study choice

Since many years, researchers in the field of educational psychology have approached gender differences in MST by looking into psychological determinants of students' choices. Among the most successful theoretical contributions in this field, we find the social cognitive theory (Bandura, 1977, 1978, 1982, 1986, 2001; Bussey & Bandura, 1999) and the expectancy value theory of academic achievement (Eccles, 1984; Eccles et al., 1983; Meece, Parsons, Kaczala, & Goff, 1982).

Social cognitive theory

Social cognitive theory (SCT) posits that human behaviour is primarily explained through self-efficacy beliefs, outcome expectations, and goal representations. Self-efficacy beliefs refer to "people's judgment of their capabilities to organize and execute courses of action required to attain designated types of performances" (Bandura, 1986, p. 391). They deal with the question: Can I do this? Outcome expectations concern a "person's estimate that a given behaviour will lead to a certain outcome" (Bandura, 1977, p. 193). These expectations deal with the question: If I do this, what will happen? Goal representations are defined as determinations of individuals to engage in a particular activity (Bandura, 1986). They deal with the question: What will I have to do to get what I want?

Of these three determinants, self-efficacy is regarded to have the strongest influence on behaviour since most people will not venture into an activity unless they have enough confidence in their own ability to perform a certain task. Self-efficacy beliefs therefore define a person's choice of activities, including educational choices, as well as one's effort expenditure, persistence, thought patterns, and reactions when confronted by obstacles (Bandura, 1978, 1986; Hackett & Betz, 1981; Hackett & Lent, 1992; Lent, Brown, & Hackett, 1994; Multon, Brown, & Lent, 1991; Pajares, 2005; Sadri & Robertson, 1993; Schunk & Pajares, 2010).

Research that has deployed SCT to explain gender differences in academic choice patterns in MST has focused on differences between men and women in self-efficacy beliefs. Mathematics self-efficacy, that is, the confidence in one's mathematics abilities and skills, is believed to be the central mechanism behind gender differences in MST (Bussey & Bandura, 1999; Lent et al., 1994).

According to SCT, individuals form self-efficacy beliefs on the basis of information from four sources: performance accomplishments, vicarious experience, verbal persuasion, and emotional arousal (Bandura, 1986). Performance accomplishments concern experiences of success or failure in the performance of a certain task related to a certain activity, for example, solving mathematical problems. Vicarious experiences relate to learning acquired from observing others performing a task. Verbal persuasion concerns beliefs about one's own abilities through verbal transmission, for example, through suggestions from others. Emotional arousal concerns forming perceptions of abilities through awareness of one's own psychological states.

The thesis of SCT is that men and women differ in mathematics self-efficacy and as a result make different academic choices towards MST because they have been presented, both explicitly and implicitly, with different information while growing up and being educated. In practice, this means that women posses lower levels of mathematics confidence than men because women have had fewer learning possibilities and role models to stimulate them in their choice of mathematics and related fields and subjects. Consequently, women opt out of advanced mathematics classes more often than men and at an earlier stage in their school careers than men. As a result, their mathematics interest remains low and their mathematical skills stay undeveloped. As this process is repeated over time, during various stages of their educational careers, women's confidence in their own mathematics abilities and skills drops further and further (Bandura, 1978, 1986; Bussey & Bandura, 1999; Lent et al., 1994).

Expectancy value theory and expectancy value model of achievement related choices

According to the expectancy value theory, as applied and developed within the framework of the so-called expectancy value model of achievement related choices (EVMARC) (Eccles et al., 1983), the main determinants of educational and vocational choices, are

> "(a) expectations of success on (sense of personal efficacy at) the various options, as well as one's sense of competence for various tasks, (b) the relation of the options to one's short- and long-range goals, core personal and social identities and basic psychological needs, (c) the individual's culturally based role schemas, such as those linked to gender, social class, religious group and ethnic groups, and (d) the potential cost of investing in one activity rather than another" (Eccles, 2005, p. 12).

According to this model, only the first two determinants, expectation of success and subjective task value, directly influence academic and occupational choices. The other

determinants have an indirect influence. Expectation of success refers to anticipated outcomes or consequences of an action. It has earlier been formulated in the literature as the subjective probability of success on a task. The concept is quite similar to self-efficacy as developed by Bandura. Subjective task value refers to the value individuals place on a particular choice in comparison to other available options. EVMARC distinguishes between four groups of subjective task values: interest, utility, attainment, and cost. Interest value refers to the enjoyment an individual gets from engaging in the task or activity. Utility value refers to the instrumental value of the task or activity for helping to fulfil other short-term or long-term goals. Attainment value concerns the link between a task and one's sense of self and identity. Cost is defined in terms of negative experiences associated with a choice and by considering other opportunities that are given up, so-called opportunity costs (Eccles, 1987, 1994, 2005).

Applying the EVMARC framework, gender differences in academic choice are explained primarily as a result of different values men and women attach to various options, especially in terms of utility, attainment, and cost. Differences in subjective task value are the result of a complex interaction between short- and long-term goal representations, gender and ethnicity schemes, and core identities of men of women (Eccles, 1994, 2005; Eccles et al., 1983; Eccles, Wigfield, Harold, & Blumenfeld, 1993; J. E. Jacobs, 2005).

Recent progress in micro-level explanations for gendered choice patterns

In recent years, several empirical studies have focused on micro-level variables that explain differences in study choices between men and women. In these studies, a major focus lies on self-efficacy, subjective task value, and the effects of role models.

Self-efficacy

Recently, academic choice patterns of men and women in MST have been explored using social cognitive theory in various school and country contexts (Ashby Plant, Baylor, Doerr, & Rosenberg-Kima, 2009; Bussey & Bandura, 1999; see, for reviews, Ceci et al., 2009; Else-Quest, Hyde, & Linn, 2010; Frenzel, Pekrun, & Goetz, 2007; Hyde, 2005; Hyde et al., 2008; Usher & Pajares, 2008). In general, research outcomes reveal that boys and girls do indeed differ in perceived self-efficacy, even after controlling for achievement levels. Girls tend to hold lower self-efficacy levels than boys on tasks perceived as typically masculine (see, for an overview, Singh, Allen, Scheckler, & Darlington, 2007).

Research further reveals that boys and girls attribute their success or failure in mathematics to different sources. Girls attribute their success in mathematics and related school subjects such as physics and science more often to external factors, for example, learning time, luck, or support, than their male peers. Boys attribute their success in mathematics and related school subjects on average more often to internal factors, for example, talent (Britner, 2008; Meece, Glienke, & Burg, 2006; Zeldin, Britner, & Pajares, 2008). Research also shows that gender differences in mathematics self-efficacy are larger among students in higher secondary and tertiary education than in primary and lower secondary education (Pajares, 2005; Thomson, 2008). Boys and girls report similar confidence levels in their mathematics ability in primary school, but girls start to lose confidence as they enter puberty and enter higher secondary education, for example, middle school and high school (Archer et al., 2010). Research on so-called stereotype threat also suggests that when a student's social identity is constructed negatively, the student will tend to

underperform in a way that is consistent with the stereotype (Aronson & Steele, 2005; Miyake et al., 2010; Ong, Wright, Espinosa, & Orfield, 2011). Research on social role congruity, similarly, has revealed that college students view careers in science, technology, engineering, and mathematics (STEM), as opposed to careers in other fields, to impede the endorsement of communal goals. The pursuit of such goals, according to the researchers, negatively predicts STEM interest and as such mediates gender differences in STEM careers (Diekman, Brown, Johnston, & Clark, 2010). Research among computer science students also shows that interaction with a stereotypical role model, irrespective of role model gender, negatively influences women's beliefs of success in computer science, whilst leaving men's beliefs intact (Cheryan, Siy, Vichayapai, Drury, & Kim, 2011).

Subjective task value

Recent research also confirms that boys and girls differ in the subjective task values they attach to mathematics and related school subjects, even after controlling for achievement levels (Watt, 2006). In general, girls display much greater value and enjoyment in biology, chemistry, and life science than boys. Boys, on the other hand, show much greater value and interest in mathematics and physics than girls (Nagy, Trautwein, Baumert, Köller, & Garrett, 2006). This is also evidenced by the fact that female pupils, when given the choice between various MST-related subjects, prefer biology and chemistry to mathematics and physics.

Research examining the beliefs, expectations, attitudes, and images of young adolescents regarding academic careers in science and scientific occupations also makes these differences visible (Christidou, 2011; Rommes, Van Gorp, Delwel, & Emons, 2010). Girls associate science more often with developing medicines and finding cures to cancer, whilst boys relate science to building machines, rockets, and inventions (Baram-Tsabari, Sethi, Bry, & Yarden, 2006, 2009; Jenkins & Pell, 2006). Additionally, gender differences in the uptake, interest, and the perceived value of mathematics and mathematics-related subjects become larger as pupils grow older (Archer et al., 2010; Baram-Tsabari & Yarden, 2008, 2011).

Role models

Finally, recent studies have focused on the importance of role models, such as parents, peers, teachers, and school counsellors (Sjaastad, 2012). These actors provide pupils with crucial information and feedback on educational, academic, and career options available to them and on the gender appropriateness of these options (see, for an overview, Adya & Kaiser, 2005; Leaper & Friedman, 2007). Recent longitudinal research has shown that parents generally support the cultural stereotype that mathematics is more natural for boys than for girls (Eccles, Freedman-Doan, Frome, Jacobs, & Yoon, 2000; Furnham, Reeves, & Budhani, 2002; Herbert & Stipek, 2005; Li, 1999). Research by J. E. Jacobs, Chinn, and Bleeker (2006) shows that parents' gender-typed occupational expectations are significantly related to their children's expectations at age 15 and to their children's actual career choices as adults. Research has also shown that boys and girls use peers to evaluate their own achievement and occupational aspirations and that peers reinforce gender stereotypical behaviour and punish non-conformity (Hannover & Kessels, 2004; Kessels, 2005; Young et al., 1999).

Macro-level studies: culture, gender, and socialization

Whereas research in social psychology has focused on the individual and on psychological determinants that explain the MST gender gap, social-cultural research has since long focused on macro-level determinants that play a role. From a macro-level perspective, gendered patterns in MST participation have been attributed to societal determinants and to differential socialization of men and women.

According to Glick and Fiske (1999, p. 368), gender, or the cultural construction of sex differences, emerges as the "most automatic, pervasive and earliest learned" categorization that shapes social relations and identities in the contemporary world. It often is the primary framing device for social relations (Bem, 1993; Connell, 1987; Ridgeway, 2006; Scott, 1986).

One possible explanation for persistently gendered patterns of academic choice in MST is provided by modernization theory, as developed by Ronald Inglehart and his colleagues (Inglehart, 1997; Inglehart & Norris, 2003; Inglehart & Wezel, 2005). This theory claims that:

> women's and men's lives have been altered in a two stage modernization process including (i) the shift from agrarian to industrialized societies, reducing fertility rates, bringing women into the paid labor force, and increasing rates of literacy and education and (ii) the move from industrial towards postindustrial societies, generating more substantial gains towards gender equality in the public sphere and workplace (Inglehart & Norris, 2003, abstract).

Schreiner and Sjøberg (2005) have applied Inglehart's modernization theory to explain cross-national variations in gender differences in the uptake of science and technology-related subjects in secondary school between economically developed (Western) and developing countries (Bøe, Henriksen, Lyons, & Schreiner, 2011; Jenkins & Nelson, 2005; Relevance of Science Education [ROSE], 2004; Schreiner, 2006). In doing so, they focus on the following question: "is the low recruitment to S&T [science and technology] studies in more economically developed societies related to social development and the associated changes in the spirit, values and ideas of the society?" (Schreiner & Sjøberg, 2005, p. 2). To answer this question, they draw on different sociological perspectives describing aspects of youth culture in late-modern societies. For Schreiner and Sjøberg (2005), identity construction of young people and their subject interests are crucial for understanding gendered patterns in MST. According to the authors, identity construction in late-modern societies is characterized by the individual's freedom and independence from collective structures, such as social class, gender, and family institutions. Young people in late-modern societies feel more free in comparison to young people in less developed societies to make their own choices irrespective of background, including the choice to choose one's own religion, sexuality, political affiliations, education, and profession (Beck & Beck-Gernsheim, 2002). An individual's identity is no longer perceived as something that is given, but rather as something that one has to choose and develop (Giddens, 1991).[2] In this context, students in late-modern societies make fundamentally different educational choices than students in traditional and modern societies. Educational and academic choices of students are guided less by concerns for material security and more by the question: Who do I want to be? (Illeris, 2003; Illeris, Katznelson, Simonsen, & Ulriksen, 2002; Schreiner & Sjøberg, 2005). The relevance of this question, according to Schreiner and Sjøberg, depends on the level of economic prosperity of a specific country and the extent to which students have alternatives to choose from.

Schreiner and Sjøberg (2005) explain gendered academic choice patterns in MST through these differences. Women in late-modern societies will, when offered the choice between different alternatives in higher education, tend to choose to study in traditionally female fields that are more connected with their core identity, which is assumed to be heavily influenced by gender and gender roles. Women in less developed societies are less concerned with these issues and more often choose to study in non-traditional fields, including MST. The same explanatory mechanism also applies for men and their educational and academic choices. Schreiner and Sjøberg argue that the differences in academic choices between men in late-modern societies and in less developed societies are nonetheless much smaller because men's core identities and gender roles are much less contested in other academic fields than women's in MST.

Recent progress in macro-level explanations for gendered choice patterns

In explaining gender roles and gendered patterns of academic choice, socialization theory has argued that the roles of men and women in societies are the result of complex interactions between various social-cultural factors (see, for an overview, Leaper & Friedman, 2007; Trauth, Quesenberry, & Huang, 2008). Within this approach, inequalities between men and women within the education system and the labour market were thought to become extinct with the progression of women's rights over time (Baker & LeTendre, 2005; Charles & Bradley, 2009; Inglehart & Norris, 2003; Jackson, 1998). Most sociologists, however, have now abandoned this idea, as recent studies have shown that increases in gender equality have not led to more equal representations of women in male-dominated fields as MST and related professions (Charles & Bradley, 2009; Scantlebury & Baker, 2007; Schreiner & Sjøberg, 2005). Even in countries with high overall female enrolment rates in higher education, including most European Union countries and the United States, women remain underrepresented in MST (Charles & Bradley, 2002; England et al., 2007; England & Li, 2006; J. A. Jacobs, 2003; Xie & Shauman, 2003).

Recent empirical cross-national research supports the hypothesized relationship between societal development, gendered identities, and gendered choice patterns. Research by Charles and Bradley (2009) on sex segregation by field of study in higher education across 44 societies, including both developed, developing, and transitional countries, shows that sex typing of MST is indeed stronger in more economically developed contexts. The authors link the positive correlation between sex segregation in MST and socioeconomic modernization to two cultural forces: gender-essentialist ideology and self-expressive value systems.

Gender-essentialist ideology refers to "cultural beliefs in fundamental and innate gender differences", which according to the authors are more resilient in egalitarian contexts (Charles & Bradley, 2009, p. 925). Self-expressive value systems refer to the cultural emphasis in late-modern societies on individual expression and self-realization, which according to Charles and Bradley "create opportunities and incentives for the expression of gendered selves" (p. 924).

Assumptions that men and women are differently affected by modernization and as a result make different academic choices towards MST is also evidenced by research on work preferences, life values, and personal views of top mathematics and science graduate students. Ferriman, Lubinski, and Benbow (2009), for example, show that men more than women motivate their choice to enter MST by referring to the opportunity to develop high impact products, taking risks, and gaining recognition. Women tend to motivate their choices to enter MST in other ways. They, for instance, regard a choice for MST as an

opportunity to escape from traditional gender roles and stress the opportunities an MST study may offer in terms of flexibility of work place, which may be help to follow a husband if he finds a job abroad (Besecke & Reilly, 2006; Birbaumer, Lebano, Ponzellini, Tolar, & Wagner, 2007; Frome, Alfeld, Eccles, & Barber, 2006; Kazim, Schmidt, & Brown, 2007; Trauth et al., 2008).

Institutional studies: characteristics of education systems

Finally, institutional studies focus on the idea that differences in study choice may be affected by the specific characteristics of education systems.

Since long, the institutional perspective has flourished in the study of education systems as vehicles of social reproduction. Here, it has been argued that different education systems have different outcomes for pupils from different social classes and that various education-system characteristics can further equal opportunity in education. Examples of such characteristics are: a more extended period of compulsory education, the provision of pre-school education, single-sex versus co-education schooling, regulation of the maximum class size, regulation of the length of the school day, late ability tracking, higher educational spending, and the existence of bursary systems (Ammermüller, 2005; Brunello & Checchi, 2007; Ceci & Williams, 2011; Hanushek & Wößmann, 2006; Schütz, Ursprung, & Wößmann, 2008; Schütz & Wößmann, 2005; Wößmann, 2009; Wößmann & Schütz, 2006).

Whereas within-countries variation in such institutional features of education systems is of course limited, solid statistical evidence for this perspective came only available after the development of cross-national databases, such as PISA and TIMMS, in recent years. Since then, however, more and more studies have provided empirical support for this institutional perspective. Differences in education systems clearly matter in the (re)production of inequality in education (Buccheri, Gürber, & Brühwiler, 2011; OECD, 2005, 2007, 2010; Schütz et al., 2008; Schütz & Wößmann, 2005).

Moreover, recent studies have also shown that these differences in education systems do not only interact with class structures but also with other background characteristics of pupils. Cross-national studies of educational performance of children of Turkish and Yugoslavian origin, for example, show clear differences in outcomes for different educational systems. These are differences which cannot be explained through earlier established individual achievement scores. This suggests that the institutional school contexts in which children are educated have a strong influence on values, norms, and beliefs that are associated with study choice and often interact with characteristics of cultural backgrounds (Anderson, Lin, Treagust, Ross, & Yore, 2007; Crul & Heering, 2008; Eccles, 2005; Levels, Dronkers, & Kraaykamp, 2008; OECD, 2006b, 2007).

Recent progress in macro-level explanations for gendered choice patterns

Although a comprehensive theory about the relationship between institutional design and gendered choice patterns is still lacking, several recent studies have entered into this field. Together, they provide evidence that institutional explanations form part of the puzzle. They suggest that gendered patterns in study choice are related to the extent of differentiation in education systems, to the extent that pupils are given free choice to select their specific paths and to methods of assessment used in education.

Extent of differentiation

Research into the effects of so-called tracking in education systems had already shown that highly differentiated educational systems tend to produce more outcome inequality for pupils from different classes and from different ethnic backgrounds (Buchmann & Park, 2009; Charlton, Mills, Martino, & Beckett, 2007; Hillmert & Jacob, 2010; Lynch & Lodge, 2002; Van de Werfhorst & Mijs, 2010). Bedard and Cho (2007) revealed a similar effect for gendered educational choice patterns, namely, that countries with highly differentiated education systems produce more gender inequality than countries with less differentiated systems (Bradley & Charles 2004; Charles, 2011; Van Elk, Van der Steeg, & Webbink, 2009, 2011; Van Langen, 2007; Van Langen, Rekers-Mombarg, & Dekkers, 2006, 2008; Wößmann, 2009).

With respect to the effects of differentiation in school systems, special attention has also been given to the comparison of single-sex schooling to co-educational schooling (see, for reviews, Hubbard & Datnow, 2005; Smithers & Robinson, 2006; Younger & Warrington, 2006).[3] The outcomes of these comparative studies have, however, produced mixed results, in the sense that single-sex education does not seem to have a straightforward effect on gendered study-choice patterns. While single-sex schooling may reduce the gender gap in education, additional conditions seem to be required, such as a positive school culture and a strong overall learning environment.

Freedom of choice

Closely related to this effect of differentiation is the effect of freedom of choice. In countries in which students are given more freedom to choose between alternative trajectories, gendered patterns of educational choice are found to be less equal. Research results include an increase in the number of female students entering science after an expansion of A-level subjects that students were required to take in the United Kingdom (Van de Werfhorst, Sullivan, & Cheung, 2003). Research conducted in The Netherlands on the effects of two curriculum reforms known as Second Phase (*Tweede Fase*) and Renewed Second Phase (*Vernieuwde Tweede Fase*) produced similar outcomes. These reforms that limited the freedom of choice for pupils to compose their own exam programmes, had a positive influence on female choice towards MST-related exam programmes in secondary education (Van Langen, 2005; Van Langen & Dekkers, 2005; Van Langen et al., 2008). In addition, Abbiss (2009) has reported similar findings on gendered patterns of participation in specialist ICT subjects in New Zealand. Here, more opportunity for choice in the ICT curriculum effectively reinforced gender stereotypes. Abbiss calls this "the paradox of choice" (p. 345).

Assessment

Finally, there is also evidence that the way in which students and pupils are assessed impacts boys and girls differently. Girls, on average, perform lower on traditional exams in comparison to continuous assessment (Adamuti-Trache, Canadian Council on Learning, & Council of Ministers of Education, 2006; Lyons, 2003; Murphy & Ivinson, 2004).

A critical confrontation

In the previous sections, we have explored three different frameworks for explaining gendered patterns of academic choice towards and away from MST: a micro-level, a

Table 1. Main factors explaining gendered patterns in academic choice.

Micro-level	Macro-level	Institutional
Self-efficacy beliefs *Subjective value expectancy* • Utility • Attainment • Costs *Role models* • Parents • Peers • Teachers • Media representations	*Socioeconomic conditions* • Material prosperity • Stage of societal development (pre-modern, modern, late-modern) *Socialization* • Gendered identity	*Education-system characteristics* • Extent of differentiation • School and classroom composition • Extent of freedom of choice

macro-level, and an institutional framework. Within each of these frameworks, hypotheses have been identified and tested that provide explanations for differences in study choice patterns between men and women.

Table 1 summarizes the main variables that have been found to matter in each perspective. In micro-level approaches, gendered patterns of academic choice have primarily been explained as the result of differences in self-efficacy and subjective value expectancy between men and women, and these variables are found to be highly influenced by the availability of role models. In macro-level approaches, gendered patterns of academic choice have primarily been explained as a result of differences in socioeconomic conditions and the extent to which these conditions open up opportunities for expressing gendered identity in educational choice. From an institutional perspective, gendered patterns of academic choice have primarily been explained as the result of education-system characteristics. Important factors found so far are the extent of differentiation and the extent to which students are given freedom of choice.

Strengths and limitations of individual frameworks

As with all efforts in the social sciences, any dedication to a specific disciplinary framework, or paradigm, may facilitate scientific advance but may at the same time obfuscate relevant issues which are outside the framework's scope (Kuhn, 1996; Schön & Rein, 1994). This also applies to the application of micro-level, macro-level, and institutional frameworks to gendered study choice.

The main strength of micro-level theories like SCT and EVMARC is that they provide a solid basis for understanding how men and women can differ in making individual choices, as a result of differential role models, differential experiences, and differences in external pressure from parents and peers. This perspective, however, is clearly insufficient when it comes to explaining the vast variety in gendered study choice patterns that exists across countries. Remarkably, neither SCT nor EVMARC researchers elaborate on the exact processes through which these factors influence gendered patterns of academic choice in MST (see, also, Eccles, 2005; Usher & Pajares, 2008). Of the two approaches,

only the expectancy value model of achievement related choices refers to variations in cultural milieu (Eccles, 1987, 2005; Eccles et al., 1983; Wigfield, Battle, Keller, & Eccles, 2002). Despite the reference, however, EVMARC does not provide the theoretical framework to explain cross-national variations in choice patterns on a structural level. Moreover, it is still unclear how micro-level explanations of gendered study choice relate to institutional variables that are known to matter, such as school and classroom contexts. In the research on single-sex classes, for example, we have seen that achievement scores of girls and boys in non-gender-specific subjects can be positively influenced if certain institutional conditions have been met. Yet, the link between those conditions and gender-specific choice patterns towards MST clearly requires further study.

The strength of macro-level sociocultural research is that it has uncovered factors that can explain part of the cross-national and cross-cultural variation in the MST gender gap (Bussey & Bandura, 1999; Ceci & Williams, 2009; Iş Güzel & Berberoğlu, 2005; Leaper & Friedman, 2007; Schreiner & Sjøberg, 2005; Trauth et al., 2008; Van Langen & Driessen, 2006). The overall result, however, has been limited, in the sense that this research not only is less precise in explaining how these factors affect an individual's choice, but also because it still fails to explain many aspects of cross-national variation in gendered patterns of academic choice between countries with similar cultural gender beliefs and similar levels of economic development. Moreover, efforts to increase the participation of women in MST have had mixed results at the best (see, for an overview, European Commission, 2009a, 2009b, 2010a, 2010b, 2012; Lynch & Feeley, 2009; OECD, 2006a).

Finally, the results of recent institutional studies show that differences in the make-up of educational systems, including school and classroom contexts, can account for unexplained variance between apparently similar countries. The exact relation between the design of education systems and gendered choice, however, still largely remains unclear. Research suggests that institutional variations in education systems interact with other factors in explaining gendered patterns in academic choice in MST, but it is still unclear why a system characteristic such as freedom of choice has more effect on the choices of girls than on the choices of boys.

When, however, we confront the evidence from the different frameworks, it becomes possible to make connections between them, and lines of a more comprehensive understanding of gendered study choice come to the fore.

A first, and rather obvious conclusion with respect to the results of micro-level studies is that a micro-level perspective, alone, will not result in a full understanding of gendered patterns of study choice, as it is clear that individual choices are being made within social and institutional constraints, and that these constraints matter greatly. Individual characteristics such as self-efficacy beliefs are not innate personality traits but rather self-images that girls and boys develop within a societal and institutional context.

With respect to the societal impact on girls' choices, a self-image of low efficacy in MST may be *assumed* to depend on whether the society they are brought up in – a society that includes their parents and peers – *ascribes* low MST efficacy to them and *prevents* them from experiencing successful performance. It depends on whether that society offers role models of women fulfilling MST occupations, that is, opportunities for vicarious learning, and it depends on whether the educational system of that society puts a premium on making early choices based upon one's self-image of efficacy in MST, or not. A similar argument can be made for expectancy value characteristics. Whether or not girls expect positive outcomes from educational choices towards MST may be *assumed* to depend on whether their societies reward these choices and on whether there are examples of

women reaping the benefits from such choices. The question, however, remains in what way and to what extent these assumptions can be verified in practice and in what way and to what extent other macro-level explanations such as gendered identity in post-modern societies actually translate into measurable differences in micro-level constructs.

With respect to the effects of education systems on women's choices, there is additional reason to reconsider the idea that highly gendered study-choice patterns are simply the effect of innate female character traits. Let us take the effects of early tracking as an example. It has been found that early tracking tends to increase differences in study choices between boys and girls. Following Bandura (1978), this may be explained as the result of a magnifying effect of early tracking systems on initial differences between boys and girls. Our feeling, however, is that this is not the whole story, by far. We hypothesize that comprehensive education systems affect gendered study choice in many ways, and that in order to fully understand the effects of education system design, a variety of interactions has to be taken into account that has largely been ignored in previous micro- and macro-level studies. Most crucial in this respect are the age at which selection events take place and the educational contexts in which pupils are placed prior to these events and also afterwards (and thus in anticipation of future selection events). With respect to age, we propose that differences between boys and girls in study choice behaviour may well have to do with the fact that in many countries important events in education take place at about the time girls enter puberty (see, also, Archer et al., 2010). Thus, the equalizing effects of more comprehensive systems may be the result of delaying decisions until after this critical age. The same holds for various aspects of the school context in which study choices are made, such as classroom composition. The essence of early tracking is that it homogenizes classroom composition, and this homogenization may affect girls and boys in different ways. Maybe the problem of low self-efficacy beliefs among girls is lessened by a more heterogeneous classroom composition, in which real differences in MST aptitude are more apparent.

So, again, many questions remain regarding the nature and the extent of the translation of higher level factors into micro-level constructs.

Towards a more comprehensive research agenda

In order to come to a further understanding of cross-national differences in gendered study choice patterns, it is desirable that researchers adopt multiparadigmatic approaches in their studies.

On the one hand, it is clear that "[modern] individuals are deeply invested in beliefs about gender difference, and [that] these are embedded in virtually all organizational structures and interactional contexts, including labour market and educational systems" (Charles & Bradley, 2009, p. 927). This means that micro-level studies need to be very careful in explaining study choice as the result of generic differences between the sexes. This even holds for core findings within the micro-perspective, such as the finding that low participation rates of women in MST primarily result from low self-efficacy. This may be true in many countries, but that does not mean that low-self efficacy in itself is a real explanation. As it does not explain the actual variety in study-choice patterns that exists across socioeconomic and cultural settings, and also across a wide variety of educational systems, it should rather be regarded as an intermediate variable which deserves an important place in a far more complex explanatory model.

On the other hand, macro-level and institutional studies could benefit greatly from studies in which the effects of higher level conditions on micro-level constructs are

studied, with more rigor. This would help to understand more precisely how cultural, socio-economic, and institutional conditions affect individual study-choice behaviour. The conclusion that girls in late-modern societies exhibit gender-essentialist study choice, for instance, begs for a more thorough analysis at the micro-level. How, exactly, do the choices of these girls differ from the choices girls in other societies make? Are these gender-essentialist choices primarily the result of subjective value expectancies or are other factors important as well? And, do gender-essentialist outcomes really reflect large differences between boys and girls, or are they the result of small micro-level differences which are magnified by the institutional characteristics of education systems?

Conclusion

This article has summarized theories and empirical evidence on gendered patterns of academic choice in MST. It has done so from three perspectives that were distinguished in the current literature in the field. The identified micro, macro, and institutional factors reveal some of the mechanisms through which gendered patterns of academic choice in MST are constituted in different social, cultural, and educational contexts. They also enable us to understand why some countries with more traditional gender roles actually have higher female participation rates in MST than countries with more egalitarian gender roles. What is still missing, however, is a more thorough understanding of how these factors at the different levels interact. In order to achieve this understanding, more integrated research designs have to be developed, which build on the findings now available from the three separate perspectives. As we write this, research that makes use of the recent availability of cross-national databases with micro-data are already venturing into the field of more integrated study design in terms of multi-level studies (e.g., Breen & Goldthorpe, 1997; Breen & Yaish, 2006; Lent & Brown, 2006; Van de Werfhorst & Mijs, 2010). For a more thorough and complete understanding of choice and of the factors and mechanisms at play, it is necessary to continue and deepen these efforts, by including more systematically the theoretical constructs identified in the existing literatures.

Notes

1. The levels and fields of education and training used follow the 1997 version of the International Standard Classification of Education (ISCED97) and the Eurostat manual of fields of education and training (Andersson & Olsson, 1999).
2. Note that this is an ideology of autonomy; they think they are free. In reality, also in late-modern societies people's identities and hence choices are heavily socially informed.
3. One problem with most research conducted on single-sex education versus co-education is that single-sex schools are generally private schools, which make it difficult to produce valid comparisons.

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