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How to foster students' motivation in mathematics and science classes and promote students' STEM career choice. A study in Swiss high schools

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ABSTRACT

Programs aimed at increasing the attractiveness of STEM professions should encompass women as well as men. Based on that premise our study focuses on the research question: How can high school students' motivation in mathematics, physics, and chemistry classes be increased and what impact does students' high motivation in math and science have on a career choice in STEM? The study is embedded in the Eccles' expectancy-value model. Applying structural equation modeling, it provides evidence that fostering students' motivation has a positive impact on their willingness to choose a STEM study field. Moreover, the results show that classes supporting students' motivation increase the intrinsic value of math and science among students and the probability of a STEM career choice.

1. Introduction

Although participation rates of men and women in secondary and tertiary education and their educational success have largely evened out (Rodax & Rodax, 1996) the gender disparities in the preference of study and occupational fields have remained surprisingly stable in most western societies (OECD, 2012; Scott, Crompton, & Lyonette, 2010).[1] Women are catching up in demanding occupations in the social and health care sectors, while they continue to avoid male-dominated occupations in the areas of sciences, technology, engineering, and math (STEM) (Jarman, Blackburn, & Racko, 2012; OECD 2012; Smith, 2011). The persistent gender segregation in career choice according to "so called female- and male-occupations" (Leemann & Keck, 2005, p. 73, translation by authors) leads not only to the reproduction of anachronistic gender stereotypes but also to shortfalls in the recruitment of employees in the sciences and technology sectors. This is an alarming situation in a knowledge society that increasingly depends on technological competencies (e.g. Anger, Demary, Koppel, & Plünnecke, 2013; Sadler, Sonnert, Hazari, & Tai, 2012; Quaiser-Pohl, 2012). The concern is even more serious since young men's willingness to study STEM subjects (esp. physics, IT, and engineering) has recently been dwindling (Becker,

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[1] A few fields of study record an increase in female enrollment. However, in Switzerland and in other western countries the female share only increases slowly and these increases do not occur across all the STEM fields.

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2010; Smith, 2011; Xie & Achen, 2009). To increase the attractiveness of STEM professions generally, research should no longer be limited to women but include men as well. This especially holds true for research seeking the educational determinants of unequal career choices, because students' interest in school subjects like math and science has great influence on their decision for or against a professional career in a STEM field (cf. e.g. Eccles & Wigfield, 2002; Gottfredson, 2002). Thus, our study focuses on the instructional design of mathematics, physics, and chemistry high school classes that explicitly foster female *and* male students' motivation. We assume that an instructional design that takes care of the different motivational needs of male *and* female students may not only foster the interests of both genders in the respective school subjects, but may also contribute to a reduction of the gender disparity in career choice.

2. Theoretical background

2.1. Motivational issues in math and science classes

The underrepresentation of women in science and technical occupations can be explained by a range of factors extending from macro-sociological and economic to evolutionary-biological and neuro-psychological approaches (Blakemore, Berenbaum, & Liben, 2009; Buchmann, DiPrete, & McDaniel, 2008; Ceci, Williams, & Barnett, 2009). All of these approaches have revealed significant determinants of gender segregation in career choice (Halpern et al., 2007). However, for the development of reforms it is useful to focus on areas that can be influenced through interventions. This includes, specifically, the pedagogical realm. Aside from the family, math and science education offers a starting point to counter the low willingness of women *and* men to choose a course of study in the STEM fields.

In their extensive interdisciplinary and causally argued analysis of the research literature, Ceci et al. (2009, p. 229ff.) attribute the greatest explanatory power for the underrepresentation of women in STEM professions to motivational issues. What remains an open question in their analysis is which factors influence motivation. While they mention the proximal conditions of family and school, the methodological aspects of the motivational instructional design of math and science classes remain ignored. This seems unjustified since a number of studies have shown that motivational instructional design offers a potent approach for raising the interest of students in math and science education (Aeschlimann, Herzog, & Makarova, 2015a, 2015b; Murphy & Whitelegg, 2006). These studies are based on the well-substantiated fact that the interests of boys and girls in science classes partly differ (e.g. Eisenberg, Martin, & Fabes, 1996; Rustemeyer, 2009). While male students show greater interest in technical questions, female students are more interested in contextual aspects, such as meaning in everyday life or application in medicine, environment, energy, and nutrition (Miller, Blessing, & Schwartz, 2006; Murphy & Whitelegg, 2006). Underlying these findings are gender divergent preferences for relationships with humans and objects: women prefer activities that involve humans, while for men interactions with objects have a higher priority (e.g. Ceci et al., 2009). Unfortunately, these pre- and extra-scholastic conditioned differences between boys' and girls' interests find too little consideration in school teaching, where students' everyday experiences are especially important for the comprehension of the subject matter. In particular, the differing interests of girls in math and science subjects are seldom taken into account in educational settings (e.g., Hoffmann, 2002; OECD, 2009).

Interest in a subject is generally an important precondition for academic learning (e.g. Köller, Baumert, & Schnabel, 2001; Krapp, 1999). Moreover, it has been shown that girls' interest in science strongly correlates with their academic achievements in these subjects (Blakemore et al., 2009; Weinburgh, 1995). Again, this results also applies to boys, because one cannot assume that boys always have the kind of everyday experience that motivates them for science classes. Thus, an important starting point for interventional actions aimed at raising girls' and boys' interest in STEM careers lies in the motivational design of math and science classes.

2.2. Motivational design of math and science classes

The improvement of motivational conditions in math and science classes has emerged as a promising intervention strategy in gaining more women *and* men for STEM occupations. In investigating motivational improvement, the present study makes use of the expectancy-value theory of Eccles (Eccles, 2007; Eccles & Wigfield, 2002; Eccles, Wigfield, & Schiefele, 1998), whereby the expectancy component encompasses the self-perception of one's own achievement in a particular subject.[2] Two important aspects of the value component are interest in and enjoyment of the subject. Furthermore, the Eccles-model also serves as an explanatory framework for school- and occupational decisions (Eccles & Wigfield, 2002). It can be shown that in addition to performance, academic self-concept and subject interest are relevant determinants in students' selection of secondary school majors (Eccles & Wigfield, 2002; Nagy et al., 2008; Watermann & Maaz, 2004). Similar mechanisms seem to be crucial for career choice, even when majors selection in secondary school cannot be equated with career choice or choice of majors in higher education (cf. Nagy, Trautwein, Baumert, Köller, & Garrett, 2006).

[2] It should be noted that while performance expectations and academic self-concept can theoretically be distinguished, empirically the two constructs are not distinguishable (cf. e.g. Nagy et al., 2006).