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Achievement and Motivation in Mathematics and Science: The Role of Gender and Immigrant Background

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ABSTRACT

Disadvantages for girls in mathematics and science as well as the general educational disadvantages faced by students with an immigrant background are two widely discussed equity issues. However, previous research has rarely addressed both issues simultaneously. On the basis of theoretical considerations suggesting possible interaction effects, we compared patterns of gender difference in mathematics and science achievement and motivation of students with and without an immigrant background. The results show negligible gender differences in achievement measures, providing further support for the gender similarities hypothesis. With regard to motivational student characteristics, we found significant advantages for male students in all tested domains except biology. This effect pattern was found for students with and without an immigrant background. Immigrant students, especially those with a Turkish background, lagged behind their native German peers in achievement (but not motivation), yet no clear-cut interaction effects with gender were found. We conclude that the gender gap in STEM domains still exists with regard to motivation despite the lack of significant differences in achievement. Female students with an immigrant background seem to have neither a double disadvantage nor a relative advantage. Yet there was some evidence that men with a Turkish background may be disadvantaged in science achievement.

KEYWORDS

Gender differences; immigrant background; achievement; self-concept; interest; STEM subjects



Achievement and Motivation in Mathematics and Science: The Role of Gender and Immigrant Background

This paper addresses the intersection of two equity issues that are relevant to STEM education: differences between male and female students and differences between students with and without an immigrant background. We find this topic intriguing because the assumption that gender differences may be more pronounced in immigrant populations is common but has not yet been tested, and because working on this subject allows us to bring together several of our research interests. We are both psychologists by training, focusing on different research questions related to education. Petra Stanat did a lot of work on the situation of students with an immigrant background as well as on gender differences, yet she did not specifically focus on the STEM subjects in the past. Malte Jansen examined student self-concepts in the sciences (including gender differences) in his dissertation work. Bringing these perspectives together, we review previous research and discuss possible interaction effects between gender and immigrant background. As we both work with data from large-scale school assessments in Germany, we present some empirical evidence from such studies to evaluate our hypotheses.

INTRODUCTION

Gender differences in mathematics and science subjects (STEM) are still a matter of concern in educational systems worldwide. The US Department of Commerce (2011), for example, identified a "gender gap to innovation" and just recently the OECD published a widely discussed report on the "ABC of gender equality in education" (OECD, 2015). The "gender gap" is indicated by a smaller proportion of girls and women choosing to study STEM subjects at school and at the university level and a correspondingly small proportion of women in STEM careers.

At first glance, the empirical evidence for achievement differences in STEM domains does not seem to justify the heat of discussion. A large number of studies compared ability distributions of male and female students in the STEM subjects, showing that they are clearly much more similar than different (*gender similarities hypothesis*; Hyde, 2005; Hyde, Lindberg, Linn, Ellis & Williams, 2008; Zell, Krizan & Teeter, 2015). For achievement in mathematics, meta-analytic effect sizes of $d = .05$ to $d = .15$ were found in favor of male students, indicating that the direction of the gender differences may be stereotypical albeit small (Hyde, Fennema & Lamon, 1990; Lindberg, Hyde, Petersen & Linn, 2010; Reilly, Neumann & Andrews, 2014). However, the differences vary significantly across countries (Else-Quest, Hyde & Linn, 2010). In the PISA 2012 study (*Programme for International Student Assessment*), for example, gender gaps ranging from 25 points on the PISA metric in favor of boys (Luxembourg) to 6 points in favor of girls (Iceland) were found for mathematical literacy (OECD, 2013). In general, the differences were smallest in the Scandinavian countries. In Germany, a gender difference of 13 points in favor of boys was identified, which was statistically different from the OECD mean of 10 points.

For achievement in science, Reilly et al. (2014) found an advantage of $d = .13$ in favor of men in their meta-analytic examination of data from the National Assessment of Educational Progress (NAEP). The PISA 2006 study, which focused on science, did not detect any overall gender differences; yet, again, notable variations were found across countries (OECD, 2007). Analyses of the most recent PISA study from 2012 revealed an average advantage across participating countries of 11 points ($d = .11$) in favor of boys for mathematics and no gender differences in science. Yet, none of these analyses distinguished between different domains of scientific achievement, such as biology, chemistry, and physics.

While the relatively small effect sizes found for indicators of achievement are in line with the gender similarities hypothesis, gender gaps tend to be far more pronounced for motivational variables related to mathematics and science. Advantages for boys in mathematics self-concepts and interests are consistently found and seem to emerge as early as in the first grades of elementary school (Eccles, Wigfield, Harold & Blumenfeld, 1993; Else-Quest et al., 2010; Hyde, Fennema, Ryan, Frost & Hopp, 1990; Jacobs, Lanza, Osgood, Eccles & Wigfield, 2002; Marsh & Yeung, 1998). In science, the differences in self-concepts and value beliefs appear to depend on the domain, with advantages for boys in physics and no gender gap or advantages for girls in biology (Eccles, 2007; Jansen, Schroeders & Lüdtke, 2014; Wang & Degol, 2013). Such stereotypical differences in interests are not limited to academic domains – they also occur in general vocational orientations (“Men and things, women and people”, see Su, Rounds & Armstrong, 2009).

Educational systems worldwide are also concerned with another aspect of equity, namely the integration of immigrant students. In many countries, students with an immigrant background lag behind their peers from native families when it comes to achievement (e.g., OECD, 2013; Stanat & Christensen, 2006). This is the case even though they and their parents tend to have relatively high educational aspirations (e.g., Kao & Tienda, 1995; Stanat, Segeritz & Christensen, 2010). Also, there is some indication that the motivation of immigrant youth in mathematics and science is higher (or at least not lower) than for non-immigrant youth (e.g., OECD, 2007; Stanat, Segeritz & Christensen, 2010). The extent to which male and female immigrant students differ with regard to these variables, however, is largely unclear.

The aim of this brief report is to present some research findings on the topic outlined above. We present theoretical assumptions and existing empirical evidence that suggest an interaction between immigrant background and gender with regard to STEM-related achievement and motivation. Subsequently, we present key results from two empirical studies on gender differences in achievement and motivation, in which students with different immigrant backgrounds were analyzed separately. We then draw some preliminary conclusions and point out areas for further research.

The Interplay Between Gender and Immigrant Background: Possible Mechanisms

Some theoretical considerations suggest that students' immigrant background and gender may interact in influencing both general and domain-specific educational achievement and motivation (e.g., Feliciano & Rumbaut, 2005; Suarez-Orozco & Qin, 2006). This should specifically be the case if the students' families emigrated from a country in which traditional gender-role attitudes are more prevalent than in the country of residence. Because gender-role attitudes could conceivably affect school-related attitudes in different ways, however, the interaction between gender and immigrant background may go in two directions.

On the one hand, traditional gender-role attitudes are assumed to shape identification with certain school subjects and hence interest and achievement (e.g., Hannover & Kessels, 2004; Kessels & Hannover, 2008). Mathematics and science are, for the most part, stereotypically viewed as male domains. The gender gaps in these subjects should therefore be particularly pronounced in immigrant student populations whose families emigrated from countries where stereotypical gender roles are prevalent. Following this argument, female students from immigrant backgrounds may suffer a "double disadvantage" regarding STEM subjects as they are confronted with two stereotype threats regarding their achievement (Gonzales, Blanton & Williams, 2002; Nguyen & Ryan, 2008).

On the other hand, traditional gender-role attitudes may shape the attitudes and behaviors of parents in ways that are particularly conducive to learning for girls. It has been argued that traditional gender-role attitudes may result in higher levels of parental control for girls than for boys. Although the parental restrictions might prevent girls from having important experiences outside the home, they could also have positive side effects. Based on a review of the relevant literature, Suarez-Orozco and Qin (2006, p. 172) concluded that "Heavy monitoring may benefit girls by keeping them focused on activities that keep them away from the lure of the street and its accompanying potential to (in the best of cases) distract them and (in the worst of cases) draw them into illicit activities". If this were the case, female immigrant students should be more successful at school than male immigrant students overall, and the gender gaps in stereotypically male school subjects should therefore be less pronounced or even non-existent within this student population.

State of Empirical Evidence

To our knowledge, surprisingly few studies have examined gender differences in achievement within immigrant student populations, and the evidence is mixed. There is some indication that female immigrant students are generally more successful in scholastic settings than male immigrant students (e.g., Dronkers & Fleischmann, 2010; Fleischmann et al., 2014)— a result that has also been found in African American and Latino populations in the US (Perez-Felkner, McDonald & Schneider, 2014; Riegle-Crumb, 2006; Riegle-Crumb & King, 2010; Schoon, 2015). In mathematics, some studies identified a more pronounced male advantage for students with an immigrant background compared to students from native families

(e.g., Herwartz-Emden et al., 2008), whereas other studies found no differential gender effects (e.g., Mehringer & Herwartz-Emden, 2013; Segeritz, Stanat & Walter, 2010). Overall, no clear-cut picture emerges, either for achievement or for motivation in mathematics or science, which given the dearth of relevant analyses is not surprising.

THE PRESENT REPORT

We explored the issue of inequality in STEM-subject achievement and motivation by drawing on data from large-scale assessment studies carried out in Germany. These analyses were published in German journals or books and are summarized here to make the findings available to an international audience. In addition, we present a few new analyses to further differentiate the findings. Because no clear-cut predictions can be derived from the literature, the analyses are largely descriptive and exploratory. The focus is on students whose families emigrated from Turkey, as they form the largest immigrant group in Germany. They and their parents were shown to have significantly more traditional gender-role attitudes than their peers from native German families (Rauch, Bergann & Stanat, 2014). Where possible, other immigrant groups were included in the analyses.

Study I: Gender Differences in Achievement, Self-Concept, and Interest

Based on data from the German National Assessment Study carried out by the Institute for Educational Quality Improvement (IQB) in 2012 (Pant et al., 2013), we analyzed gender differences in achievement and motivation for mathematics, biology, chemistry, and physics (for more detailed descriptions, see Jansen, Schroeders & Stanat, 2013; Schroeders, Penk, Jansen & Pant, 2013).

The overall sample of the study consisted of $N = 44,584$ ninth-grade students, $N = 8029$ of whom had an immigrant background. Students with at least one parent not born in Germany were classified as having an immigrant background. Students from Turkish immigrant families (4.5% of the overall population of students) formed the biggest sub-population, followed by students whose families came from the former Soviet Union (4.1%) or Poland (2.0%). Owing to a multi-matrix design implemented in the study, the sub-samples with available data for the different analyses presented below ranged from $N = 396$ to $N = 13,002$.

For the overall student population, the study revealed gender differences in achievement that ranged from $d = -.22$ favoring girls in biology to $d = .16$ favoring boys in mathematics.¹ Mathematics was the only domain with a significant achievement advantage for boys. Most importantly, the results for the motivational variables only partially mirrored these achievement differences. In mathematics, the gender gap in favor of boys was considerably larger for motivation than for achievement (self-concept: $d = .54$, interest: $d = .48$). Even in some of the domains with significant achievement advantages for girls, boys reported higher levels of self-concept and interest than their female peers (e.g., in chemistry: $d_{\text{achievement}} = -.08$, $d_{\text{self-concept}} = .33$, $d_{\text{interest}} = .35$). Thus, the pattern of findings was clearly more stereotypical for motivational variables than for achievement.

In additional analyses, we explored the extent to which this pattern is similar within the population of immigrant students. We distinguished three student groups according to their families' country of origin: Germany, Turkey, and other. The latter group could not be further differentiated owing to sample-size restrictions. The findings are presented in Table 1.

The pattern of effect sizes indicates that, in line with the first hypothesis, the gender difference in mathematics achievement favoring boys is slightly larger in the two immigrant samples than in the native German sample. In science achievement, girls are consistently ahead of boys in the Turkish group, where the gender differences are more pronounced than in the other groups in all three science subjects. This pattern is more in line with the second hypothesis.

For the motivational variables, the gender differences in mathematics are largely comparable across the three student groups, while in science there is a tendency for the gap to be smaller in the Turkish sample. Thus, the particularly pronounced achievement advantage of girls with a Turkish background in science is, to some extent, reflected in the motivational differences, although boys have higher self-concept and interest scores in this group as well – despite their lower achievement.

In general, however, the pattern of gender differences is relatively consistent across the three sub-samples. Clear-cut differential patterns do not emerge.

Study II: Gender Differences in Achievement-Relevant Attitudes and Behaviors, Literacy, and Mathematics

Segeritz, Stanat & Walter (2010) drew the same main conclusion in their more general exploration of achievement-related gender differences in immigrant students. Their study was based on data for 15-year old students from PISA 2003, which included an oversampling of immigrant students in Germany (Prenzel et al., 2004).

The analyses used data from $N = 29,177$ students of whom $N = 5024$ had an immigrant background. Students were defined as having an immigrant background if they or at least one of their parents had not been born in Germany. Four groups were distinguished: students whose families had emigrated from Turkey ($N = 1730$), Poland ($N = 1021$), or the former Soviet Union ($N = 2273$) as well as students from native German families ($N = 24,153$).

The study analyzed two indicators of attitudes relevant for students' achievement: general attitudes toward school (e.g., "school has taught me things that could be useful in a job") and educational aspirations (desired school degree). In addition, the study explored the extent to which parents reported as supporting their children with their homework and, as indicators of school success, achievement in reading and mathematics. Homework support was not included only as a possible mediator between immigrant status and achievement, but also as a proxy of parental monitoring that, given the mechanisms described above, may be more pronounced for girls than for boys in immigrant populations.

Table 1 Achievement, self-concept, and interest in several STEM domains by gender and immigration status

Academic domain	Student group	Achievement score			Academic self-concept			Academic interest		
		<i>M</i> (<i>SD</i>) boys	<i>M</i> (<i>SD</i>) girls	effect size (<i>d</i>) ^a	<i>M</i> (<i>SD</i>) boys	<i>M</i> (<i>SD</i>) girls	effect size (<i>d</i>) ^a	<i>M</i> (<i>SD</i>) boys	<i>M</i> (<i>SD</i>) girls	effect size (<i>d</i>) ^a
Mathematics	No immigration background	528.56 (97.10)	515.20 (93.77)	0.11*	2.90 (0.82)	2.46 (0.85)	0.53*	2.69 (0.84)	2.29 (0.81)	0.49*
	Turkish	450.45 (77.89)	427.35 (90.73)	0.23	2.92 (0.86)	2.47 (0.89)	0.52*	2.83 (0.90)	2.46 (0.90)	0.41*
	Other Countries	498.03 (96.37)	472.16 (94.97)	0.22*	2.91 (0.83)	2.38 (0.87)	0.63*	2.76 (0.87)	2.31 (0.86)	0.53*
Biology	No immigrant background	511.73 (100.91)	528.72 (92.62)	-0.15*	2.84 (0.66)	2.85 (0.63)	-0.01	2.48 (0.78)	2.56 (0.74)	-0.11*
	Turkish	427.23 (78.26)	447.78 (88.10)	-0.21*	2.7 (0.67)	2.73 (0.69)	-0.05	2.52 (0.82)	2.50 (0.75)	0.03
	Other Countries	478.97 (97.54)	497.54 (93.39)	-0.16*	2.83 (0.68)	2.82 (0.64)	0.02	2.51 (0.82)	2.59 (0.77)	-0.10
Chemistry	No immigrant background	519.63 (101.64)	521.76 (92.12)	-0.02	2.72 (0.77)	2.45 (0.76)	0.36*	2.45 (0.84)	2.14 (0.78)	0.38*
	Turkish	427.70 (91.20)	449.15 (82.98)	-0.20	2.62 (0.76)	2.48 (0.8)	0.19	2.48 (0.86)	2.21 (0.83)	0.32*
	Other Countries	482.10 (97.54)	486.87 (89.97)	-0.04	2.70 (0.77)	2.44 (0.77)	0.34*	2.46 (0.87)	2.19 (0.84)	0.32*
Physics	No immigrant background	524.87 (98.95)	518.96 (92.56)	0.05	2.79 (0.73)	2.32 (0.71)	0.65*	2.51 (0.83)	1.92 (0.71)	0.76*
	Turkish	424.42 (97.24)	443.89 (84.58)	-0.17	2.64 (0.72)	2.36 (0.76)	0.39*	2.50 (0.85)	2.00 (0.76)	0.62*
	Other Countries	483.86 (95.09)	478.53 (92.93)	0.05	2.74 (0.75)	2.31 (0.73)	0.58*	2.52 (0.87)	1.94 (0.77)	0.71*

Note. ^a positive values indicate an advantage for boys. All statistics were computed using sampling weights. Achievement in science refers to the domain "scientific knowledge". The achievement scores are scaled so that the weighted mean of the total sample of German ninth grade students is 500 and the weighted standard deviation is 100. Self-concept and interest were each measured with four 4-point Likert-type items and then aggregated to mean scale scores.

* statistically significant mean difference between gender groups ($p < .05$)

The overall picture of the findings did not indicate any more pronounced advantages for either girls or boys from immigrant populations.² For achievement, the gender gaps were neither significantly larger nor significantly smaller for immigrant students than for students from native families. There was only a marginally significant tendency ($p < .10$) for the advantage of girls in reading to be more pronounced in the Turkish group. With regard to parental homework support and attitudes toward school, however, the gender gap was significantly larger for students of Turkish origin than for students from native German families. The level of homework support was especially low for Turkish boys. Both girls and boys with a Turkish background reported quite positive attitudes toward school, and this tendency was particularly pronounced for girls. Yet, again, there was no clear-cut pattern suggesting that more traditional gender-role attitudes in immigrant groups affected achievement or motivation in mathematics and science in one direction or another.

PRELIMINARY CONCLUSIONS

Overall, the findings for achievement in mathematics and science presented above are largely in line with the gender similarities hypothesis, as the differences between men and women were small. Immigrant students in Germany, especially those with a Turkish background, lagged behind their peers from native families in all domains, yet the gender gap did not vary consistently across groups. There was, however, some evidence that men with a Turkish background may be particularly disadvantaged in science achievement. This result is consistent with previous research showing that students with a Turkish background are among the most marginalized student groups in the German education system, showing lower achievement (Pöhlmann, Haag & Stanat, 2013) and, on average, leaving the education system with lower-level degrees (Kristen, Reimer & Kogan, 2008). Explanations for this pattern refer, among other things, to the lower average SES of Turkish families (and its primary and secondary effects), language problems, segregation effects through tracking and classroom composition, less strategic educational choices due to a lack of knowledge about the German education system, and also to cultural orientations that emphasize traditional values (for an overview, see, for example, Dollmann, 2010; Kristen, Reimer & Kogan, 2008). The latter assumption may also provide an explanation for why it seems particularly hard for boys from Turkish backgrounds to adapt to the German school system, in which female students are generally more successful than male students. To the extent that boys with a Turkish background do, in fact, adopt very traditional gender roles, they may be even more prone than other students to associate masculine traits with low academic engagement and achievement (Heyder & Kessels, 2013; Kessels, Heyder, Latsch & Hannover, 2014). Yet, again, the overall picture of our findings does not clearly suggest that the gender gap is particularly pronounced for students from Turkish families (the effect sizes were generally small and math showed a different effect pattern from science).

Regarding motivation, the gender differences in all domains tended to show a stereotypical direction, favoring boys to a much larger degree than the achievement gap would justify. Although girls had higher achievement scores in chemistry, for

example, the self-concept and interest scores in this domain were significantly higher for boys. Immigrant students did not show lower levels of motivation than their peers from native families. And, again, no consistent differences between immigrant students and students from native families were found for the gender gap in motivational orientations.

Overall, the results speak neither in favor of a “double disadvantage” for girls from immigrant populations nor for a particular advantage for boys from immigrant families. The possible mechanisms described above may either not be present, or they may not result in strong, detectable effects on achievement and motivation. Another possible interpretation is that the two mechanisms cancel each other out. To get a clearer, in-depth picture of the interplay between gender and immigration background, future studies should not only measure achievement and motivation, but also include direct measures of gender-related attitudes toward different school subjects and school learning in general.

The lack of alignment between achievement and motivation of girls in mathematics and science is of concern. Girls with or without immigrant background (greatly) underestimated their abilities, especially in physics. As self-concept and interest are important predictors of educational and occupational choices (e.g., Eccles, 2007), this finding contributes to the gender gap in domain-specific educational participation. Domain-specific (rather than general) interests and self-concepts should therefore be fostered in girls. Several interventions that aim at enhancing self-concepts have been shown to be effective, particularly when the prior level of achievement is low and when the intervention targets specific domains (O'Mara, Marsh, Craven & Debus, 2006).

Given the results of our study, teachers should first of all be aware that considerable gender gaps in motivation, particularly in physics and mathematics, still exist even though achievement differences are barely relevant. They can help enhance students' domain-specific self-concepts even without special interventions. Supportive feedback, attribution retraining, and individual goal feedback, for example, have been identified as effective methods of enhancing students' self-concepts, and should hence be utilized in STEM classrooms (Craven, Marsh & Debus, 1991; O'Mara et al., 2006; Ziegler & Heller, 2000). Finally, it should be mentioned that motivational characteristics such as academic self-concepts, even though they have an effect on educational choices, are only one of several factors contributing to the choice to engage in the STEM domain. As Schoon (2015) points out, such choices are best explained by an “integrative developmental-contextual system” (p. 152), with complex, dynamic and non-linear relations between a variety of individual, developmental, and contextual factors.

ENDNOTES

¹ Group means in achievement, self-concept, and interest were compared using t-tests and effect-size estimations (Cohen's *d*). As it is common practice in large-scale assessments, plausible values (PVs) from a one-parameter logistic IRT model (*Rasch Model*) were used as achievement indicators. The standard errors were adjusted using a jackknifing procedure. Details can be found in a technical report (Hecht, Roppelt & Siegle, 2013).

² Several group mean comparisons and (mediated) regression analyses were conducted. Please refer to the original publication (Segeritz, Stanat & Walter, 2010) for a detailed account including descriptions of the statistical procedure, the different regression models (including control variables such as SES), and descriptive statistics.

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