BRAIN TYPE, SEX DIFFERENCES, AND MOTIVATION TO LEARN SCIENCE: A CROSS-CULTURAL STUDY

Albert Zeyer¹, Ayla Çetin-Dindar², Ahmad Nurulazam Md Zain³, Mojca Juriševič⁴, Iztok Devetak⁵, and Freia Odermatt⁶

¹ University of Zurich, Switzerland
² Middle East Technical University, Ankara, Turkey
³ Universiti Sains Malaysia, Malaysia
⁴ University of Ljubljana, Slovenia
⁵ University of Ljubljana, Slovenia
⁶ University of Zurich, Switzerland

Abstract: Sex is considered to be one of the most significant factors influencing attitudes towards science. However, the so-called brain type approach from cognitive science suggests that the difference in motivation to learn science does not primarily differentiate the girls from the boys, but rather the so-called systemizers from the empathizers. Boys are, on average, more motivated to learn science, not because they are boys but because boys tend to be systemizers, and vice versa for girls. Previous research on Swiss students has indeed shown full mediation between sex and motivation to learn science. The present study was conducted in order to confirm this relation in a cross-cultural study. It involved four countries (Malaysia, Slovenia, Switzerland, and Turkey) and 1200 students in upper secondary level. The study used structural equation modelling in order to test the hypothesised relationship. The results confirm the full mediation of systemizing between sex and motivation to learn science. The results are stable and the model fit is excellent. Systemizing explains 27% of the motivation to learn science. The indirect impact of sex on motivation is significant but low. The results are invariant across all four cultures. It is therefore concluded that students’ brain type, seen as a basic cognitive personal trait, is more important as a predictor for motivation to learn science than sex. It should be taken into account both in science teaching and research of science education.

Keywords: Gender, Sex, Motivation, Culture, Cognition

INTRODUCTION

A number of studies indicate that boys have a more positive attitude towards science education than girls and this trend is seen most profoundly in studies which do not differentiate between science subjects but rather investigate the general attitude of students toward science lessons (Osborne & Collins, 2003; Sjöberg & Schreiner, 2005). If, however, studies focus on students’ interest and motivation to learn science, the situation becomes less clear. Glynn, Taasoobshirazi, & Brickman (2007), for example, were unable to find a relationship between sex and motivation to learn science among American students with non-science majors. This ambivalence is also salient, when subdimensions of motivation are taken into account. For example Britner’s study (2008) found that girls had stronger self-efficacy in science classes, particularly in earth and environmental sciences, while other studies reported a reverse result (cf. Glynn, Taasoobshirazi, & Brickman, 2009).

In this unclear situation, research results from cognitive science, provided by Billington,
Baron-Cohen, & Wheelwright (2007), is of particular interest. These researchers compared natural science and human science students in view of their sex and their so-called brain type. They showed that male sex was indeed a statistical predictor for studying natural science. However, the brain type had a far greater influence on the path of study than sex. The concept of brain type was originally formed within the field of autism research (Baron-Cohen, 2002). Baron-Cohen and colleagues developed a cognition concept by proposing the interplay of two core psychological dimensions: empathizing (E) and systemizing (S) (Baron-Cohen, Knickmeyer, & Belmonte, 2005). The brain type is defined as the interplay between the two abilities. There exists a score EQ (empathy quotient) and a score SQ (systemizing quotient) to measure the empathizing and the systemizing dimensions respectively. Brain type is basically calculated as a mathematically normalized difference of EQ and SQ. Based on their results, Billington et al. (2007) suggested that perceptions toward natural science are fundamentally influenced by brain type rather than by sex. Thus, the difference between motivation for learning science does not primarily differentiate the girls from the boys, but rather the systemizers from the empathizers. The difference observed between the sexes results from the tendency for girls to be empathizers and the boys to be systemizers and from the finding that systemizers, in general, are more interested in natural sciences than the empathizers.

This hypothesis has recently been tested by research on Swiss students (Zeyer, 2010; Zeyer, Bölslerli, Brovelli & Odermatt, in press; Zeyer & Wolf, 2010). Structural equation modeling indeed showed full mediation of systemizing (one of the cognitive dimensions of the brain type) between sex and motivation to learn science. This means that sex had no direct impact on motivation to learn science, but only through its impact on systemizing, which itself explained 25% of motivation to learn science. However, results differed from expectations since there was no relation between empathizing (the second cognitive dimension of the brain type) and motivation to learn science.

The interesting and open question remained, were these relations between sex, empathizing and systemizing, and motivation to learn science specific for the Swiss science education culture, or were they indeed applicable and constant across other cultures. The present study was conducted in order to investigate this research question in a cross-cultural setting. The study involved four countries (Malaysia, Slovenia, Switzerland, and Turkey) and 1300 students in upper secondary level.

Structural equation modeling was used in this study in order to confirm the hypothesized relationship in the overall sample and in each of the involved cultures.

**THEORETICAL BACKGROUND**

**Brain type**

The Brain Type Theory initially emerged from a theoretically and empirically substantiated concept from Baron-Cohen and colleagues (2005). In this theory, two fundamental psychological dimensions are proposed: systemizing and empathizing (Billington et al., 2007). These relate respectively to the “consciousness of a physical world” and to the “consciousness of a mental world” (Baron-Cohen, 1999).

The basic principle of the brain type theory is that each human uses both of the available psychological dimensions systemizing and empathizing. Generally, however, one of the dimensions, systemizing or empathizing, is predominant. A person who is more influenced by systemizing than by empathizing is described as a systemizer. In the reverse case, a person is called an empathizer. People who are equipped equally with both abilities are called balanced. This concept is known as the E-S-Model.
An important result from the research, which arises from using the E-S-model is that women are on average empathizers (that is their normalized Empathizing Quotient is in general larger than the normalized Systematizing Quotient, E > S). Men are on average systemizers (S > E) (Baron-Cohen, 2002). However, this generalization is only applicable on average as there are also systemizers among the women and empathizers among the men.

**Motivation to Learn Science**

The central focus in motivation research is on the conditions and processes that facilitate the students’ persistence, performance and healthy personal development (Ryan and Deci, 2009). In the study presented here, we use Glynn and Koballa’s theoretical motivation framework (2006) to ensure comparability with their results. Thus motivation is defined as “… the internal state that arouses, directs, and sustains students’ behavior towards achieving certain goals. In studying the motivation to learn science, researchers attempt to explain why students strive for particular goals, how intensively they strive, how long they strive, and what feelings and emotions characterize them in this process” (Glynn & Koballa, 2006, p. 1090). Based on research within the social-cognitive motivational framework (Bandura, 2001), Glen and colleagues identify six important motivational constructs that include intrinsic and extrinsic motivation, relevance to personal goals, self-determination, self-efficacy, and assessment anxiety (Glynn & Koballa, 2006).

**The Questionnaire**

In part A of our questionnaire, we used the SQ and the EQ questionnaire by Baron-Cohen (2003). Each country translated the questionnaire into its own language. Both the SQ and the EQ questionnaires contain 60-items in forced choice format, comprising 40 cognitive style items and 20 control items. The SQ includes questions such as “If I had a collection (e.g. coins, CDs, stamps), it would be highly organized” and “When I learn a language I become intrigued by grammatical rules”. Similarly, the EQ includes items such as “I am good at predicting what someone will do” to measure cognitive empathy or “I usually stay emotionally detached while watching a film” to measure the affective component of empathy.

On both the EQ and the SQ questionnaires, participants are asked to respond on a four-point Likert scale with “definitely agree”, “slightly agree”, “slightly disagree” or “definitely disagree”, and approximately half the items are reverse scored to avoid response bias.

In Part B of the questionnaire, we asked students to respond to the 30 items of the Science Motivation Questionnaire (SMQ; (Glynn & Koballa, 2006)). The items were translated into German. The SMQ items were developed based on the motivation concepts described earlier in this article. Students respond to each of the 30 randomly ordered items on a 5-point Likert type scale ranging from 1 (never) to 5 (always). Anxiety about science assessment items are reverse scored when added to the total, so a higher score on this component means less anxiety.

**METHOD AND SAMPLE**

A total of 1300 students from four countries, i.e. Malaysia, Slovenia, Switzerland, and Turkey were investigated. After cleaning the raw data, the sample included 1188 students, 476 male students (40.1%) and 712 female students (59.9%). The mean age was $\text{age}=16.59$ years (SD=.905). The distribution of the students in the different countries is indicated in Table 1.

The students were visited in their classes. For the duration of two lessons, students were required to be fully involved in the research by filling out the questionnaires. They were in-
formed that a study was being conducted to further understand students’ motivation to take science classes. Thereafter, the general conditions for the research were presented and finally, the questionnaires were distributed. The students had a break in between filling out each of the questionnaires and then the completed questionnaires were collected. In each class, the same standardized process was adhered to.

Table 1
*The structure of the sample by the countries*

<table>
<thead>
<tr>
<th></th>
<th>Malaysia</th>
<th>Slovenia</th>
<th>Turkey</th>
<th>Switzerland</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>126</td>
<td>107</td>
<td>119</td>
<td>124</td>
</tr>
<tr>
<td>Female</td>
<td>159</td>
<td>218</td>
<td>142</td>
<td>193</td>
</tr>
<tr>
<td>Total</td>
<td>285</td>
<td>325</td>
<td>261</td>
<td>317</td>
</tr>
</tbody>
</table>

**RESULTS**

**The procedure of structural modeling**

For the simultaneous test of the structural and measurement hypotheses, a causal structure was posited among the concepts of the EQ and the SQ, the SMQ, and sex. The tested structural equation model reflects the hypothesis that engagement in science is influenced by the SQ and by the EQ, and that sex only has an indirect (mimic) effect on the engagement in science through its impact on the two latent variables EQ and SQ. The model is a first order model, that is, the second order construct of brain type has not been introduced in the model.

**Item Reduction**

In order to be able to include SQ, EQ, and SMQ as single latent variables into the model, each of them had to undergo a substantial item reduction. Given the sample size and the number of SMQ items, 12-15 items at most for the structural model seemed to be adequate (Kim, 2005). Concerning the unidimensional item sets of EQ and SQ, a random assignment method was used (Little, Cunningham, Shahar, & Widaman, 2002). Each item from the EQ resp. the SQ was randomly and without replacement assigned to three parcels. This method is appropriate when items stem from a common pool, as it is the case for questionnaire items like those in the EQ resp. the SQ questionnaire.

A domain-representative approach was used for the SMQ, a multidimensional item set. With this method, parcels are constructed by combining items from different dimensions into item sets. It attempts to account for multidimensionality by creating parcels that encompass not only the common variance, but also the reliable unique facets of the multiple dimensions. Given that each of the six subdomain of the SMQ consists of five items, the domain-representative approach produced five parcels of six items each stemming from the different subdomains.
Model Confirmation

Due to the complexity of the empirical test, a two-step process was employed to confirm the first order model. All the estimates were produced using AMOS 16.0 (Airbuckle, 1997) and the estimation method of maximum-likelihood. As a first step, the measurement models of the EQ, the SQ and the SMQ were tested through confirmatory factor analysis. As discussed in subsection 2.1.3, three random parcels of the SQ items resp. the EQ items and five domain-representative parcels of the SQM items were used to operationalize the three latent variables. In the second step, the full structural model was directly tested. It reflects the core hypothesis of this study that the SQ and also the EQ have an impact on each PISA key concept of engagement in science, and that the impact of sex is only indirect (mimic) via the EQ and the SQ.

The full structural model

After an intensive analysis of the modification indices, significance tests, standard errors, and several intermediate model modifications, the structural equation model in Figure 1 is regarded as the best fit for the data. The definitive model has undergone important structural modifications. A salient feature is the complete absence of the EQ, the empathizing quotient, in the diagram. This latent variable indeed showed only small and non-significant loadings on all other latent variables in the model. Sex also had no impact on the EQ. Its removal entailed an improved overall fit. The factor loadings of the remaining measurement instruments are statistically highly significant (p<.01) and the corresponding signs concur with the hypotheses. The standardized estimates, from .74 to .89, confirm the formal validity of the individual items (see Bollen, 2002). The explained variances of the items vary between .54 and .79; this is a highly acceptable range of magnitudes. Descriptively, the model works very well which is indicated firstly by a highly acceptable goodness of fit index (GFI) of .982. Secondly, the baseline comparison (CFI) is 0.987. From an inferential point of view, the model is compatible with the data (CMIN/DF=3.876). Finally, RMSEA<.49 and PCLOSE=.530 indicate a very good fit (for the fit measures see Arbuckle, 1997, p. 551ff).

The standardized regression weight of the SQ on the SMQ (.52) is considerably high. Thus, the explanatory power of the model is high. The impact of the SQ can explain 27% of the variation of the SMQ. There is also a highly significant factor loading of sex on the SQ. The standardized regression weight is negative (-.29) because this variable represents “female” by the value 1, while 0 represents “male.” Therefore, in this model, males have a higher SQ (which aligns with the result in the descriptive part of this study). The impact of sex explains 9% of the variation of the SQ. Given the good fit, the high amount of multiple square correlations, the high, equally distributed and highly significant factor loadings, this model is considered to be appropriate as a full model for the presented theory. It reflects the theoretical background of the brain type theory. It confirms the hypothesis that motivation to learn science is highly influenced by the systemizing cognition, while the EQ, representing the empathizing cognition, has no significant influence on this motivation. It also confirms the hypothesis that sex indirectly affects the motivation to learn science via the SQ.

The indirect effect of sex was calculated by bootstrapping. The standardized indirect effect of sex on the SMQ (-.152) is highly significant, but very small. Since there is no significant direct loading of sex on the SMQ, the effect of sex on the motivation to learn science is strictly indirect and minimal.
Group comparison between male and female students

In order to compare the results of the different cultures, the method of simultaneous multiple group comparison was used, which allows an examination of the structure of the causal relations in both the measurement and the structural model (see Byrne, 2010). Firstly, a configural model (with no equality constraints imposed) was created by introducing the four data sets of the four different cultures. As expected, it reproduced the goodness of fit results of the basic model (CFI=.993, RMSA=.019, PCLOSE=1). Therefore, the four cultural groups show a comparable model structure, i.e. configural invariance.

Secondly, the metric (measurement) and the scalar invariance (structural) models were created and tested for invariance. The fit of the measurement model was consistent with that of the configural model (CFI=.985; RMSEA =.025). The difference in the comparative fit
ΔCFI = .008 is smaller than .01, which accepts the invariance hypothesis (Cheung & Rensvold, 2002). The model therefore shows metric invariance. The fit of the structural model was also consistent with that of the configural model (CFI = .911; RMSEA = .056). Therefore, the intercepts were released in both SQ and SMQ, for one resp. three indicators. The released model presented a much better fit (CFI = .979, RMSEA = .028), and the CFI difference test now yielded ΔCFI = .006), which accepted the hypothesis of partial scalar invariance. Therefore, it was concluded that the multiple group model displayed partial scalar invariance, which allows for a comparison of factor loadings and latent means between the four groups (Steenkamp & Baumgartner, 1998). Table 2 shows the squared multiple correlations and the implied means of the SMQ, and the means of the SQ for all four cultures.

Table 2.
Cross cultural comparison of the squared multiple correlations (SMC) and the latent means (means)

<table>
<thead>
<tr>
<th></th>
<th>SMC SQ</th>
<th>SMC SMQ</th>
<th>mean SQ</th>
<th>mean SMQ</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switzerland</td>
<td>.18</td>
<td>.3</td>
<td>7.27</td>
<td>16.55</td>
</tr>
<tr>
<td>Turkey</td>
<td>.03</td>
<td>.47</td>
<td>10.08</td>
<td>16.05</td>
</tr>
<tr>
<td>Malaysia</td>
<td>.05</td>
<td>.29</td>
<td>10.22</td>
<td>14.01</td>
</tr>
<tr>
<td>Slovenia</td>
<td>.13</td>
<td>.25</td>
<td>8.89</td>
<td>14.62</td>
</tr>
</tbody>
</table>

The difference between the impacts of sex on the SQ across the cultures is not significant. The same holds for the impacts of the SQ on the SMQ. It is the same across all the involved cultures. The difference of the mean SMQ across the cultures is not significant, neither. The only significant difference can be found between the mean SQs. The Swiss mean SQ is the lowest, followed by the mean SQ in Slovenia (p<.01). The mean SQs of Turkey and Malaysia are higher, but equal.

**DISCUSSION**

The Structural Equation Modeling (SEM) part of the results provides a structural model that reflects and confirms the theoretical background of the E-S theory and confirms the results of the previous Swiss studies (Zeyer, 2010; Zeyer, Bölsterli, Brovelli & Odermatt, in press; Zeyer & Wolf, 2010) in a cross-cultural context. As in the Swiss studies, three salient aspects are included in the model: the impact of the SQ on the engagement in science, the absence of an impact of the EQ on the engagement in science, and the strictly indirect influence of sex on E-S. These features are remarkably the same in all four cultures. The only significant difference can be found in the means of the SQ, which is lowest among Swiss students. The impact of the SQ on motivation to learn science is fairly large. The more somebody systemizes, the greater their motivation to learn science will be. Secondly, the structural model suggests that the EQ does not influence the engagement in science. Empathizing is defined as a drive to identify another person’s mental state and to respond to a mental state with one from a range of appropriate emotions. Significantly, the personal disposition to empathize seems to have no influence on a person’s motivation to learn science. This partially corrects the hypothesis suggested in the work of Billington et al. (2007). If brain type were to influence a person’s motivation to learn science, then not only the SQ but also the EQ would be involved. Since brain type is essentially calculated as the difference between the SQ and the EQ, a positive effect of the brain type on the motivation to learn science would imply a negative effect of the EQ on these constructs. Such a negative effect could indeed be motivated
from a theoretical point of view. If empathizing is the drive to deal with mental states, it could well be that a strong interest in mental things could simultaneously diminish engagement in science, at least with science that is explicitly dedicated to physical things. However, in the structural model presented in this article, this is not the case. Instead, motivation to learn science is independent of a person’s drive to empathize. A strong empathizer can be poorly engaged in science; however, their engagement can also be strong. It depends on their SQ. The inverse holds true, i.e. for a low empathizer. This can be interpreted in two different ways. Firstly, one could argue (based on the aforementioned reflections) that general science simply has no link to empathizing at all and therefore, it does not affect the empathizing cognition of a person whatsoever. Another point of view could be that the empathizing dimension of students is not affected because of the particular way general science is taught in the investigated schools (or at least it has no negative impact as suggested by previous research, which could also be taken as a positive point). From the presented data, it is not possible to determine which interpretation is correct. The third salient feature of our model is that sex only has an indirect (mimic) effect on the motivation to learn science. This is in fact the core hypothesis derived from the findings of Billington et al. (2007) and it is the main motivation for the investigations presented in this paper. The argument follows: engagement in science depends primarily on the SQ of a person. If the systemizing cognition of a student is strong, then they will show a high engagement in science independent of their sex. Since men tend to be stronger systemizers than women, men are prone to be more engaged in science. However, if a man is a weak systemizer, he will not be engaged in science despite his sex. On average, men are more motivated to study science than women, because they are, on average, stronger systemizers. In terms of empathizing, the same holds true for women who are more likely to be less systemizing.

CONCLUSIONS

Overall, the present structural equation model suggests a clear situation. The motivation to learn science is directly and fairly strongly influenced by the SQ and indirectly and very weakly influenced by sex. The study confirms the Swiss results and shows a remarkable stability across four different cultures. Indeed, studies by Wakabayashi, Baron-Cohen, Uchiyama, Yoshida and Wheelwright (2007) have already shown a cross-cultural stability of the E-S theory which fits satisfactorily into their biological framework. Empathizing and systemizing are, according to Baron-Cohen, not cognitive styles but biological abilities. This could explain the stability of our results across the cultures. Generally, more research must be done to be able to reliably link our findings to the situation in the real science classroom. The challenge for school science seems to be determining how to teach low SQ students, whether they are good empathizers or not. It would be an interesting area of research to investigate how these two groups differ, and how they should be approached to improve the systemizing dimension of their cognitive style, i.e. their drive and ability to analyze the rules underlying a system in order to predict its behavior. The findings suggest that successfully improving the systemizing dimension of these students’ cognitive style could consequently lead to improvements in their engagement in science. Research must show if and the extent to which the initial level of systemizing can be improved and how this might be achieved. Although cognition is biologically rooted, it does not mean that it must remain stable over time and inert to education. A second area of inquiry that remains seemingly uninvestigated is if the hypothesis holds true that science lessons do not affect the empathizing cognition of students.
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