Norwegian, Swedish, and Finnish first-year engineering students' motivational values and beliefs about the nature of mathematics

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We report from a Nordic research project that has investigated first-year engineering students in Norway, Sweden, and Finland, and the relationships between their task performance, motivational values, and beliefs about the nature of mathematics. The present paper focuses on the covariance between their motivational values and beliefs from the perspectives of gender and nationality. The results show that female students' motivational values are more strongly related to their beliefs than is the case for male students. Further, the Finnish students' motivational values are only weakly related to their beliefs, whereas the Norwegian and the Swedish students' motivation to mathematics is quite strongly related to how much they appreciate the applications of mathematics.

Keywords: beliefs, engineering students, gender, motivation, nature of mathematics.

Introduction

This study is an outcome of a larger project investigating first-year engineering students in Norway, Sweden, and Finland, and how students' task performance depends on their motivation, self-efficacy, and beliefs about the nature of mathematics. The project was motivated by the well-known 'Transition problem' which refers to the challenges related to transition from studying school mathematics to studying university mathematics. Often this includes also changes in the social setting when a student moves to a new location but, especially, concrete and practical changes in what and how to learn in mathematical courses (Gueudet, Bosch, diSessa, Kwon & Verschaffel, 2016) and their connection to a student's motivation and performance (e.g., Anthony, 2000).

The present paper focuses on the relationship between the participated students' motivational values and their epistemological beliefs about the nature of mathematics from the perspectives of gender and nationality. Our research questions are as follows.

1. How do the Nordic students' motivational values correlate with their beliefs about the nature of mathematics across gender?

2 How do the correlational relations vary across the national cohorts?

Theoretical framework and literature review

We consider students' motivation values with aid of the Expectancy–value theory which explains how expectations and values affect an individual's learning behaviour. In this theory, the motivational values are categorised into four classes: 1) *intrinsic value* refers to the enjoyment of and interest in studying the subject, 2) *attainment value* represents the perceived importance of being good at mathematics, 3) *utility value* is related to the perceived usefulness of knowing mathematics for short- and long-term goals, and 4) *cost* portrays how much an individual is ready to invest his or her resources in studying mathematics (e.g., Wigfield & Eccles, 2000).

The role of motivation for success in studying mathematics is a topic that has been extensively studied and the positive effect of high motivation is well known. Due to the limitation for the length of the NORMA articles, we review only one Nordic study which is most relevant to us; for a more thorough review, see Tossavainen, Rensaa, Haukkanen, Mattila, and Johansson (2021). Bengmark, Thunberg, and Winberg (2017) examined Swedish engineering students' motivation, beliefs about and expectations on studying mathematics, and study habits as well as their relative importance for the students' performance in the transition to tertiary mathematics. They noticed that students' characteristics, e.g., motivation and beliefs, play a significantly more important role than, for instance, their study habits when predicting students' achievement during the first year in university.

The epistemological beliefs about the nature of mathematics are also called orientations. Felbrich, Müller, and Blömeke (2008) have formulated and applied them as follows.

- A *formalism-related* orientation is mathematics viewed as an exact science with an axiomatic fondation and being developed by deduction (e.g., 'Mathematical thinking is determined by abstraction and logic.')
- A *scheme-related* orientation is mathematics given as a set of terms, rules and formulae (e.g., 'Mathematics is a collection of procedures and rules which precisely determine how a task is solved.')
- A *process-related* orientation is mathematics regarded as a science which in most parts consists of problem solving processes and where finding structure and regularities is important (e.g., 'If one comes to grip with mathematical problems, one can often discover something new (connections, rules and terms).')
- An *application-related* orientation is mathematics regarded as a science which is relevant for society and life (e.g., 'Mathematics helps to solve practical tasks and daily problems.').

The formalism and scheme-related orientations are of a static nature, taking mathematics merely as a ready-made construction, whereas process- and application-related orientations are more dynamic embracing developing and discovering activities. Students usually acknowledge several aspects of mathematics simultaneously, yet most of them can name which orientation best corresponds to their view of mathematics (e.g., Tossavainen, Rensaa, et al., 2021).

For example, Harris et al. (2015) have noticed that freshmen engineering students recurrently highlight the application-related orientation to mathematics. In their study, the students accentuated that the ”use-value” of mathematics is lost if mathematics is not taught with an emphasis on the applicable examples in engineering. Similarly, the dynamic orientations were three times more often mentioned as a primary orientation than the static orientations in the study of Tossavainen, Rensaa, et al. (2021). However, previous studies that we are aware of have not focused on the relationship between the orientations and the motivational values. In this sense, the present study is the first of its kind.

Sax and colleagues (Sax et al., 2016) have surveyed 40 years of the changing gender-related dynamics among engineering students. They found that female students' self-efficacy in mathematics has long been lower than that of male students. Concerning self-concept, performance expectations, and motivation, similar findings from the adult learners have also been reported in the Nordic context by Skaalvik and Skaalvik (2004). However, Tossavainen, Rensaa, et al. (2021) showed that this is not necessarily true anymore; female students outperformed male students in a set of seven mathematical tasks and set more demanding learning goals for themselves than male students. Further, they expressed higher intrinsic motivational values, whereas male students emphasised utility values.

Method

The present investigation is based on 431 first-year engineering students' responses to a questionnaire; out of these 71 were from Norway, 88 from Sweden, and 272 from Finland. The students were just starting their engineering studies; the data were collected during the first weeks of their first basic calculus course. The same questionnaire was used in all countries, yet translated to the native language. The universities taking part in Norway and Sweden are medium-sized and situated in northern, sparsely populated areas, while the university in Finland is one of the largest and most popular ones in Finland situated in a densely populated area in Southern Finland. This explains the difference in the sizes of the national cohorts. It is important to notice that this kind of design does not automatically lead to a bias. Differences, for instance, in the entrance requirements could easily affect, e.g., first-year students' task performance across the cohorts, but there is no a priori reason to believe that the differences between the participating universities have an effect on the relationship between the students' motivational values and orientations. A main motivation for studying different kinds of Nordic cohorts was to increase a variety of educational settings in our data.

The cohorts represent 17% (NOR), 18% (SWE), and 32% (FIN) of all first-year engineering students at the universities. The proportions of female students in the cohorts are 13% (NOR), 19% (SWE), and 34% (FIN). In the whole data, 27% are female students, 71% male students, and 2% did not express their gender. For more details, see Tossavainen, Rensaa, et al. (2021).

The questionnaire used in the study contained a set of propositions equipped with a five-step Likert interval scale measuring a student's self-efficacy, motivation, and view of the nature of mathematics. The items used to measure the distribution of orientations were based on the instrument developed by Tossavainen, Viholainen, Asikainen, and Hirvonen (2017). The items are shown in the first column of Table 1. Similarly, the eight items measuring the motivational values are shown in Table 1. The statements were deliberately formulated in positive terms to encourage engineering students to reflect on their motivation. The letter in the parenthesis at the end of each item indicates which value or orientation the item is intended to measure. For each of value and orientation, there are two items. The Likert scales were directed so that 1 corresponded to ”strongly disagree” and 5 to ”strongly agree”.

For the statistical analyses, the variables standing for the orientations and motivational values have been computed as mean values of the corresponding items, see Table 1. The Pearson correlation analyses between these notions have been conducted using SPSS Version 25. For interpreting the effect sizes, we have used the critical values given by Cohen (1988).

Orientations	**Motivational values**
O1. Mathematics is about describing the real world (A)	M1. I really like mathematics (I)
O2. It is not mathematics if it cannot be proved theoretically (F)	M2. I am motivated to study maths mainly because it is useful to other studies (U)
O3. Mathematics is a collection of formulas and concepts (S)	M3. I want to succeed as well as possible (A)
O4. Mathematics is problem solving (P)	M4. I would suspend a hobby in order to succeed in a maths exam (C)
O5. The purpose of mathematics is to maintain functionality in society (A)	M5. I would do extra exercises to guarantee that I succeeded well (C)
O6. Mathematics is about discovering structures and regularities (P)	M6. I would study maths voluntarily because every engineer must know it (U)
O7. The main task of mathematics is to give correct rules for calculations (S)	M7. If I get a low grade in mathematics, I want to take the exam again (A)
O8. In mathematics, all concepts must be defined in a precise and clear way (F)	M8. Mathematics is full of interesting problems and results (I)

Table 1. Items in the questionnaire

Results

In the following tables, the number of participants vary slightly between columns and rows because a few students' entries in certain items of the questionnaire were empty or ambiguous. These entries have been excluded from the analyses.

Table 2 answering the first research question shows some significant differences between female and male students. For female students, the correlations between the motivational values and orientations are higher and there are more significant relations between the motivational values and orientations than for male students. For both groups, all significant correlations are positive, which indicates that a higher motivation (in general) in mathematics is related to a higher appreciation of various natures of mathematics. It is not surprising that the utility values are related to appreciating the usability of mathematics in applications, but a less obvious relation is the relatively high correlation between Cost and Applications for female students. In other words, those female students who appreciate mathematics for its applications are prepared to invest extra time for studying mathematics. This relation is more than double higher for female students than for male students. Female and male students differ from one another even more in the relation between Attainment and Application; the female students who appreciate mathematics for its applications also want to perform well in mathematics. The effect size in this correlation is already medium. A finding worth mentioning is also the fact that the orientation that measures appreciation of exact reasoning and defining mathematical notions precisely has no significant correlation with motivation in mathematics.

	Application	**Process**	**Scheme**	**Formalism**
Male (N=298–305)				
Intrinsic	0.17**	0.08	–0.10	0.01
Attainment	0.11*	0.06	0.06	0.00
Utility	0.21**	0.05	0.15*	0.03
Cost	0.12*	-0.03	0.04	0.01
Female (N=116–118)				
Intrinsic	0.26**	0.16	–0.04	0.16
Attainment	0.30**	0.05	–0.03	–0.02
Utility	0.20*	0.19*	0.21*	0.06
Cost	0.27**	0.09	0.07	0.14

* = p<0.05; ** = p<0.01

Table 2. Correlations for the male and female participants

Table 3 summarizes differences between the Finnish, Norwegian, and Swedish students. The main finding is that the Finnish students differ significantly from the Norwegian and the Swedish students in one issue, but the Norwegian and the Swedish students differ from one another only slightly in a few issues. For the Finnish students, none of the orientations is highly correlating with the motivational values although some of the correlations are statistically significant even at the level $p < 0.01$. But the effect size is small in each case. This means that the Finnish students' motivation values do not depend on their orientations; recall that zero correlation between the normally distributed variables is an evidence for the independence of the variables. An interesting detail is that the correlation between the formalism orientation and interest in mathematics is statistically significant and positive for the Finnish students as opposed to the other students.

A common feature for all nationalities is that the relationship between the motivational values and orientations is first and foremost established via the application-related orientation and two or more values. When it comes to the Norwegian and the Swedish students, there are several quite high correlations with medium or almost large effect size between the motivational values and the application-related orientation. Other orientations are not related to their motivational values. The relationship between the motivational values and orientations is broadest for the Swedish students, there are altogether four significant correlations in the Swedish part of Table 3, of which two are significant even at the level $p < 0.001$.

The most remarkable difference between the Norwegian and the Swedish students is that those Swedish students who are interested in and appreciate the applications of mathematics often indicate also that they want to perform well and they are prepared to invest extra time in studying mathematics, whereas the Norwegian students do not have this kind of relation between their motivational values and orientations. Their appreciate mathematics merely for its usability.

	Application	**Process**	**Scheme**	**Formalism**
Finnish (N=270–272)				
Intrinsic	0.04	0.08	–0.09	0.13*
Attainment	0.14*	0.02	–0.03	–0.01
Utility	0.12*	0.01	0.08	0.09
Cost	0.17**	–0.08	–0.09	0.11
Norwegian (N=65–68)				
Intrinsic	0.46***	0.12	–0.04	–0.14
Attainment	0.10	0.08	–0.23	–0.02
Utility	0.35**	0.17	0.03	0.01
Cost	0.01	–0.02	–0.13	–0.04
Swedish (N=85–86)				
Interest	0.42***	0.16	–0.13	–0.08
Attainment	0.31**	0.04	0.03	0.05
Utility	0.42***	0.12	0.05	–0.01
Cost	0.26*	–0.02	–0.03	0.02

* = p<0.05; ** = p<0.01; ***= p<0.001

Table 3. Correlations for the Finnish, Norwegian and Swedish participants

Discussion

Our findings related to the first research question are somewhat surprising. If the application orientation becomes more central in the Nordic engineering students' view of mathematics, it increases female students' motivation in mathematics clearly more than male students' motivation. This outcome cannot be explained by a larger variation in female students' motivational values or orientation variables because there are no such differences in the data. However, the difference between male and female students lies in the magnitude of the relationship, not in the quality of the relationship. Further, the findings show that the Nordic first-year engineering students get motivation for mathematics from studying meaningful and relevant applications. This finding seems to be universal, cf. Harris et al. (2015).

Concerning the second research question, we found some correlations with larger effect sizes when compared with the results to the first question. The main result however is that, for the Finnish students, the motivational values and orientations are only weakly related, whereas for the Norwegian and Swedish students, there are quite strong relationships between the values and orientations.

Again, it is difficult to find a self-evident reason for this outcome. Why the first-year students from a university, which is situated to a more populated area and, therefore, has got somewhat higher entrance requirements, should have a weaker relationship between their motivational values and orientations? A possible reason might be that the study programmes provided by the participating universities are not completely similar. As the Finnish university offers many theoretical alternatives, it could explain the positive correlation between the motivational values and the formalism-related orientation. On the other hand, also the other two universities provide theoretical programmes. Moreover, the descriptive statistics for the formalism orientation are similar for all national cohorts (Tossavainen, Haukkanen & Rensaa, 2020; Tossavainen, Rensaa & Johansson, 2021). Hence this explanation is not completely convincing.

A more plausible explanation for the above-mentioned unexpected findings is as follows. We computed, both for the whole group and across the national cohorts and the gender groups, the Cronbach alphas for the items used in the sum variables. Surprisingly, we found some remarkable differences which above all are related to the items used for measuring the utility value. For the Scandinavian students, $\alpha \approx 0.5$, whereas $\alpha \approx 0$ for the Finnish students. In other words, the internal consistency of these items for the Scandinavian students differs remarkably from that for the Finnish students. There is a similar yet somewhat milder difference in the alphas between the groups organised due to gender. This phenomenon has an effect on the correlations of the utility sum variable with other variables in Tables 2 and 3. The observed correlations are likely weaker than they would be if the utility value had been measured using a more consistent instrument. This is seen as we compute the Pearson correlations between the single utility items and the orientation sum variables. For example, for male students, the Pearson correlation between the item M2 in Table 1 and the scheme-related orientation is 0.25 ($p<0.001$), whereas the correlation coefficient between the other utility item M6 and the scheme-related orientation is –0.05 ($p>0.05$). These variations damp one another which explains why the corresponding correlation for the utility sum variable is only 0.15 in Table 2.

Now afterwards, we can only say that we should have used more than two items for each value and orientation so that the sum variables would have been more coherent, and then we might have found more significant relationships. For the reason discussed in the above paragraph, it is very unlikely that our instrument would come up with correlations that were not real. In this sense, the low internal consistency is not a too serious problem now. On the contrary, it reveals that the motivational values in the real world make a more complex structure than the four dimensions described by the Expectancy–value theory. Moreover, this incident revealed a very interesting phenomenon: the same instrument may work differently in different contexts.

To sum up, our study succeeded to reveal gender- and culture-related variation in the relationship between the motivational values and the orientations. These relationships are far from being examined completely. Consequently, this topic deserves further investigations.

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