Gender differences favouring females in Estonian university students' views of mathematics

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This study reports on first-year Estonian university students' views of mathematics. The data were collected from 970 university students of different disciplines. The participants completed a Likert-type questionnaire that was compiled from previously published instruments. The results reveal the importance of Mastery Goal Orientation as central to the structure of their views of mathematics. In this study, in five of six dimensions, females hold a more positive view of mathematics than do male students. Performance-Approach Goal Orientation was the only dimension in which we found no statistically significant gender difference. In all the other dimensions, the female respondents expressed a more positive affect towards mathematics: They showed a more powerful mastery orientation, valued mathematics more, felt more competent, perceived their teacher more positively, and cheated less frequently.

Students' beliefs, attitudes and motivation towards the teaching and learning of mathematics play an important role in mathematics education (McLeod, 1992). The study of students' mathematical affect has received continuous attention since the 1990s. The extensive research on gender and mathematics education has reported that males achieve more and hold more favourable attitudes and beliefs about mathematics (e.g. Leder, Forgasz & Solar, 1996). However, studies have shown that gender differences in achievement are declining and disappearing in several countries (Mullis, Martin, Gonzalez & Chrostowski, 2004). Recent data from the US indicate that the gender difference in mathematics achievement has been eliminated (Hyde, Lindberg, Linn, Ellis & Williams, 2008). Their study shows that, for grades 2 to 11, the general population no longer shows a gender difference in mathematics skills, a result consistent with the gender similarity hypothesis, which maintains that males and females are similar in most, but not all areas. Else-Quest, Hyde and

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Linn (2010) meta-analysed two major international data sets, the 2003 TIMMS and PISA, representing 493 495 students 14 to 16 years of age, to estimate the magnitude of gender differences in mathematics achievement, attitudes and affect across 69 nations throughout the world. Consistent with the gender similarities hypothesis, they found gender similarities in achievement, although boys reported more positive attitude and affect towards mathematics. In the Forgasz, Leder and Kloosterman (2004) study, an Australian sample of students indicated that they believed mathematics was more likely to be the favourite subject of girls than of boys, and that girls were more likely than boys to enjoy mathematics and to think that mathematics is interesting. Unfortunately, studies of gender differences in mathematics-related beliefs at the university level are an almost unknown theme. The ICMI studies *Towards gender equity in mathematics education* (Hanna, 1996) and *Teaching and learning of mathematics at university level* (Holton, 2001) failed to explore this topic. Also, the special issue entitled *Beliefs and beyond: affecting the teaching and learning of mathematics* in the journal ZDM (The International Journal on Mathematics Education) in 2011 failed to touch the mathematics-related beliefs of students at the tertiary level.

Research on mathematics-related attitudes and beliefs has been rather separate from research on motivation, with mathematics-related attitudes serving as the main trend among mathematics educators and mathematics-related beliefs among educational psychologists (see Hannula, 2011 for details). This article uses the term *View of mathematics* to emphasise the inclusion of motivation, attitude and beliefs. This term was originally introduced by Schoenfeld (1985) and later adapted by others (Hannula & Laakso, 2011; Pehkonen, 1996; Pehkonen & Törner, 1996; Roesken, Hannula & Pehkonen, 2011). This article focuses on the cognitive component described by beliefs as well as on motivational aspects. Our use of "view" instead of "beliefs" aims to emphasise that not all of the dimensions we address are cognitive. In some sense, the term "beliefs" is separate, while "view" is holistic (Roesken et al., 2011). Roesken et al. (2011) measured student self-reported effort as an indicator of their motivation. In the Kaldo and Hannula (2012) paper, as in previous research (Diego-Mantecon, Andrews & Op 't Eynde, 2007; Midgley et al., 2000; OECD, 2009; Roesken et al., 2011; Yusof & Tall, 1994), first-year Estonian university bachelor students' views of mathematics are influenced mainly by similar constructs and the motivational component is improved. This result supported the approach that students' views of themselves as learners of mathematics can be separated into different categories (Roesken et al., 2011) and are coherent with Op 't Eynde, De Corte and Verschaffel's (2002) classification that dimensions can be assigned to all the main categories: a) Beliefs about mathematics education; b) Beliefs about self; and c) Beliefs about the social context. This also coincides with the works of Roesken et al. (2011) and Pepin (2011). The results of the present study are in line with the results of studies by De Corte and Op 't Eynde (2003). The concepts we use, their theoretical background, and the results regarding the structure of university students' views of themselves as learners of mathematics at the tertiary level is described more thoroughly in the paper (Kaldo & Hannula, 2012). In this paper, Kaldo and Hannula also described factor solutions. In another study, Kaldo and Reiska (2012) found that, for most factors, there is a significant difference in students' attitude towards mathematics, with science students holding a more positive attitude than non-science students.

Our research question in this article are: 1) Which are the correlations between the variables on the structure of affect; 2) Are the correlations between different affective variables equal for both genders; 3) Do the means between the variables differ for males and females?

Gender and views of mathematics

Beginning in the 1970s, there used to be clear gender differences favouring males in large-scale mathematics performance tests (Hyde, Fennema & Lamon, 1990). The PISA 2003 results (OECD, 2003) revealed that males generally outperformed females, while TIMSS 2003 showed gender differences in some countries, but not others (Mullis, Martin, Gonzalez & Chrostowski, 2004). Moreover, Hyde, Fennema and Lamon (1990) concluded that gender differences in mathematics performance, even among college students or college-bound students, were at most moderate.

Moreover, as soon as mathematics becomes optional in school, male students tend to be overrepresented over female students. At the university level in Sweden and Norway, mathematics programs typically attract mainly male students (Grevholm, 1996; Hag, 1996), although mathematics teacher education programmes typically attract more female than male students. In such programmes the proportion of female students in Finland is 86 % (Finne, 1996). On the other hand, in Estonia the majority of students in the technical, exact and natural sciences are male (Estonian Ministry of Education and Research, 2011).

As numerous studies on achievement differences indicate, there is no reason to believe that female students are underrepresented in mathematics-related studies due to inferior mathematics skills. Rather, female students tend to opt out of mathematics more often than male students at equal performance levels. Some studies have shown that students tend to perceive mathematics as a male domain (Frost, Hyde & Fennema, 1990), but this belief is held mainly by male students and therefore does not appropriately explain why female students who perceive mathematics as gender neutral nevertheless opt out of mathematics.

Studies of student beliefs about mathematical self-efficacy have produced very consistent results indicating that across age and performance levels, female students tend to show lower self-efficacy in mathematics than male students (e.g. Hannula, Maijala, Pehkonen & Nurmi, 2005; Leder, 1995). Related to low self-efficacy, female students also suffer mathematics anxiety more often than male students (Frost et al., 1994; Hembree, 1990). A study by Op 't Eynde and De Corte (2003) showed that girls held no more positive mathematics-related beliefs than boys did in any educational track of the Belgian school system. In humanities, boys held significantly more positive beliefs about themselves than did girls, thus indicating that the relationship between beliefs, gender and context is rather complex. Andrews, Diego-Mantecón, Op 't Eynde and Sayers (2007) discovered that girls in both Spain and England, regardless of age or nationality, were less positive in their beliefs about their own competence than boys. In terms of the inaccessibility and elitism of mathematics, they found that both males and females shared this negative view; females, however, held a significantly more negative viewpoint. Finally, they found that both the boys and girls in their study were equally positive in terms of their teachers as facilitators of their learning and of the relevance of mathematics to their lives. In effect, these results explain why female students usually choose not to study optional mathematics. There is no reason to believe that the low level of female students' self-efficacy beliefs is a natural and permanent gender characteristic of females. Recent research has accumulated evidence for the hypothesis that female students' lack of confidence in mathematics is consistent with their teachers' beliefs (Li, 1999; Soro, 2002; Sumpter, 2009), and thus that teachers' typical interaction patterns with male and female students may thus contribute to the generation of gender differences. Mathematics teachers tend to believe that their male students often have hidden talent, but underperform due to laziness and carelessness, whereas female students tend to reach their performance potential through diligence and hard work, even if they are not very talented (Sumpter, 2009). These teacher beliefs presumably lead to different feedback for male and female students, and thus contribute to observed gender differences in self-efficacy beliefs. Another theory characterises female beliefs as "learned helplessness" (Licht & Dweck, 1987). In some countries, however, female students hold a more positive attitude. For example, Li (2007) collected data from 450 secondary students (grades 7–12) and found that in general female students in Canada hold significantly more positive attitudes toward mathematics. That is, female students tend to enjoy learning mathematics and think it is more important to learn mathematics than male students do. Steinthorsdóttir and Sriraman (2007) showed that in Iceland, significant gender differences in mathematics achievement favoured girls.

Leder (1982) found that among high-achieving secondary school mathematics students, females showed more ambivalence about their success than males did. The nature of the attributions of male and female students has become an important theme in mathematics education. Males are more likely than females to attribute their success in mathematics to ability, whereas females are more likely than males to attribute their failures to a lack of ability (McLeod, 1992). In addition, females tend to attribute their success to extra effort more than males do, whereas males more than females tend to attribute their failures to a lack of effort. Differences in participation in mathematics-related careers appear to reflect these gender differences in attributions (Fennema, 1989; Fennema & Peterson, 1985).

The Brandell and Staberg (2008) study in Sweden shows that both sexes often tend to regard mathematics as a male domain. In their study, all subgroups tended to find that men are more likely than women to enjoy challenging mathematical problems, to find mathematics easy, and to be in need of mathematics in their future lives. On the other hand, many, especially female students, were more likely to find mathematics boring and difficult. Another finding was that females are supposed to work hard and worry about not getting on well. Interestingly enough, female students discover that women more often find it important to understand mathematics (Brandell & Staberg, 2008).

More recent studies have shed new light on gender differences in mathematics-related affect. Hannula, Kaasila, Laine and Pehkonen (2006) found in their study the core of a view of mathematics, comprising three closely related elements: belief in one's own talent, belief in the difficulty of mathematics, and a fondness for mathematics. They found gender differences in self-confidence, but not in a fondness for mathematics or in considering mathematics difficult. In addition, female students perceived themselves as more hardworking and diligent than male students. Nurmi, Hannula, Maijala and Pehkonen (2003) concentrated on pupils' self-confidence in mathematics, which belongs to pupils' mathematical beliefs in themselves as well as their beliefs about achievement in mathematics. Their study showed that boys in both grades 5 and 7 had markedly higher self-confidence in mathematics than did girls. Moreover, a gender difference in self-confidence was also identified among those students who had received the highest grade in mathematics.

No previous survey studies have explored Estonian university students' gender differences in mathematics-related affect. A study by Kikas, Peets, Palu and Afanasjev (2009) examined the development of mathematics skills in 269 Estonian primary school children (119 boys and 150 girls; 20 classes). Testing was carried out over a three-year period (grade 1–grade 3). As regards gender differences, girls and boys showed similar development in and similar final levels of mathematics skills. Estonian state-level mathematics achievement tests carried out in Estonia show no gender differences (Kikas et al., 2009). In another study, Lam et al. (2011) examined gender differences in student engagement and academic performance in school. Participants included 3420 students (7th, 8th, and 9th graders) from Austria, Canada, China, Cyprus, Estonia, Greece, Malta, Portugal, Romania, South Korea, the United Kingdom, and the United States. The results indicated that girls reported higher levels of engagement in school than did boys and their teachers rated the girls higher in academic performance. Student engagement accounted for gender differences in academic performance, but gender did not moderate the associations between student engagement, academic performance, or contextual supports. Gender differences may become more evident as children grow older (e.g. Ai, 2002). Kislenko (2009) analysed the differences between gender and grade in Norway and Estonia. In her work, the only significant difference in terms of gender was that boys generally claimed to be less afraid of making mistakes or of becoming nervous in test situations in mathematics than girls. Kislenko's (2009) results also indicated that both boys and girls know that mathematics is important, yet still find it boring.

Few studies are available of mathematics-related beliefs at the tertiary level. Studies at the university level typically focus on mathematics majors (Yusof & Tall, 1994), teacher education students (Hannula et al., 2006) or students of compulsory statistics courses (Murtonen, Olkinuora, Tynjälä & Lehtinen, 2008). Juter (2005) studied attitudes towards mathematics of students taking a basic mathematics course at a Swedish university, and explored possible links between their attitudes and how well students managed to solve tasks about the limits of functions. Einaste (2013) studied the difference of academic motivation and self-efficacy between bachelor students of mathematics and of informatics (113 men and 74 female) in four Estonian tertiary-level schools: the University of Tartu, the University of Tallinn, the Tallinn University of Technology and the Estonian Information Technology College. She used a different motivation scale. One important part of her work was translating the Academic Motivation Scale College Version (Vallerand et al., 1992) to Estonian and using that scale in her study. This scale defined motivation as intrinsic motivation, extrinsic motivation and amotivation. Einaste (2013) found that factors on the Academic Motivation Scale were: proving to oneself and complacency, amotivation, external regulation, motivation to know, and motivation to experience stimulation. Factors on the self-efficacy scale were: the student persistence, effort, management skills, experiencing stimulation, and having a realistic aim. Rööp (2013) analysed results of the 564 men and 258 women in the mathematics-informatics department at the University of Tartu in 2007–2012. Her main findings are that females select mathematics and statistics curricula more often than males do, and that during their university studies females earned higher grades than males did. She also found that the drop-out rate was higher for males than for females.

Method

Instrument

First, we clarify here that the instrument used was developed not only to compare gender differences, but also to explore the structure of Estonian university students' views of mathematics. The instrument was developed from previous work in this area by synthesising conceptual frameworks; the instrument combines scales and items from five previously published studies of mathematical beliefs/attitudes and motivational orientation towards mathematics at students of different educational levels and in different countries (for details, see Kaldo & Hannula, 2012). The resultant instrument consisted of the following elements of students' view of mathematics: Performance-Approach Goal Orientation (Midgley et al., 2000), 4 items; Mastery Goal Orientation (Midgley et al., 2000), 6 items; Mathematics as a Rote-Learnt Subject (Diego-Mantecon et al., 2007), 4 items; Attitudes towards Mathematics (Yusof & Tall, 1994), 6 items; Relevance (Diego-Mantecon et al., 2007), 9 items; Personal Value of Mathematics (OECD, 2009), 3 items; Student Competence (Roesken et al., 2011, 3 items; Diego-Mantecon et al., 2007, 3 items), 6 items; Teacher Role (Diego-Mantecon et al., 2007), 5 items; Cheating Behaviour (Midgley et al., 2000), 3 items; and Effort (Roesken et al., 2011), 4 items.

In this instrument, seven factors yielded reasonably good values for Cronbach's alpha (0.70–0.82), and their reliability for Estonian university students was confirmed (Kaldo & Hannula, 2012). The structure of the students' view of mathematics in this paper presumably consisted of the following confirmed factors (Kaldo & Hannula, 2012): Performance-Approach Goal Orientation (Cronbach's alpha 0.78, sample item "One of my goals is to show others that I am good at my classwork"), Mastery

Goal Orientation (Cronbach's alpha 0.74, sample item "It is important to me that I learn a lot of new mathematical concepts this year"), Value of Mathematics (Cronbach's alpha 0.80, sample item "A knowledge of mathematics is important; it helps us to understand the world"), Student Competence (Cronbach's alpha 0.82, sample item "I think that what I am learning in mathematics is interesting"), Teacher Role (Cronbach's alpha 0.72, sample item "My lecturer tries to make mathematics lessons interesting") and Cheating Behaviour (Cronbach's alpha 0.82, sample item "I sometimes cheat while doing my classwork"). The Kaldo and Hannula (2012) article focused on analysing the instrument, and correlations between the confirmed factors appear in the work of Kaldo and Reiska (2012).

One developing aspect of research on mathematics-related beliefs has been the identification of its different dimensions (e.g. Op 't Eynde, De Corte & Verschaffel, 2002) and the way these dimensions relate to each other (Kaldo & Hannula, 2012; Roesken et al., 2011). Due to the high correlation between two of the scales and the high similarity of their content, we decided to combine two of the scales (Relevance and Personal Value), constructing a new scale, Value of Mathematics, with high reliability (Cronbach's alpha 0.80).

Sample and procedures

In the study, the students were asked to respond on a Likert scale (4 points: strongly disagree to strongly agree). In the survey, carried out in Estonia in the autumn of 2009, the students had 45 minutes to complete the questionnaire and were told that the answers were anonymous. Table 1 shows the results from 970 questionnaires collected from students in a first-year mathematics course at one private and four public universities: the Estonian Business School (EBS), Tallinn University (TLU), Tallinn University of Technology (TUT), Tartu University (UT), and the University of Life Sciences (ULS). The participants in this study were bachelor students from all over Estonia, from different programmes including at least one mathematics course in the first year. The survey was completed during the students' regular mathematics lectures, but participation in this survey was voluntary. The average age of the 970 students (508 males and 462 females) who responded was 19.7.

Data analysis

Parametric statistical methods, such as factor analysis and *t*-tests, are all based on the assumption of normally distributed, interval-level data.

Table 1. *Sample description*

University	No. of students in the sample	Percentage of students in the sample	Male	Female
EBS	91	9.4	43	48
ULS	228	23.5	130	98
TLU	103	10.6	52	51
TUT	314	32.4	185	129
UT	234	24.1	98	136
Total	970	100.0	508	462

Rank methods, such as Spearman's rho correlation coefficient and the Kruskal–Wallis test, are used for non-parametrical data. In her doctoral work, Kislenko (2011) noted that the factor analysis she carried out cannot be considered a proper method for analysing a Likert scale, because the data collected through a Likert scale is discrete in nature, while factor analysis assumes that the scale of the observed variables is continuous. Moreover, she pointed out that the normality of the data, another assumption of factor analysis, is questionable. Norman (2010) dissected Likert-scale analysis, and showed that many studies dating as far back as to the 1930s consistently show that parametric statistics is robust with respect to violations of these assumptions. He provides arguments and responses to the claim ”You can't use *t*-tests and ANOVA because the data are not normally distributed”:

> This is likely one of the most prevalent myths. We all see the pretty bell curves used to illustrate *z* tests, *t* tests and the like in statistics books, and we learn that ”parametric tests are based on the assumption of normality”. Regrettably, we forget the last part of the sentence. For the standard *t*-tests, ANOVAs, and so on, it is the assumption of normality of the distribution of means, not of the data. The Central Limit Theorem shows that, for sample sizes greater than 5 or 10 per group, the means are approximately normally distributed regardless of the original distribution. (Norman, 2010, p. 628)

In his work, Norman (2010) summarised that parametric statistics can be used with Likert data, with small sample sizes, with unequal variances, and with non-normal distributions, without fear of ”coming to the wrong conclusion”. De Winter and Dodou (2012) came to the same conclusion: for Likert items, the *t*-test and Mann-Whitney-Wilcoxon test generally have similar power, so researchers need not worry about finding a difference when there is none in the population. We refer here to a recent study of gender differences in mathematics (Else-Qyest et al., 2010) in which the PISA and TIMMS data sets were analysed using parametric methods. Therefore in our study we used the *t*-test, which assesses whether the means of two groups are statistically different from each other, as well as correlation coefficients between dimensions. In addition we also analysed the gender differences in the structure used *z*-scores to analyse the gender effect on the correlation between the different dimensions of the views of mathematics (Field, 2009). Each correlation coefficient was converted to a *z*-score using Fisher's *r*-to-*z* transformation. This transformation adjusts the correlation coefficient so that its sampling distribution is normal (Field, 2009). Then, using the sample size employed to obtain each coefficient, we compared the *z*-scores (Preacher, 2002).

Results of the research

The following section presents some of the main results of our analysis of the structure of students' views of mathematics before reporting the results regarding the gender differences. We used the statistical program SPSS Statistics for the data analysis.

The results of the correlation analysis showed that nearly all dimensions correlated statistically significantly with each other. However, the strength of the correlation in the survey (Hinkle, Wiersma & Jurs, 2009) varied from little, if any (0.00 to 0.29), to low (0.30 to 0.49), moderate (0.50 to 0.69), and high (0.70 to 0.89). Because the correlations were similar for

Table 2. *Correlations between the dimensions*

	PG	MG	VoM	SC	TR	CB
Perfomance-Approach Goal Orientation	1					
Mastery Goal Orientation	0.288*	1				
Value of Mathematics	0.183*	0.528*	1			
Student Competence	0.200*	0.489*	0.857*	1		
Teacher Role	0.085*	0.356*	0.764*	0.325*	1	
Cheating behaviour	-0.023	-0.280*	-0.344*	-0.365*	-0.176*	1

Note. *Correlation is significantly greater than 0 at the 0.01 level (2-tailed).
PG = Performance-Approach Goal Orientation, MG = Mastery Goal Orientation, VoM = Value of Mathematics, SC = Student Competence, TR = Teacher Role, and CB = Cheating Behaviour.

both genders, we report only the overall correlations in table 2. Belief structures and gender differences in correlations are discussed below.

We can see the belief structure: Mastery Goal Orientation, Value of Mathematics, Student Competence, and Teacher Role are related to each other. In addition, we analysed gender differences in the structure: Do the correlations between the variables differ for males and females? We also analysed the gender effect on correlation by testing the difference between two independent correlation coefficients. We tried all possibilities and found two cases where correlations between two factors differ significantly between males and females: correlation between Performance-Approach Goal Orientation and Value of Mathematics ($z = -1.818$, $p = 0.035$) factors was higher among female students, as was the correlation between the Performance-Approach Goal Orientation and Students Competence ($z = -2.107$, $p = 0.0186$) factors.

We also carried out a *t*-test between male (508) and female students (462) in order to analyse gender differences for each subscale (table 3).

Table 3. *Factors: mean values for genders, their standard deviation and statistics of the t-test*

Component	Gender	Mean	Standard deviation	*t*	Sig. (2-tailed)
Performance-Approach Goal Orientation	Male	1.980	0.672	-0.558	0.577
	Female	2.003	0.630		
Mastery Goal Orientation	Male	2.823	0.555	-6.084	0.000
	Female	3.033	0.519		
Value of Mathematics	Male	2.434	0.512	-3.416	0.001
	Female	2.547	0.515		
Student Competence	Male	2.538	0.628	-2.977	0.003
	Female	2.661	0.655		
Teacher Role	Male	2.306	0.630	-2.587	0.010
	Female	2.409	0.604		
Cheating Behaviour	Male	2.033	0.880	6.299	0.000
	Female	1.701	0.749		

Let us first examine the overall trend in the results. The component Mastery Goal Orientation received the highest level of agreement. Middle positions were taken by three other factors: Value of Mathematics, Student Competence, and Teacher Role. The lowest levels of agreement occurred in Cheating Behaviour and Performance-Approach Goal Orientation.

Although both male and female respondents tended to agree and disagree with the same components, most of the dimensions showed statistically significant gender differences. In fact, Performance-Approach Goal Orientation was the only dimension which showed no statistically significant gender difference. In all the remaining dimensions, the female respondents were more positive towards mathematics: they had more powerful mastery orientation, valued mathematics more, felt more competent, perceived their teacher more positively, and cheated less frequently.

Conclusions and discussion

Few of our results concerning the structure of mathematics-related affect can be considered surprising. Indeed, the results are in line with Hannula and Laakso's (2011) hypothesis that as students grow older, Performance Goal Orientation becomes part of their overall positive disposition. Performance Goal Orientation correlated positively with Mastery Goal Orientation, and although the correlations with the other components were weak, they related statistically significantly to all the components associated with a ”positive” affective structure, and related insignificantly to Cheating Behaviour. Moreover, our results indicate that Performance Goal Orientation is more strongly integrated into the overall positive view of mathematics among female students, as it correlated slightly more strongly with Value of Mathematics and Student Competence in the female population than among males.

We also analysed whether there were gender differences in the way different aspects of the view of mathematics correlate with each other. The results indicate that for three pairs, correlation coefficients differed significantly. Separate examination of these correlations between factors for male and female students shows that they are weak (0.130–0.339). Therefore we can conclude that the belief structures showed only minor gender differences.

Most previous studies have shown that male students hold more positive views of mathematics than do female students (Frost et al., 1994; Op 't Eynde & De Corte, 2003). Estonian state-level mathematics achievement tests have shown no gender differences (Kikas et al., 2009), and gender differences in attitudes have been small (Kislenko, 2009). In a study by Else-Quest et al. (2010), the results for Estonia were consistent with the gender similarity hypothesis and showed no gender differences. In our study, however, we found that female university students hold more positive views of mathematics than do male university students. In five of the six dimensions of our instrument, female students had a more positive score than males. Although modest, the difference between means was statistically significant. In Estonia, in her recent study Einaste (2013) found that the students' academic motivation is influenced by the sex of the students, and favours females. In other countries, studies have shown that female students hold more positive attitudes towards mathematics than do males. Our findings from Estonia coincide with those of studies in Canada, where Li (2007) found female secondary school students to hold significantly more positive attitudes toward mathematics than did male students, and that Icelandic females held more positive views than did their male peers (Steinthorsdóttir & Sriraman, 2007). Our results are also similar to those of Forgasz et al. (2004) who found that Australian girls in grades 7–10 both enjoyed mathematics and showed interest in it more than boys did. In addition, Brandell and Staberg (2008) and Hannula et al. (2006) have also observed that female students perceive themselves as harder working, and the results of Brandell and Staberg (2008) showed that females understood the importance of mathematics more than males did.

We point out here that our results indicate that both males and females find knowledge of mathematics to be important, as it helps them understand the world. They study mathematics because they know how useful it is. They feel that they are good at mathematics and are motivated to study it. The Teacher Role holds a middle position close to disagreement, suggesting that for most of them, the teacher has not been a particularly important source of inspiration. Students' self-perceived competence also holds a middle position close to agreement. They find mathematics to be an important subject. Additionally, most students do not cheat in their studies.

Although our instrument provided only limited possibilities to identify possible causes for the gender differences observed among Estonian university students, we have described some of our ideas about why female students in Estonia might hold more positive views of mathematics than do male students. The results of Else-Quest et al. (2010) identify the specific domains of gender equity responsible for gender gaps in mathematics. They pointed out that gender equity in school enrolment, women's share of research jobs, and women's parliamentary representations were the most powerful predictors of cross-national variability in gender gaps in mathematics. Steinthorsdóttir and Sriraman (2007) suggested that in Iceland, the environment, such as the labour market, prevents males from seeing value in academic education; in fact, this same environment encourages females to do well in school in the hope of achieving some status in their future or to leave their hometown in search of a "better" life. This explanation may also apply to Estonian female students. The Estonian Ministry of Education and Research (2011) found that in the 1993/94 academic year, male and female students were equally represented (49 % and 51 %), while in the 2010/11 academic year, the percentage of female students had increased to 60. In the 2010/2011 academic year, females in universities outnumbered males at any educational level. In bachelor's degree studies, females comprise 59 %, in master's degree studies, 66 %, and in doctoral degree studies, 58 %. The Estonian Ministry of Education and Research (2011) reported that among the graduates in the exact and natural sciences in 2008, females comprised 42.1 %, the highest percentage in the European Union (the average in the EU was 33 %). One possible reason for this phenomenon is that female students in Estonia hold more positive views of mathematics than do female students in other countries. Another fact from this report is that at the university level, Estonian females had lower drop-out rate than males did. One reason for this may be that female students are more motivated to graduate from university than male students are, a trend, which enjoys the support of the work of Einaste (2013). Another supporting result showed that of those students at Tartu University in 2007–2012 who studied the mathematics curriculum, 65 % were female, and in the statistics curriculum, 60 % were female (Rööp, 2013). Rööp analysed marks by gender in the mathematics-informatics department, and the results indicated that males received higher grades only in the first semester; over the next five semesters, females received higher grades. These results support the positive view of females in our study.

Einaste (2013) concluded in her study of tertiary-level mathematics education in Estonia that in academic motivation and academic self-efficacy, where statistical differences occurred, females always hold more positive views than males do. For females, the motivational reasons (greater than for males) are that they want to prove to themselves that they are successful at learning, that they can surpass their ability and they will successfully graduate from university. Also, for females more than for males, the motivating reasons were that they wanted to earn a higher salary and find a secure position in the labour market after graduating from university. Einaste's (2013) findings can be possible causes also for the results of our study, which indicate that this phenomenon extends beyond students in mathematics and informatics.

An Estonian Ministry of Education and Research (2011) report indicates that research and science favour males. A study by Karu and Nurmela (2007) about gender and career in Estonia in 2005 indicated that women are employed mostly in the public sector, are more often employed on a part-time basis, and less often in management positions. Positive role models in the sciences or a perception of a promising career in the sciences are therefore unlikely to influence the observed gender differences favouring female students in Estonia.

Our findings indicate that females are more positive towards mathematics in their freshman year and improve after that more than men do, therefore the gender difference between older students is likely to be greater than the difference we observed between first-year students. Recent data (Rööp, 2013) indicate that more female than male students study in the field of mathematics at Tartu University, and data from the Estonian Ministry of Education and Research (2011) indicate that in the exact and natural sciences, the percentage of female graduates is above the EU average. These data also support data from our study; so in conclusion, females are motivated to study mathematics, science and technical subjects at all educational levels, most likely because students' choices are not limited by gender stereotypes, allowing them to choose a subject field at the university level which best suits their expectations and potential.

In summary, female students in most dimensions hold a more positive view of mathematics than male students do. Because mathematics-related beliefs as well as gender differences at the university level have received little attention in recent years, more studies are needed in this field.

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References

Ai, X. (2002). Gender differences in growth in mathematics achievement: three-level longitudinal and multilevel analyses of individual, home, and school influences. *Mathematical Thinking and Learning*, 4, 1–22.

Andrews, P., Diego-Mantecón, J., Op 't Eynde, P. & Sayers, J. (2007). Evaluating the sensitivity of the refined mathematics-related beliefs questionnaire to nationality, gender and age. In D. Pitta-Pantazi & G. Philippo (Eds.), *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education* (pp. 209–218). Larnaca: CERME.

Armstrong, J. M. (1981). Achievement and participation of women in mathematics: results of two national surveys. *Journal for Research in Mathematics Education*, 12, 356–372.

Brandell, G. & Staberg, E.-M. (2008). Mathematics: A female, male or gender-middle domain? A study of attitudes among students at secondary level. *Gender and Education*, 20 (5), 495–509.

Diego-Mantecón, J., Andrews, P. & Op 't Eynde. (2007). Refining the mathematics-related beliefs questionnaire (MRBQ). In D. Pitta-Pantazi & G. Philippo (Eds.), *Proceedings of the Fifth Congress of the European Society for Research in Mathematics Education* (pp. 229–238). Larnaca: CERME.

Einaste, I. (2013). *Eesti kõrgkoolide matemaatika ja informaatika üliõpilaste enesetõhususe ja motivatsiooni analüüs* [Difference of academic motivation and self-efficacy between the mathematics and informatics students of Estonian colleges] (Unpublished Bachelor's thesis). Tartu University, Estonia. Retrieved from http://dspace.utlib.ee/dspace/bitstream/handle/10062/30448/einaste_ingi_2013.pdf

Else-Quest, N. M., Hyde, J. S. & Linn, M. C. (2010). Cross-national patterns of gender differences in mathematics: a meta-analysis. *Psychological Bulletin*, 136 (1), 103–127.

Estonian Ministry of Education and Research. (2011). *The number of students studying according to higher education curricula*. Retrieved from http://www.hm.ee/index.php?048183

Field, A. (2009). *Discovering statistics using SPSS* (3rd Ed.). London: Sage Publications.

Fennema, E. (1989). The study of affect and mathematics: a proposed generic model. In D. B. McLeod & V. M. Adams (Eds.), *Affect and mathematical problem-solving: a new perspective* (pp. 205–219). New York: Springer.

Fennema, E. & Peterson, P. (1985). Autonomous learning behavior: a possible explanation of gender-related differences in mathematics. In L. C. Wilkinson & C. B. Marrett (Eds.), *Gender influences in classroom interaction* (pp. 17–35). San Diego: Academic Press.

Finne, L. M. (1996). Gender and mathematics education in Finland. In G. Hanna (Ed.), *Towards gender equity in mathematics education: an ICMI Study* (pp. 155–178). Dordrecht: Kluwer Academic Publishers.

Forgasz, H. J., Leder, G. C. & Kloosterman, P. (2004). New perspectives on the gender stereotyping of mathematics. *Mathematical Thinking and Learning*, 6 (4), 389–420.

Frost, L. A., Hyde, J. S. & Fennema, E. (1994). Gender, mathematics performance, and mathematics related attitudes and affect: a meta-analytic synthesis. *International Journal of Educational Research*, 21 (4), 373–385.

Grevholm, B. (1996). Women's participation in mathematics education in Sweden. In G. Hanna (Ed.), *Towards gender equity in mathematics education: an ICMI Study* (pp. 111–124). Dordrecht: Kluwer Academic Publishers.

Hag, K. (1996). Gender and mathematics education in Norway. In G. Hanna (Ed.), *Towards gender equity in mathematics education: an ICMI Study* (pp. 125–137). Dordrecht: Kluwer Academic Publishers.

Hanna, G. (1996). *Towards gender equity in mathematics education: an ICMI study*. Dordrecht: Kluwer Academic Publishers.

Hannula, M. S. (2011). The structure and dynamics of affect in mathematical thinking and learning. In M. Pytlak, E. Swoboda & T. Rowland (Eds.), *Proceedings of the Seventh Congress of the European Society for Research in Mathematics Education* (pp. 34–60). University of Rzesów.

Hannula, M. S., Kaasila, R., Laine, A. & Pehkonen, E. (2006). The structure of student teachers' view of mathematics at the beginning of their studies. In M. Bosch (Ed.), *Proceedings of the Fourth Congress of the European Society for Research in Mathematics Education* (pp. 205–214). Barcelona: Fundemi IQS – Universitat Ramon Llull.

Hannula, M. S. & Laakso, J. (2011). The structure of mathematics related beliefs, attitudes and motivation among Finnish grade 4 and grade 8 students. In B. Ubuz (Ed.), *Proceedings of the 35th conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp. 9–16). Ankara: PME.

Hembree, R. (1990). The nature, effects, and relief of mathematics anxiety. *Journal of Research in Mathematics Education*, 21, 33–46.

Hinkle, D. E., Wiersma, W. & Jurs, S. G. (2009). *Applied statistics for the behavioural sciences*. Belmont: Wadsworth Publishing.

Holton, D. (2001). *Teaching and learning of mathematics at university level mathematics education: an ICMI study*. Dordrecht: Kluwer Academic Publishers.

Hyde, J. S., Fennema, E. & Lamon, S. J. (1990). Gender differences in mathematics performance: a meta-analysis. *Psychological Bulletin*, 107, 139–155.

Hyde, J. S., Lindberg, S. M., Linn, M. C., Ellis, A. & Williams, C. (2008). Gender similarities characterize math performance. *Science*, 321, 494–495.

Juter, K. (2005). Students' attitudes to mathematics and performance in limits of function. *Mathematics Education Research Journal*, 17 (2), 91–110.

Kaldo, I. & Hannula, M. S. (2012). Structure of university students' view of mathematics in Estonia. *Nordic Studies in Mathematics Education*, 17 (2), 5–26.

Kaldo, I. & Reiska, P. (2012). Estonian science and non-science students' attitudes towards mathematics at the university level. *Teaching Mathematics and its Applications*, 31, 95–105.

Karu, M. & Nurmela, K. (2007). Gender and career development — Estonia. *EIROonline*. Retrieved from http://www.eurofound.europa.eu/eiro/studies/tn0612019s/ee0612019q.htm

Kikas, E., Peets, K., Palu, A. & & Afanasjev, J,. (2009). The role of individual and contextual factors in the development of maths skills. *Educational Psychology*, 29 (5), 541–560.

Kislenko, K. (2009). Mathematics is a bit difficult but you need it a lot: Estonian pupils' beliefs about mathematics. In J. Maaß & W. Schlöglmann (Eds.), *Beliefs and attitudes in mathematics education: new research results* (pp. 143–164). Rotterdam: Sense Publishers.

Kislenko, K. (2011). *Exploring pupils' beliefs about mathematics: cases from Estonia and Norway* (Unpublished doctoral dissertation). University of Agder, Norway.

Lam, S., Jimerson, S., Kikas, E., Cefai, C., Veiga, F. H., et al. (2011). Do girls and boys perceive themselves as equally engaged in school? The results of an international study from 12 countries. *Journal of School Psychology*, 50 (1), 77–94.

Leder, G. (1982). Mathematics achievement and fear success. *Journal for Research in Mathematics Education*, 13 (2), 124–135.

Leder, G. (1995). Equity inside the mathematics classroom: fact or artifact? In W. G. Secada, E. Fennema & L. B. Adaijan (Eds.), *New directions for equity in mathematics education* (pp. 209–224). Cambridge University Press.

Leder, G. C., Forgasz, H. J. & Solar, C. (1996). Research and intervention programs in mathematics education: a gendered issue. In A. Bishop, K. Clements, C. Keitel, J. Kilpatrick & C. Laborde (Eds.), *International handbook of mathematics education* (pp. 945–985). Dordrecht: Kluwer.

Li, Q. (1999). Teachers' beliefs and gender differences in mathematics: a review. *Educational Research*, 41 (1), 63–76.

Li, Q. (2007). Mathematics, science, and technology in secondary schools: Do gender and region make a difference? *Canadian Journal of Learning and Technology*, 33 (1), 41–57.

Licht, B. G. & Dweck, C. S. (1987). Sex differences in achievement orientations. In M. Arnot & G. Weiner (Eds.), *Gender and the politics of schooling*. London: Unwin–Hyman.

McLeod, D. B. (1992). Research on affect in mathematics education: a reconceptualization. In D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning* (pp. 575–596). New York: Macmillan.

Midgley, C., Maehr, M. L., Hruda, L., Anderman, E. M., Anderman, L., et al. (2000). *Manual for the patterns of adaptive learning scales (PALS)*. Ann Arbor: University of Michigan.

Mullis, I. V. S., Martin, M. O., Gonzalez, E. J. & Chrostowski, S. J. (2004). *TIMSS 2003 international mathematics report: findings from IEA's Trends in International Mathematics and Science Study at the fourth and eighth grades*. Chestnut Hill: Boston College.

Murtonen, M., Olkinuora, E., Tynjälä, P. & Lehtinen, E. (2008). Do I need research skills in working life? University students' motivation and difficulties in quantitative methods courses. *Higher Education*, 56 (5), 599–612.

Norman, G. (2010). Likert scales, levels of measurement and the "laws" of statistics. *Advances in Health Sciences Education*, 15 (5), 625–632.

Nurmi, A., Hannula, M. S., Maijala, H. & Pehkonen, E. (2003). On pupils' self-confidence in mathematics: gender comparisons. In N. A. Pateman, B. J. Dougherty & J. Zilliox (Eds.). *Proceedings of the 27th conference of the International Group for the Psychology of Mathematics Education held jointly with the 25th conference of PME-NA* (Vol. 3, pp. 453–460). Honolulu: PME/PME-NA.

OECD. (2003). *First results from PISA 2003. Executive summary*. Retrieved from http://www.oecd.org/dataoecd/1/63/34002454.pdf

OECD. (2009). *PISA 2006 Technical Report*. Paris: Author.

Op 't Eynde, P. & De Corte, E. (2003, April). *Students' mathematics-related belief systems: design and analysis of a questionnaire*. Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Op 't Eynde, P., De Corte, E. de & Verschaffel, L. (2002). Framing students' mathematics related beliefs. A quest for conceptual clarity and comprehensive categorization. In. G. C. Leder, E. Pehkonen & G. Toerner (Eds.), *Beliefs: a hidden variable in mathematics education?* (pp. 13–37). Dordrecht: Kluwer.

Pehkonen, E. (1996). Some findings in the international comparison of pupils' mathematical views. In E. Pehkonen (Ed.), *Current state of research on mathematical beliefs III. Proceedings of the MAVI-3 workshop* (pp. 65–69). University of Helsinki.

Pehkonen, E. & Törner, G. (1996). Mathematical beliefs and different aspects of their meaning. *ZDM – The International Journal on Mathematics Education*, 28, 101–108.

Pepin, B. (2011). Pupils' attitudes towards mathematics: a comparative study of Norwegian and English secondary students. *ZDM – The International Journal on Mathematics Education*, 43 (4), 535–546.

Preacher, K. J. (2002, May). *Calculation for the test of the difference between two independent correlation coefficients* [Computer software]. Retrieved from http://quantpsy.org

Roesken, B., Hannula, M. S. & Pehkonen, E. (2011). Dimensions of students' views of themselves as learners of mathematics. *ZDM – The International Journal on Mathematics Education*, 43 (4), 497–506.

Rööp, M. (2013). *Matemaatika-informaatikateaduskonna bakalaureuseastme üliõpilase kirjeldus ja õppetöö tulemusi ennustavad tegurid* [Learning outcomes predictors of bachelor students in the faculty of mathematics and computer science] (Unpublished Bachelor's thesis). Tartu University, Estonia. Retrieved from http://dspace.utlib.ee/dspace/bitstream/handle/10062/30437/roop_madli_2013.pdf

Schoenfeld, A. (1985). *Mathematical problem solving*. Orlando: Academic Press.

Soro, R. (2002). *Opettajien uskomukset tytöistä, pojista ja tasa-arvosta matematiikassa* [Teachers' beliefs about girls, boys, and equity in mathematics]. Annales Universitatis Turkuensis, C (191). University of Turku.

Steinthorsdóttir, O. B. & Sriraman, B. (2007). Girls' belief about the learning of mathematics. *The Montana Mathematics Enthusiast. Festschrift in honor of Günter Törner's 60th birthday*, 3, 169–178.

Sumpter, L. (2009). O*n aspects of mathematical reasoning: affect and gender* (Doctoral thesis). Department of Mathematics, Umeå University. Retrieved from http://www.diva-portal.org/smash/record.jsf?pid=diva2:216376&rvn=1

Vallerand, R. J., Pelletier, L. G., Blais, M. R., Brière N. M., Senécal, C. B. & Vallières, E. F. (1992). Academic motivation scale (AMS-C 28) college (CEGEP) version. *Educational and Psychological Measurement*, 52–53. Retrieved from www.er.uqam.ca/nobel/r26710/LRCS/scales/emecegep_en.doc

Winter, J. C. F. de & Dodou, D. (2012). Five-point Likert items: *t* test versus Mann-Whitney-Wilcoxon. *Practical Assessment*, *Research & Evaluation*, 15 (11), 1–16.

Yusof, Y. B. M. & Tall, D. (1994). Changing attitudes to mathematics trough problem-solving. In J. P. da Ponte & J. F. Matos (Eds.), *Proceedings of the 18th International conference for the Psychology of Mathematics Education* (Vol. 4, pp. 401–408). Lisbon: PME.

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