THEMES FOR MATHEMATICAL MODELING THAT INTEREST DUTCH STUDENTS IN SECONDARY EDUCATION

Cor Willem Buizert, Jeroen Spandaw, Martin Jacobs, Marc de Vries

Delft University of Technology, Netherlands

In this paper we describe empirical research into the question which possible themes for mathematical modeling interest Dutch high school students. We investigate possible differences between boys' and girls' interests. We also study differences between students in two different streams of the Dutch school system, called havo and vwo. Our study confirms in the mathematical domain the conclusion of international surveys about students' interests in the natural sciences that there are marked differences between boys and girls. However, our study did not find such differences between the havo and vwo streams, although Dutch literature suggested otherwise.

Keywords: Mathematical modeling, high school students, students' interests, empirical study

INTRODUCTION

Modeling is widely seen as an important part of mathematics education. To motivate high school students for mathematical modeling, the modeling context should be appealing to them. Indeed, interest plays a role in determining what people want to learn (Dohn, 2010). Interests that come from the individual itself last longer, whereas interests that are externally induced last for only a short period of time (Carmichael, Callingham, Hay, & Watson, 2010). However, interest is not just a mean. To quote Lavonen, Byman, Uitto, Juuti, and Meisalo (2008, p. 9): "Since Herbart (1841/1965a, 1841/1965b), modern pedagogy has emphasized the value of interest not only as a mean, but as an educational end in itself." Referring to Hidi, Renninger and Krapp (2004), Lavonen et al (2008) write on p. 9: "…interest-based motivation to learn has positive effects both on the studying processes and on the quantity and quality of learning outcomes."

This paper focuses on the question which topics for mathematical modeling high school students are interested in. Whether these topics satisfy other suitability criteria for modelling problems for these students is a different matter, which we did not investigate. However, if one wants to design modelling problems for high school students, then it is useful to know which themes do or do not interest these students. In this paper we restrict ourselves to this question.

The research was carried out as part of a Dutch project, called *Havo-Pro*, which aims to help teachers improve their *havo*-education. '*Havo*' is a stream in Dutch secondary education. It is sandwiched between a large pre-vocational stream called '*vmbo*', which takes about 60 percent of primary school pupils, and a small pre-university stream called '*vwo*', which takes about 15 percent of the pupils. It is meant for students with 'intermediate cognitive abilities'. From now on we will simply use the Dutch acronyms '*havo*' and '*vwo*' to refer to these streams.

The third and fourth grades of *havo* are perceived by many educational professionals (teachers, school leaders, policy makers) as problematic (Vermaas & Van der Linden, 2007). Many students in those classes, usually 15 or 16 years old, seem to lack interest, and to under-achieve (Vermaas and van der Linden, 2007), resulting in stagnation. Lack of motivation is identified as the main problem. With our research into *havo* students' interests we hope to help alleviate this motivational problem.

Hamer (2010) addresses these issues for science and mathematics education. (In the Netherlands, it is customary to group the natural sciences and mathematics together under the heading '*bèta*'.) Whereas at *vwo*, more than 50% of the students choose the science, rather than the humanities track, at *havo* less than 30% of the students do so. *Havo* students tend to think that only especially talented students are qualified to choose the science track (Hamer, 2010). Furthermore, these students tend to underestimate their abilities when it comes to mathematics and science. This holds in particular for girls. Van Langen and Vierke (2008) report that only 39% of the boys and 19% of the girls choose the science stream, even though grades indicate that 65% of the boys and 54% of the girls are sufficiently talented. The lack of *havo* students entering technological tertiary education is thus not a consequence of absence of talented students. Schreiner & Sjøberg (2010) report that lack of interest in science among high school students is a widespread phenomenon in developed, wealthy countries, such as the Netherlands. This confirms the relevance of this phenomenon and shows the importance of investigating students' interests.

Additional support to study students' interests about possible modeling themes is given by Ryan & Deci (2000). According to this paper, the main factors contributing to intrinsic motivation are authenticity, competence and relatedness. Modeling tasks usually involve team work, which can contribute to relatedness. Modeling themes that align with students' (daily life) interests can contribute to authenticity and competence as perceived by the students.

As the title of her report indicates, Hamer (2010) lists 10 points of attention for mathematics and science teachers which may help to improve *havo* students' motivation, such as 'working in groups', 'activating students', 'connecting theory and practice', and 'accessibility'. From a constructivist point of view this is hardly surprising. Hamer (2010) claims that these issues are especially important for the *havo* stream. Mathematical modeling problems seem to have the potential to naturally incorporate these recommendations. Other points of attention were concerned with procedural clarity, guidance, and positive feedback. These points are important in the actual design and execution of modeling problems. However, given the motivational problems of *havo* students described above, to design mathematical modeling problems, one first has to address the crucial question which possible topics for mathematical modeling *havo* students are interested in.

Since almost all schools with a *havo* stream also have a *vwo* stream, we investigated both groups at the same time. There is a second reason for considering both *havo* and *vwo* students. As teacher trainers at Delft University of Technology (except for the first author), we wish to develop a module which we can use to train our pre-service teachers how to design modeling problems for high school students. These pre-service teachers will usually teach at both *havo* and *vwo*. Therefore we are interested in *vwo* students' interests, too. Furthermore, it is interesting to investigate which (if any) differences exist between *havo* students' and *vwo* students' preferences. Since Schreiner & Sjøberg (2010) found remarkable differences between boys' and girls' interests, we will also study these differences.

So we arrive at the following research questions for this paper:

1. Which themes for mathematical modeling are interesting to students in second, third and fourth year (students aged 13 – 16) of *havo* and *vwo* ?
2. What are the differences between *havo* and *vwo* students?
3. What are the differences between boys and girls?

THEORETICAL BACKGROUND

Researchers have recently performed an international study into high school students' interests in the natural sciences and technology. This research project is called ROSE, an acronym for 'Relevance of Science Education' (Schreiner & Sjøberg, 2010). To investigate students' interests, the international research team used a questionnaire. Schreiner and Sjøberg (2010) report that there are remarkable differences between countries, but even more striking differences between boys' and girls' interests. Lavonen, Byman, Uitto, Juuti, and Meisalo (2008) used the questionnaire to investigate interests of Finnish high school students. They also found remarkable differences between boys' and girls' interests.

Other well known large-scale studies such as TIMSS and PISA do not measure the affective dimensions of science education. Indeed, as Schreiner & Sjøberg (2010) write on p. 4: "It is a worrying observation that in many countries where the students are on top of the international TIMSS and PISA score tables, they tend to score very low on interest for science and attitudes to science. These negative attitudes may be long-lasting and in effect rather harmful to how people later in life relate to S&T [science and technology] as citizens."

Constructivism also teaches that educators should not ignore the affective dimensions. Furthermore, one should connect to pre-existing knowledge, and align with real world problems students are familiar with and that appeal to them. Hamer (2010) suggests that this is of key importance especially for havo.

Since research into interest is usually done using questionnaires, we decided to use a questionnaire, too. For mathematics education, however, we did not find a suitable questionnaire in the literature, so we had to develop one for ourselves.

METHOD

The validated ROSE questionnaire served as a starting point in the development of our own questionnaire. To generate potential themes of interest related to mathematics education, we looked at the Dutch mathematics curriculum, topics used in national modeling contests *Wiskunde A-lympiade* (Alympiade, 2011), and mathematical games. We also used the results of surveys into trends concerning young people (see Youngmindz, 2011). We used these different sources to minimize the risk of overlooking potential themes of interest. These trends were grouped by mathematics education experts into gaming, music, technology (gadgets, computers), environmental engagement, money, health, and sports. All our items were related to one of these groups, and we tried to give the different groups equal importance in our questionnaire. Finally, we tried to cover different branches of mathematics, deterministic and probabilistic, discrete and continuous, using computers or not. Exemplary questions can be found in table 3.

The questionnaire consisted of 70 questions, 51 of which dealt with the theme of this paper: students' interests. The first 50 items were of the ROSE type, i.e. questions of the form "Would you like to learn about…?" using a four point Likert scale with extremes marked "no" and "very much". The remaining item was an open question, asking for an interesting topic that was missing in the preceding questions. This question did not reveal new topics, except 'fashion' and unserious answers.

DATA COLLECTION AND ANALYSIS

The questionnaire was answered by 287 students, aged 12 to 18 (M = 14.46, SD = 1.16) from 7 Dutch secondary schools. Since we will be interested in differences between boys and girls, havo and vwo students, we list their numbers in table 1.

	girls	boys	total
havo	53	80	133
vwo	76	78	154
total	129	158	287

Table 1: questionnaire sample

Due to missing values, the data analysis below may use fewer students.

To verify the structure of the questionnaire, we first ran a principal component analysis (PCA) on the 50 items. The overall Kaiser-Meyer-Olkin measure (KMO) was 0.90 (‘superb’ according to Field, 2009), and all KMO values for individual items were >.79, so the sample size was adequate for factor analysis (Field, 2009). Bartlett’s test of sphericity $\chi^2(1225) = 6376$, $p < .001$, showed that correlations between items were sufficiently large for PCA (Field, 2009 Using a scree plot (see Figure 1), we decided to keep 5 components, which together explained 48,2% of the variance. We discarded the 13 items with absolute loadings < .4 (Field, 2009). All Cronbach α’s were >.78 and they were not improved by deleting more items, so statistical reliability of the 5 subscales was good.

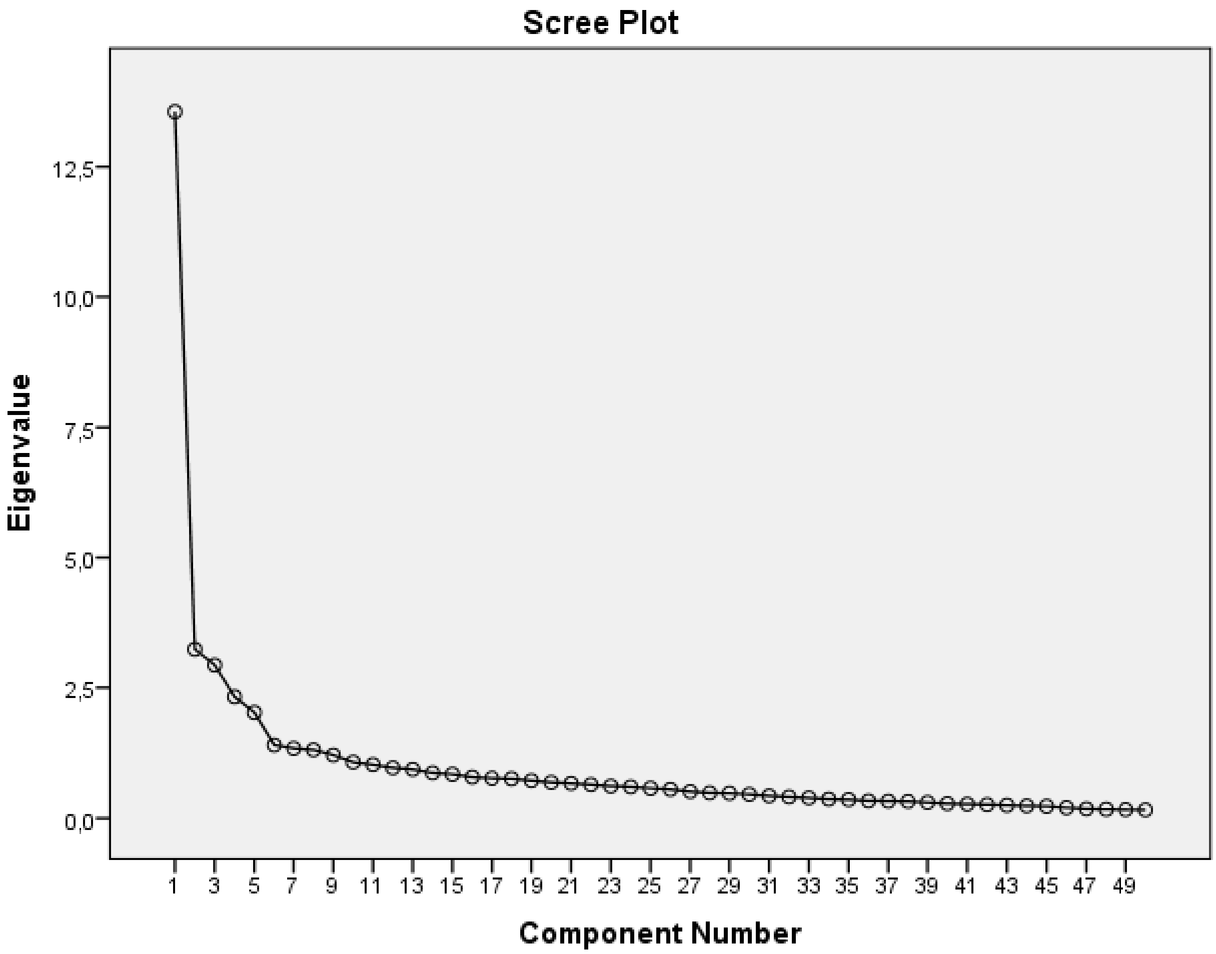

Figure 1: Scree plot of eigenvalues

Looking at the pattern matrix (oblique rotation), the five factors turned out to centre around the themes ‘environment and climate’, ‘sports’, ‘finance and politics’, ‘electronic devices and computer games’, and ‘finance and consumership’. Recall that to set up the questionnaire we used the seven categories ‘gaming’, ‘music’, ‘technology (gadgets, computers)’, ‘environmental engagement’, ‘money’, ‘health’, and ‘sports’. ‘Health’ and ‘music’ have disappeared, ‘gaming’ and ‘technology’ have merged into one factor, whereas ‘money’ has split into a ‘politics’ and a ‘consumership’ version.

The number of items in the pattern matrix for our five factors were 9, 5, 6, 9, and 8, respectively. Interpretation of the first factor was a little problematic, since 4 out of the 9 items did not fit our description ‘environment and climate’. Similarly, the third factor ‘finance and politics’ contained 2 items dealing with voting systems. Finally, the fifth factor ‘finance and consumership’ contained 2 items about music, one about epidemics and one about lotteries. Fortunately, the dissident items in the third and fifth factor had small loadings, except for the epidemics item in factor 5.

We computed factor scores by averaging the remaining questions for each factor: 5 for factor 1, 5 for factor 2, 4 for factor 3, 9 for factor 4, and 4 for factor 5. In table 2 we give the mean factor scores. Mean scores which are higher than the average 2.5 of the Likert scale are set in boldface. We have performed *t*-tests to compare boys with girls, *havo* students with *vwo* students. For (2-sided) *p*-values < .10 we give the effect score $r = \sqrt{t^2 / (t^2 + \text{df})}$. Effect scores near .1 are small, effect scores near .3 are medium (Field, 2009).

	Mean *N*	*M*(girl) *N*	*M*(boy) *N*	*p* *r*	*M*(havo) *N*	*M*(vwo) *N*	*p* *r*
F1	1.87 281	1.77 128	1.95 153	.02 .14	1.85 129	1.89 152	.62
F2	**2.62** 285	2.44 129	**2.77** 156	.002 .18	**2.53** 132	**2.71** 153	.11
F3	2.26 280	2.01 126	2.47 154	< .001 .29	2.30 130	2.23 150	.42
F4	**2.69** 284	2.49 128	2**.85** 156	< .001 .23	2.60 132	**2.79** 152	.08 .11
F5	**2.60** 283	**2.72** 127	2.**50** 156	.02 .14	**2.54** 132	**2.65** 151	.23

Table 2: Factors and means

Table 2 shows clearly that differences between boys and girls are quite substantial, whereas differences between *havo* and *vwo* students are negligible. Not a single difference has 2-sided *p*-value < .05. There is only one difference between *havo* and *vwo* with $p < .10$, namely ‘electronic devices and computer games’. The effect is small ($r = .11$), *havo* students being a little less interested than *vwo* students.

Differences between boys and girls were more pronounced. All factors have 2-sided *p*-values < .05, boys being more interested than girls, except for the fifth factor. However, since the sample was quite large, small differences can already be significant. Indeed, the first and fifth factor have small effect size ($r = .14$). The largest difference with medium effect size ($r = .29$) was found in the factor score belonging to ‘finance and politics’. The remaining two factors ‘sports’ and ‘electronic devices and computer games’ are a little more popular among boys (effect sizes .18 and .23, respectively).

The most popular factor is ‘electronic devices and computer games’ with $M = 2.69$, especially among boys ($M = 2.85$) and *vwo* students ($M = 2.79$). Girls seem to favour the slightly mysterious factor 5, which we dubbed ‘finance and consumership’.

Now we have a rather clear picture on the level of our five factors, we return to the individual items. Which items had the highest mean scores, corresponding to highest level of interest? In table 3 we give the top ten items for boys and girls. We indicate which factor (if any) the items belong to. Since we know that differences between *havo* and *vwo* are small, we do not separate between these two groups.

CONCLUSIONS

We found that the themes which interested our students most were ‘electronic devices and computer games’, ‘finance and consumership’, and ‘sports’. Surprisingly, there were no significant (2-tailed $p < .05$) differences between students in the *havo* and students in the *vwo* stream. At first sight, this seems to be at odds with Hamer (2010), which deals with differences between these two streams. However, that paper deals with *pedagogical* differences between *havo* and *vwo*, not with subject matter. On the other hand, there were significant and sizeable differences between boys and girls. This confirms the findings of Schreiner and Sjøberg (2010), and Lavonen et al. (2008).

Teachers and other developers of teaching materials for secondary schools should be aware of these findings when selecting topics for mathematical modeling assignments. To attune to the needs of *havo* students, they should also take into account the list of ten points of attention by Hamer for *havo* education.

Although we did not investigate this in depth, we expect that the favourite themes mentioned above are suitable for modeling tasks. Indeed, many such modeling tasks have already been designed more or less successfully in the Netherlands and elsewhere. Furthermore, one can use our results to improve existing modeling tasks.

boys		girls	
item	mean	item	mean
Mathematics and the design of videogames (F4)	3.20	What is the probability to win the first prize in a lottery? (F5)	3.11
Computing probabilities in a casino	3.15	What is the cheapest cell phone contract? (F5)	2.94
What is the probability to win the first prize in a lottery? (F5)	3.13	How does an i-pod work? (F4)	2.91
Mathematics and making money (F3)	3.10	How much do peers spend on cell phones? (F5)	2.80
How does an i-pod work? (F4)	3.09	How do pin codes work? (F4)	2.77
What is the most popular game console? (F4)	3.04	How does an mp3 player work? (F4)	2.71
Can one predict world records in sports? (F2)	2.97	Computing probabilities in a casino	2.71
How to develop a game strategy (F4)	2.96	Can one predict world records in sports? (F2)	2.67
The optimal training scheme for a top sportsperson (F2)	2.85	Mathematics and making money (F3)	2.62
How does a computer work? (F4)	2.82	Mathematics, music and noise (F5)	2.60

Table 3: Top 10 items for boys and girls.

For example, in order to improve students' motivation we modified a modelling task about traffic jams by adding a financial component about the costs involved.

Of course, the design of modeling problems involves much more than identifying topics of interest. For example, which activities are best suited to develop certain modeling competencies at a certain level? Interesting and important as these questions are, they were not part of the research described in this paper.

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