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Research Article

Relevance of School Mathematics for Students of Economics

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A cross-sectional questionnaire study was conducted to assess beginning university-level students' competence in various areas of school mathematics. Moreover, the students judged the relevance of different items for their study program and professional future. Results were compared to expert ratings. In addition, a sample of high school students was investigated for comparison. Findings indicate that after completing high school, students have hardly adequate judgments about the relevance of school mathematics.

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Introduction and Theoretical Background

The question of whether students see the relevance of mathematics for their study programs seems important for motivation and learning success. There is evidence that relevance expectations depend on the specific study program. Flegg et al. (2011) found that engineering students typically see the relevance of mathematics, while for teacher students this is much less the case (Eichler & Isaev, 2023). A related question is if mathematical content in the curricula is actually used in later studies and in the workplace that students aspire to. Faulkner et al. (2020) found that only a very limited part of the mathematics taught in introductory math courses in engineering programs is actually needed in applied fields such as circuit analysis. Besides the actual use of mathematics in their future, it is also interesting what parts of mathematics students expect to be important in their future. In fact, for content-related motivation, individual expectations of the relevance are more important than the actual relevance. Wood & Reid (2006) investigated mathematics students' expectations about the role mathematics will play in their future. Students answered free-form questions, e.g., "What role do you think mathematics will play in your future career?" Wood & Reid found that students attribute higher relevance to procedural than to conceptual skills, both for studies and for their further career. Moreover, they concluded that students have rather unclear ideas about the role of mathematics in their future life.

It is a well-known challenge for mathematics education to provide an adequate view of the relevance of mathematics for our society. Niss (1994) coined the term "relevance paradox" for the fact that mathematics infiltrates almost all areas of science and society, while the actual use of math becomes less visible because it gets embedded in computer devices that hide it from the surface. As a reaction, curricula in Germany have increased the weight of applications and modelling (Blum 2015; Hankeln 2020). There is evidence that specific modelling activities can increase relevance judgement (Hernandez-Martinez and Vos 2018). However, it is unclear if the approach to emphasize applications in the curriculum is successful in the long run. Our study will provide some insights into students' relevance attribution.

The role of relevance judgements for motivation and achievement has been investigated in several studies, and the connections between these concepts are complex. Priniski et al. (2018) report, among other things, on the relationship between relevance and (extrinsic) motivation, and Lee et al. (2014) document an influence of interest on achievement. Liebendörfer and Schukajlow (2020) investigated if reflecting on utility-value can increase interest in mathematics and found this is not always the case, although it can achieve this goal for some students.

For students of mathematics, one can expect that they attribute high values to the relevance of mathematics – otherwise, they would not have chosen this subject. Moreover, it is known (Ufer et al. 2017) that their interest in mathematics does not significantly correlate with their interest in the application of mathematics and hence their relevance attribution for the profession. Therefore, for the present study, we decided to investigate the relevance judgements of beginning students of an economics program at a university of applied sciences.

The study reported here was carried out in the first week at the university, so that one can assume that the experiences that shaped relevance judgements were formed by their education in school. This allows us to interpret our results, as will be shown, from two perspectives: looking back to math education in school and looking forwards to math used in their further studies.

The concept of relevance is rather intricate. Priniski et al. (2018) give an overview of the field and suggest a model that describes a continuum of relevance, ranging from personal association over personal usefulness to identification. We expect little identification with mathematics for students who decided to start a study program in economics. As it is not easy to distinguish these aspects of relevance, we decided to ask students simply to judge the relevance of the ability to perform certain mathematical tasks. The German connotation of "relevance" (Relevanz) is strongly associated with utility value. Thus, we are expecting to be in the middle of Priniski's spectrum. Relevance attribution may be related to (or influenced by) the individual's proficiency, and it may also vary over the sub-disciplines of school mathematics. Apparently, there is no study that investigates these relations. Other studies have investigated which parts of mathematics university lecturers consider to be important (Weber et al., 2023), but they have not compared this to students' judgement. To be able to draw such a comparison, we also asked experts to rate relevance both for studies and for profession. Thus, we aim to answer the following research questions:

1. Which areas of school mathematics are attributed higher resp. lower relevance by students of economics?
2. Is there a relation between relevance attribution and proficiency?
3. What is the relation between relevance expectation regarding the study program and the later professional life?
4. How do relevance judgements of students and of experts relate?

Method

320 students of economics at a university for applied sciences completed an anonymous online questionnaire. This was carried out during a lecture so that most students in the lecture hall answered the test. The test consists of 13 parts that span most areas of school mathematics. 12 of 13 items have a multiple-choice format while one free-form item asked to give an estimation for $\sqrt{17}$ up to one decimal place. Calculators were not allowed. For each item, 90 seconds of time was allocated, and students were asked to go on after that time, but still having the opportunity to give their answers.

Examples of questions translated from German were:

- The expression $\frac{y}{x} - \frac{x}{y}$ is equivalent to a) $\frac{(x^2-y^2)}{xy}$, b) $\frac{(y-x)\cdot(x+y)}{xy}$, c), $\frac{(y-x)}{(x-y)}$, d) $\frac{(y-x)}{xy}$
- Solve $|x-4|<1$. Options: a) $3 \leq x \leq 5$, b) $1 \leq x \leq 4$, c) $1 < x < 4$, d) $3 < x < 5$
- How many solutions does the equation $2^x = sin(x)$ have? a) 0, b) 1, c) 2, d) infinitely many.
- What is the derivative of $\sin(x^2+1)$? a) $(2x+1)\cdot\cos(x^2+1)$, b) $2x\cdot\cos(x^2+1)$, c) $\cos(x^2+1)$, d) $2x\cdot\cos(2x)$
- Which sequence of numbers has the largest standard deviation? a) $1,2,3,4,5$, b) $5,4,3,1,1$, c) $5,3,2,4,6$, d) the standard deviation of a-c is equal.

Moreover, there was an item on the Wason card selection task (Wason 1968) to test reasoning in propositional logic.

The choice of tasks was made with the intention to span school mathematics as broadly as possible. It was not tried to define a homogenous construct that can be assessed with high internal consistency. Hence, it is not to be expected that Cronbach alpha or related measures are high for this scale of mathematical ability.

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After solving these tasks, students were asked to give three judgements for each of these items on a five-point Likert scale:

- Difficulty: How difficult was this task for you?
- Study relevance: Do you expect that you will have to cope with such requirements as in the task in your studies, i.e., that they are relevant for your study?
- Professional relevance: Do you expect that you will have to cope with such requirements as in the task in the professional career that you aspire to?

Response data were retrieved from the online testing system and further processed in the R statistical programming language. Ninety students were excluded from the test because they had more than 10 (out of 52) missing answers. Hence, in effect, only data from 230 students were used. Most items were encoded as binary variables (correct 1, wrong 0). Descriptive correlations for binary variables were calculated by the tetrachoric function of the polycor package of R. Likert scale responses were linearly transformed to the unit interval. We use the terms “relevance attribution” or “relevance judgement” for the scales defined by the Likert scale responses. Besides correlative measures, implicative measures were calculated as well. The non-entropic version of statistical implicative analysis (Gras et al., 2008) was used for this.

Moreover, 44 experts (professors and lecturers at the University of Applied Sciences) were asked to judge the relevance of the mathematical abilities represented by the tasks for the study content they teach and for the professions they are preparing for.

Furthermore, the same test was taken by 69 high school students shortly before the end of their schooling. Thus, this group has the same amount of mathematics education, but they are not taken from the same faculty; thus, their future plans are much more diverse. Their career plans included, for example, becoming police officers, teachers, doctors, lawyers, mechanical engineers, to name just a few.

Results

Data from students and experts are analyzed in different sections:

Results of Students for Scales over Items

From the 4×13 design, four scales (A) (ability), (D) (judged difficulty), (S) (judgement of relevance in study program), and (P) (relevance in profession) were formed. They average over the different topics of school mathematics. Their descriptive statistics are displayed in Table 1. The difference between relevance attribution for studies and profession is highly significant (with Cohen d = -0.78). Table 2 reports correlations, and Table 3 reports implications between these scales.

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Scale	Cronbach Alpha	Mean	SD
A (Ability)	-0.04	0.39	0.12
D (Difficulty)	0.77	0.55	0.17
S (Rel. for Study)	0.92	0.59	0.20
P (Professional Rel.)	0.93	0.36	0.22

Table 1. Descriptive statistics of scales over all items

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Scale	A	D	S	P
A (ability)	1	−0.19**	−0.11	0.03
D (difficulty)		1	0.22**	0.00
S (rel. for study)			1	0.31***
P (professional rel.)				1

Table 2. Correlations of scales over all items

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Scale	A	D	S	P
A (ability)	1	0.35	0.39	0.53
D (difficulty)	0.39	1	0.67	0.50
S (rel. for study)	0.43	0.65	1	0.69
P (professional rel.)	0.54	0.50	0.86	1

Table 3. Implications of scales over all items

Interpretation of these results: The ability scale A measures mathematics as broad and diverse as possible, and hence it is not surprising that its Cronbach alpha is approximately zero. This is reflected as well by the fact that the maximal polychoric correlation between items is only -0.46, namely between the item on integrals and the item on standard deviation. Absolute values of most other polychoric correlations are below 0.2.

The other scales (judgements), however, can be seen as measuring homogeneous constructs. An important, although possibly not a surprising, result is that relevance attribution drops drastically from studies to profession. That means that – based on their previous experience as (high) school students – these university students have little idea about how mathematics could be relevant in the real world of their future professional life. The significant negative correlation between ability and judged difficulty is, of course, expected, but the fact that the correlation is only of moderate strength indicates that students are not very good at judging their own ability correctly. Although relevance attributions for study and profession differ much, there is a relatively high correlation between them. This may be interpreted as a sign that those students who expect that school math is relevant in their professional life also expect that the study program will reflect this. This is in line with the fact that the highest implication intensity in table 3 is for the implication P→S. This means that students who give high values for the relevance in professional life also give high values for the relevance of math in their studies. This may indicate that positive beliefs about professional life influence positive attributions to the study program.

There is a significant correlation between the difficulty judgements and the judgements of relevance for studies, but there was no significant correlation between difficulty judgements and the judgements of relevance for profession. Maybe students expect that the study programs contain some math topics just to make studies harder, not because they are relevant for professional life.

Results of students for individual items

In this section, results for the individual items are reported so that the role of different subjects within mathematics can be explored. Results are given in table 4. The “mean” column gives the fraction of correct answers. The column labelled by “cohen d” reports Cohen’s d when compared to the average over all items.

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Item	Mean	Cohen d	Difficulty	Relevance study	Relevance profession
Fraction	0.58	0.39	0.58	0.82	0.31
Percentage	0.78	0.91	0.00	0.57	1.00
Equivalent expressions	0.25	−0.29	0.61	0.68	0.11
Estimate $\sqrt{17}$	0.47	0.17	0.67	0.69	0.18
Inequality	0.27	−0.26	0.78	0.66	0.15
# solutions sine eq.	0.44	0.11	0.96	0.69	0.02
Derivative	0.32	−0.14	0.83	0.77	0.01
Circumcircle of triangle	0.27	−0.26	0.67	0.17	0.00
Expectation value	0.33	−0.11	0.82	0.90	0.30
Wason Card	0.54	0.63	0.52	0.00	0.03
Probability from binomial distribution	0.27	−0.25	0.84	1.00	0.18
Standard deviation	0.22	−0.39	0.82	0.82	0.18
Integral	0.20	−0.43	1.00	0.86	0.03

Table 4. Statistics for individual items (means on scale [0,1])

The Wason card item was judged by partial credits. If only fully correct answers were counted, the solution rate would be only 4%.

Interpretation: The items with the best success rates are those on calculations with fractions and percentages. This is an interesting finding because in the German discussion of achievements in school, it is often said that calculating with fractions is an ability that beginning university students lack. Our study does not support this point of view. The Wason card task was rated to be the most irrelevant one for the study program, and similarly for the professional rating. This is remarkable because the instruction (that was repeated with every item) was not to judge if solving exactly this task is relevant but whether being able to cope with such requirements as exemplified by the task is relevant. There are two possible explanations for the low scores: Either students think that logical reasoning is irrelevant, or, perhaps more likely, they did not recognize the logical core of the question.

Furthermore, it is remarkable that the three items on statistics and probability were estimated as highly relevant for study, but not for profession. This is an interesting outcome of their learning in school because German textbooks contain lots of more or less authentic applications and modelling tasks in all areas of mathematics, including statistics and probability – but obviously students don't draw the conclusion that these are relevant applications. On the other hand, students are probably right in assuming that geometry is irrelevant for their economic study program.

Results for experts' judgements

The relevance judgements given by the students will now be contrasted with the judgements by the university professors who teach at the same university of applied sciences. Means of judgements scaled to [0,1] are given in table 5. The last row gives correlation r and Cohen d.

Interpretation: Difficulty judgements between students and professors agree largely. Thus, it seems that professors have a realistic impression of students' abilities. However, their mean difficulty judgement is 0.54, while students' mean is 0.7. Thus, one might conclude that they have a slight tendency to overestimate students' abilities. However, the professors′ assessment of difficulty correlates with the students′ demonstrated competence at -0.72, while for the students there was only a correlation of -0.19 (see

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Table 2). Thus, professors judge actual competence on different tasks much more accurately than students themselves do.

There is a huge gap between mean relevance attribution for profession (mean for students is 0.19, for professors 0.54), while for studies this gap is much smaller (0.66 for students compared to 0.62 for professors). However, the correlation of items shows a different picture: While students and professors judge the average relevance for studies almost equally (with professors' judgement slightly lower!), the correlation over items is rather low with only 0.26. This results from the fact that students overestimate the relevance of calculus for studies compared to professors, while they tend to underestimate the relevance of math from lower secondary education and logic compared to professors.

Interestingly, professors judge the relevance of items for profession lower (means 0.54 vs. 0.62, $d=-0.46$, $p=0.054$) than for study, indicating that studies and profession pose different challenges.

Large differences in judgements for individual items can be seen, especially for the algebraic items (equivalent expressions, equations, inequality). For these items, students expect a large drop in relevance from studies to profession, while professors don't. For calculus items, the situation is almost the same. An extreme item in judgement is the card example, which is rated very differently between students and professors.

Item	Difficulty		Relevance study		Relevance profession	
	Students	Professors	Students	Professors	Students	Professors
Fraction	0.58	0.31	0.82	0.74	0.31	0.67
Percentage	0.00	0.14	0.57	0.82	1.00	0.89
Equivalent expressions	0.61	0.41	0.68	0.71	0.11	0.55
Estimate $\sqrt{17}$	0.67	0.52	0.69	0.57	0.18	0.56
Inequality	0.78	0.47	0.66	0.65	0.15	0.53
# solutions sine eq.	0.96	0.73	0.69	0.48	0.02	0.34
Derivative	0.83	0.60	0.77	0.62	0.01	0.48
Circumcircle of triangle	0.67	0.59	0.17	0.44	0.00	0.33
Expectation value	0.82	0.64	0.90	0.56	0.30	0.49
Wason Card	0.52	0.45	0.00	0.57	0.03	0.53
Probability from binomial distribution	0.84	0.78	1.00	0.55	0.18	0.47
Standard deviation	0.82	0.64	0.82	0.74	0.18	0.66
Integral	1.00	0.69	0.86	0.60	0.03	0.46
	r=0.89, d=-0.53		r=0.26, d=-0.15		r=0.85, d=1.14	

Table 5. Comparison of students' and professors' judgements

In line with the findings of Wood & Reid (2006), it seems that students expect procedural abilities (e.g., determining a derivative or calculating with fractions) to be more important for studies than conceptual abilities (logic, geometry).

Results from high school students

Although the diversity was higher in this group than in the university students' group, the results were very similar. Therefore, we will give only a brief overview. On average, high school students showed exactly the same proficiency on these tasks as the beginning university students, but they rated the tasks significantly more difficult. The students were tested shortly before their final high school examinations, so they might have had less self-confidence than the university students who had already mastered this exam. Relevance for study (or other career plans) was judged slightly lower by the high school students. This might reflect that this sample also included students with career plans like music or police that are even less associated with mathematics than economics. Relevance for professional life was judged very similar by both groups. Seven of these 69 high school students indicated that they wanted to study a STEM subject, 5 of those computer science. This sample of 7 students showed significantly higher proficiency, but the relevance judgments for studies were the same as in the whole group.

Discussion and Conclusion

Our results are important both for mathematics education in school and at the university level.

Since the first PISA study, German curricula and textbooks have been redesigned in a comprehensive reform process. A central goal was to exhibit the importance of applications of mathematics in society and in professional life. The results above indicate that this goal has not been achieved yet. The huge drop in relevance attribution from studies to profession indicates that they view mathematics mostly as an area specific to the education system (with only moderate difference between school and university) that has little to do with the real world of profession.

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Interestingly, both students and professors judge the relevance of school math items for profession relatively low and moreover expect a drop of relevance between studies and profession. Of course, the goals of math education in school and also in university are wider than preparation for professional life, so that differences are to be expected, but still, it seems sensible to rethink the importance of some subjects.

Overall, our results suggest that mathematics educators, both in school and in university, should make more efforts to bring the relevance of mathematics into students' minds.

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