MATHEMATICS AS “META-TECHNOLOGY” AND “MIND-POWER”: VIEWS OF ENGINEERING STUDENTS

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The paper reports an exploration of first year undergraduate engineering students' rationales for choosing engineering programmes at master's level and the potential gains for their future professions they see from studying mathematics. As a means for organising the data, we used some notions of Bourdieu's theory of the economy of forms of social practice. The study aims to contribute to understanding differences in the students' experiences of and interest in university mathematics.

INTRODUCTION

In informal conversations at the mathematics departments where the authors have worked, engineering students from different programmes often are attributed different study habits, different approaches to mathematics and different chances to reach higher achievement levels, in particular on the more theoretical parts of the examination. This observation invites an investigation into the “reality” of such differences, but also asks for explanations of their origin. While descriptions of differences by referring to students' attitudes and beliefs might help to investigate similarities and differences within “categories” of students (e.g. Berkaliev & Kloosterman, 2009; Hassi & Laursen, 2009), an approach including student background and professional aspiration may contribute to further understanding students' experiences of and interest in university mathematics. Even when the basic calculus or linear algebra courses often are the same across different programmes, as is the case at the two universities where the study was conducted, students from different programmes may expect different exploitability of these courses. Based on the interest outlined above, this paper investigates the following research question(s):

What are the rationales of students from different engineering programmes for choosing university studies at master's level in general, and for the choice of particular programmes? Are there differences in the potential gains they see from studying mathematics for their future professions?

CONTEXT

University education in Sweden encompasses professional training of, for example, pre-school teachers and nurses, besides traditional academic programmes. Despite educational reforms to open admission to university studies for students from less theoretical upper secondary programmes, statistics show no increase of students from families without university education. The pattern over the period from 1999 till 2009 instead shows decreasing numbers of these students, in particular for civil engineering, where in 2009 only 23% of the beginning students come from a family where none of the parents has higher education (Högskoleverket och SCB, 2009, p. 39).

Policy discussions about the structure of the work force in Sweden continue to emphasise the need of more qualified engineers to secure that the country does not drop in economic development, which is seen to rely heavily on a strong development of technologically based industries. In this scenario mathematics and science education, at all school levels and in higher education, have been given key roles. Statistics of the number of university entrants and completed exams of engineering master's in Sweden show, however, very small changes during the last years, with around 6000 new students and 3500 exams per year (Högskoleverket och SCB, 2012).

THEORETICAL CONSIDERATIONS

With a focus on university students' preferences and orientations towards their further education and future professional positions with a specific reference to the role of mathematics, some notions provided by Bourdieu's theory of the economy of forms of social practice seemed relevant and useful for organising our data. Bourdieu (1983) assumes that even practices seemingly unrelated to the economic system can be analysed in terms of maximising material or symbolic profit. Capital and profit appear in a range of forms. In different fields, these forms of capital possess different values and thus contribute differently to the chances of gaining profit. According to Bourdieu (1983), capital is accumulated labour in the widest sense that exists in material form or in an embodied form, 'incorporated' within the individual. It is a *force* inhabiting both objective and subjective structures, as well as a *principle* shaping the structural regularities of the social world (p. 183). Bourdieu (1983) discusses three forms of capital (economic, cultural and social capital) and their interrelations. As Bourdieu notes a dominance of the economic field, economic capital seems to be more relevant than the other forms, which can be transformed into economic capital, or acquired through economic capital, including more or less transformational work for producing the kind of power relevant in different fields. Economic capital comprises all things that are institutionalised through "possession" and are more or less directly transferable into money. Cultural capital refers to different kinds of cultural productions. Even if under certain conditions it can be exchanged into economic capital, the reproduction of cultural capital follows its own logic. Social capital includes actual and potential resources that rely on an affiliation with a group and it is realised through exploitation of social networks.

In mathematics education research, notions from Bourdieu's work have been productively employed in diverse contexts, as for example by Aaron and Herbst (2012) to explain differences in students' more or less teacher focussed "instructional identities" in geometry lessons, by Gates (2001) to explore how teachers' beliefs are grounded in the social fields they operate and to understand how these beliefs are maintained and reproduced, by Teese (2000) to account for secondary students' achievement in relation to the cultural homogeneity of the mathematics school curriculum, or by Zevenbergen (2001, 2005) to account for middle-class students' advantage in classroom interaction, using the notion "mathematical habitus".

Most relevant for this paper is the notion of cultural capital, which according to Bourdieu (1983) exists in three forms, an *embodied*, an *objectivised*, and an *institutionalised*. The notion of objectivised cultural capital shows some overlap with the one of economic capital, as it comprises all reified forms of cultural capital, available for example in the form of books, machines or pieces of art. Embodied cultural capital (also referred to as *cultivation* or *Bildung,* ibid., p. 187) comprises all forms of skills and cultural orientations that can be acquired through education and socialisation and it is realised as a habitus of the one who possesses it, for example in the form of knowledge, competence or taste. Accumulation of this form of capital needs time and personal investment, and also a form of a socially constructed *libido sciendi* (ibid., p. 186). Institutionalised cultural capital includes all forms of certificates or titles that formally accredit a person's possession of some specified form of embodied cultural capital. Further, Bourdieu states that symbolic capital is the potential of the other forms of capital for gaining social status within a system of struggle over symbolic power. Along with the more obvious transmission of economic capital, cultural capital and social capital play a major role in social reproduction. Bourdieu (1983) notes a dynamic relation between all forms of capital acquired by a group, as the possession of one form reinforces the acquisition of the others. We have taken up the latter idea in our research question, as we assume that the students' previously acquired cultural capital might account for differences in the potential gains they see from studying mathematics for their future professions.

We were thus interested in how engineering students, depending on their background and career aspirations, think they would make use of their mathematical knowledge. It is not evident that the cultural capital acquired in more theoretically oriented mathematics studies is seen by the students as directly applicable in the field they want to enter, but there are often gains in symbolic capital. The symbolic value of mathematics is in the context of symbolic production kept high by means of policing, most prominent with strategies that draw on knower characteristics, such as being a good problem solver or being able to think logically (cf. Bergsten, Jablonka, & Klisinska, 2010). We were also interested in whether the students from different programmes see their academic achievement differently, as exchangeable into economic capital, or primarily useful as institutionalised cultural capital or as symbolic capital.

METHOD

The empirical basis for this study consists of interview data from students enrolled in five different engineering master's programmes at two different Swedish universities. Within a larger study, funded by the Swedish Research Council, investigating various issues related to the transition from upper secondary to university mathematics education, three series of audio taped individual semi-structured interviews, each lasting around half an hour, were conducted during the students' first year of study at university. Among the questions asked in the last of these interviews, conducted at the end of the year, some focused on the students' backgrounds and reasons for their choice of studies, as well as on their views about the use of the mathematics studied at university at a possible future workplace. In particular, the students' answers to the following four interview questions will be analysed in this paper:

1. Why did you choose to study at university?
2. Why did you choose to study to become an engineer (master's programme), and to start the particular engineering programme that you follow?
3. What do you think influenced you to make these choices?
4. Do you think that you will use the mathematics you are studying at your future work place, and if so how?

As data for the reported investigation, interviews with 20 and 13 first year engineering master's students from the two universities, respectively, were selected to represent the five main different study programmes (see "Outcomes" below) as well as different achievement levels within each programme (low, medium, high). For the analysis of the transcribed interviews, similarities and differences among the responses from students across the different engineering programmes were investigated. The study followed the ethical guidelines of the Swedish Research Council, granting participant information, openness, freedom of participation, and anonymity.

OUTCOMES

In the interview quotes below, 1X3 for example means student number 3 from university 1 in programme X. H stands for 'Parents with higher education'.

Computer Technology, CT (4 students: 4 male, 1 H)

On question 1, most of the students referred to the possibility of getting a good job as their reason for enrolling at university. Some pointed out that it was the only reasonable option after the theoretical programme they had followed during upper secondary school, but many (also) referred to their parents:

> nice to get a little higher salary (1CT7, H)
>
> It felt well like the only real alternative … didn't know what else to do after leaving upper secondary … and then yes the parents always encouraged you to go on studying (2CT1)

In addition, one student mentioned his living environment, a middle class area, as a contributing factor. All students emphasised their interest in computers (or programming) as an answer to question 2, while two students also said that owing a master's in engineering is a very strong educational merit, and one that he is good in mathematics. The information provided by two of the students on question 3 was thin, while the other two students said their main influence came from their family/parents. On question 4, two students were hesitating about the use value of mathematics for their future profession, two said mathematics is useful, one of them emphasising the understanding of mathematical relations as a route to a more general ability.

> you learn to take in to understand mathematical relations then you learn to understand relations kind of generally (1CT6)

However, one student did not think mathematics is of any use:

> No, to be completely honest I don't think so (1CT7, H)

Energy and Environment, EE (5 students: 4 female, 1 male, 3 H - 1 unclear)

When answering question 1, four students said that it was the natural option (in one case related to the interest in mathematics and physics) after the theoretical programme they had followed at upper secondary school. The fifth student pointed to the influence of her parents and that she would not be satisfied with herself if she did not get a university education. On the second question all students emphasised their aspiration to do something good for the world, the environment or the future.

> you do want to influence and make the world to something better in some way (1EE3, H)
>
> you kind of feel that you do something … good you contribute with something that is good … meaningful (1EE8)
>
> if we are going to take care of the next generation I guess we will have to do it (1EE4, H)

Two of these students also mentioned a good job as a reason to become an engineer along with an interest in energy management. Family influences were in three cases mentioned.

> Both parents have studied at university … that surely has an influence (1EE3, H)

Two students reported experiences from upper secondary school, and one also mentioned an interest in nature and a wish to help. In question 4, three students pointed to a general learning experience from (mathematical) problem solving as most useful for their future professional work:

> That is I guess what it means to be an engineer master's to be a problem solver (2EE1, H)

One student mentioned "learning to learn" through mathematics, and one said that mathematics is "there in everything".

Industrial Economy, IE (6 students: 2 female, 4 male, 5 H)

To get a good job was mentioned by four students as a reason to study at university:

> you can get a somewhat better job … that was the main thing (1IE1, H)

Two students said that it was natural to them to go on with their studies. An additional reason given by two students was the influence from their parents:

> it was quite natural /…/ I did the science programme at upper secondary so I liked math and I wanted to go on studying and also both my parents have higher education /…/ but then all my relatives kind of my aunts and uncles also (1IE6, H)

To question 2, three students referred to their parents and three to the wide scope and the strong combination of, or an interest in, economy and technology of the programme, while two again pointed to the possibility to get a good job:

> I think I was very much influenced by my father to become a master's engineer … yes that he thought it was good (1IE9, H)

would like to work with project management … quite a lot about leadership in this programme … you kind of want to become a boss and then it felt like a good alternative (1IE6, H)

On question 3, all four students from university 1 pointed only to the influence from their parents, one emphasising the values.

yes I don't know at least the values … so that technical subjects are pretty good … yes of course I am inspired by my parents it would be hard to say something else (1IE12, H)

To the last question, only one student answered a clear yes but then mainly very basic mathematics. However, almost all students very strongly emphasised the role of mathematics for increasing a general problem solving ability:

if not doing the calculations it is more this way of thinking … the problem solving ability (1IE9, H)

you more easily see through the problem somehow … you can put it down into small pieces somehow so that it doesn't get so big … I will probably I will definitely use this I think … I already feel that one has kind of changed as a person by the math (1IE12, H)

one always has a structured way, in math, to solve a problem and then one can bring that way of thinking into many other things in life (2IE2)

Mechanical Engineering, ME (10 students: 10 male, 3 H)

Six of the ten students in this group mentioned the opportunities for a good job as a reason to study at university (question 1). That it is natural and rewarding to go on studying after secondary school was mentioned by four students, while only one student referred to an interest in technology. However, on question 2 as much as eight students in this group pointed to such interest, most often with the specification of "construction". Some also mentioned the wide scope of the programme.

the interest in technology has always been there … more interesting [when comparing with energy] with CAD and construction (2ME3)

to construct …cool to understand what is happening (2ME4)

Also eight students attributed the main influence of their study choice to their family (question 3). In some cases practical work was emphasised, while one student explained that in his family it was not a tradition to enter higher education.

it became like that my daddy has an engineering master's and my mother a physician … so I was directly accepted for the engineering master's (1ME5, H)

actually I am the first one in the whole family (1ME7)

When answering question 4, doubts were raised about the usefulness of mathematics at a future workplace. It was most common (six students) to underline the value of understanding the foundations, for example what is behind automated calculations:

I don't think one will use it so much but yet I think it is good for the understanding (1ME5, H)

> you have to understand the basis, otherwise there is no purpose, if you don't understand what you are doing you can't understand if something gets wrong (2ME5, H)

> the calculations are done by the computer but the very understanding of what you are actually doing, the process, is perhaps important but not calculation ability itself (2ME1)

Also the general ability to solve problems, or to think analytically, was seen as an important outcome of their mathematics studies:

> yes … that is maybe not the mathematics itself but … the analy- analytical thinking and … yes but maybe not just sitting calculating but … you learn to analyse the problem in a somewhat different way than you did in high school (1ME1, H)

> yes I think so definitely … eh … partly that one learns to solve a problem, not … not just to calculate but also … one does learn a certain way of thinking and to break up a problem into smaller parts and then solve each part kind of separately … and so finally solve the whole thing (1ME9)

Technical Physics and Electric Engineering, TE (8 students: 2 F, 6 M, 4 H)

The answers to question 1 were quite varied for this group of students. Some said they did not want to work in an "ordinary" job, wanted to "become something", and that it was natural to continue the studies after secondary school. In response to question 2, seven of these eight students referred, directly or indirectly, to an interest in mathematic and/or physics, and some argued that the engineering master's will provide a strong background, especially with technical physics. Only one student explicitly mentioned to get a good job as the reason, and one seemed to aim at doing research. Family influence on the choice of study was mentioned by four students.

> my father had an engineering master's and my mother was a teacher … and then I always heard shall you be like your mother or your father … and it was no I shall not be a teacher I shall get an engineering master's (1TE2, H)

One student emphasised that the parental influence was not experienced as forcing, while another one said "probably" and one "not much". Two students said they did not know. The potential use of mathematics at a workplace (question 4) was seen mainly as indirect, through the ability to understand what is behind the calculations (five students), while a problem solving ability or an ability to "learn to learn" was mentioned by two students. As one student formulated this aspect:

> It is easier to formulate the problems if you can do it mathematically (1TE3)

One student was wondering and two hoping that they will have an opportunity to use their mathematics knowledge later on, for example to develop mathematical models.

Patterns in interview data

There are some patterns visible in the data, which are relevant for the overall research question set up for this paper. These concern similarities across the five engineering programmes as well as some noteworthy differences between the programmes.

Students from different programmes provided some similar rationales for starting to study at university, such as to get a ‘good’ job (where ‘good’ referred to a job that pays well and/or is not so boring) and that it was a ‘natural’ continuation of their choice of study at upper secondary school (or that it was the only real option). The first rationale, however, was less common amongst EE students. Linking to this the reasons for choosing an engineering master’s, and a particular programme (study direction), an interest in this kind of study programme was mentioned by most of the students in all programmes except the EE and IE. The answers to the question about the use of mathematics in a future profession varied and developed in some cases into much detail and discussion. However, a very strong common view on this issue was that a general problem solving ability, or way of thinking in problem solving, was the outcome of their mathematics studies which they thought would be the most useful one (but not any specific mathematical skill, such as to calculate integrals “by hand”). It was also common, across programmes, to point to the importance of an ‘understanding’ one has developed through the work in the mathematics courses included in the engineering studies, as for example to be able to evaluate mathematical inputs and outputs in computer software. However, this view on understanding was much more dominating in the ME and TE groups.

Some very clear differences can also be seen between the programmes. The aspect of getting a good job was much more emphasized by students from the IE and ME programmes than by students from other programmes. However, the reasons given by IE and ME students for their choices seem to be of a different character, the former acknowledging a stronger influence of their parents and expressing a stronger focus towards a career (this is also the group with the largest proportion of parents with higher education), while the latter provided reasons of a more pragmatic character, including an interest in the kind of work normally done by a mechanical engineer (this is the group with the smallest proportion of parents with higher education). A strong individual “will” behind their choice of study was expressed in particular by the TE students, also the group that most explicitly pointed to an interest in mathematics as one reason for their choice. However, the most programme-dependent rationale for their choice was given by the EE students, who all expressed a very explicit will, or even need, to change the world into something better (related to sustainability). The CP students were the least ‘optimistic’ group in relation to how much they would be able to use the mathematical knowledge acquired during their studies.

DISCUSSION

Not surprisingly, the outcomes clearly show how the cultural capital possessed by the families influence the choice to enrol at a university. However, in the group of students interviewed there were about a half from families without higher education, which are more than suggested by the Swedish statistics. Many talked about ‘a natural continuation’, suggesting that during their studies in the science or technology programme at upper secondary school, these students have acquired a cultural capital that has developed into a disposition towards academic studies.

When differentiating between positions the students aim at in social space (from an intellectual towards an economic pole), then it is visible that the EE students see the embodied cultural capital resulting from their studies as most important, and to some extent also the TE students, while the IE students hope for accumulation of economic capital. As to their position towards engineering, they see different roles for themselves. The EE group sees their future field of engineering more independent from the economic field and more related to the political field, as they think of themselves as an autonomous group who aim at transforming technology. The ME students talk about constructing technology, and for the students in the CT and TE programmes there is no clear tendency, except that the TE students also see their field as not very much linked to economy, possibly due to its clear theoretical nature.

Even if we started by expecting differences in their views of mathematics as more or less helpful for further gains in economic or cultural capital, respectively, or differences in the type of cultural capital they think mathematical studies provide, we did not find very clear patterns, with the only exception that most of the CT students did only see a use in its institutionalised form as symbolic capital provided by the certificate. The others referred to very general notions of problem solving competences or to an ability of structured thinking, including one who states that mathematics has changed him as a person, and two who say it helps learning to learn. These general abilities reflect an essentialising discourse about mathematics as enhancing individuals' problem solving abilities. The focus is less on particular mathematical skills as a form of cultural capital, but rather on a habitus to which engagement with mathematics amounts, seen as a general habituation to solve problems in a rational way. Only one TE student mentions that mathematical knowledge would help to build mathematical models, which constitutes it as a technology-related cultural capital. However, students from this programme generally expressed a disposition towards studying mathematics. A couple of students referred to mathematics as a means for understanding the principles behind other technology. The IE students did not mention any relation between mathematics and economic models, despite the tradition in their field to use theoretical models and statistics.

All of these views reflect a view of mathematics as unlinked to the social context of its use, despite the differences in social positions the students aim at. Mathematics is either conceptualised as *mind-power*, a kind of universal thinking tool in the form of a general embodied cultural capital contributing to the formation of a person (a habitus; cf. Zevenbergen, 2005), or as a universal method, a *meta-technology*, that helps to access otherwise hidden principles. We did not employ notions of ideology or discourse, to which the engineering students' views could be linked. However, the outcomes show some unexpected uniformity in their views, which did not depend so much on their different career aspirations or backgrounds, that is, on different forms of cultural capital, as we had anticipated. It is rather a discourse about the value of mathematics that might have shaped their conceptualisations, which foregrounds the values of rationality and objectivity that are associated with technological and economic progress. The students' views match very well the general discourse about the role of mathematics education in secondary schools that aim at channelling more students towards engineering careers to sustain economic development, which is seen to rely heavily on a strong development of technologically based industries.

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