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“I want a high-educated job that pays well and is fun”: Secondary students’ relevance beliefs for taking advanced mathematics

Anders Wiik and Pauline Vos

Faculty of Science and Engineering, University of Agder, Norway

anders.wiik@uia.no, pauline.vos@uia.no

Many students experience the content of the mathematics classroom irrelevant to their lives. At the same time, achievement in mathematics is widely regarded as an important part of general education. In this paper, we report on a study regarding students’ relevance beliefs. For this, we network Engeström’s cultural-historical activity theory with Skovsmose’s theory on foregrounds, and introduce the terms ‘realized’ and ‘emergent’ activity systems. Students provided a wide variety of beliefs, in which the belief of mathematics as door opener to higher education and key to options in life was leading. The belief in the exchange-value of mathematics overshadowed beliefs on the use-value of school mathematics (for other school subjects, for undefined jobs or for mental training). We recommend teachers and textbook authors to include more information on the relevance of mathematics in future studies and jobs.

Keywords: Beliefs, exchange-value (of mathematics), cultural-historical activity theory, emergent activity systems, relevance (of mathematics).

Introduction

Many teachers of mathematics encounter the question “*why do we need to learn this?*”. While sitting in the mathematics classroom, listening to the teacher, doing tasks and tests, many students find little relevance in the mathematical activities they are made to engage in (Bishop, 1988; Onion, 2004). Rather than learning about the usefulness of mathematics or using mathematics to solve authentic problems from out-of-school contexts, the students learn that mathematics is about mathematical objects (numbers, triangles, x , etc.), and that they must find an appropriate procedure to reach a correct answer (and only one) within a short time frame (Dowling, 2002).

The finding that students ask this ‘why?’ question has been consistent for several decades. It opens a range of questions: why is it that many students find school mathematics irrelevant, how can mathematics teachers convey relevance, can mathematical modelling improve students’ experiences of relevance, do experiences of relevance influence performances, and so forth. We cannot cover all these issues. In the present study we focus on students and their reasons for engaging in advanced mathematics; if they chose that path, then they must somehow see it as relevant.

Students’ reasons for engaging in advanced mathematics are part of their belief system. Students have beliefs about themselves, about the school, about their peers, about life, and so forth. According to Skott (2014), beliefs are mental constructs that are subjectively true for the person in question, beliefs are considered relatively stable, and beliefs affect the person’s interpretations of experiences.

Following Hernandez-Martinez and Vos (2018), relevance is a connection between (1) a person’s subjective perception, (2) an activity by the same or another person, (3) an objective (an aim), and

(4) a value. In the present study, we consider *relevance beliefs* as a category of students' beliefs connected to a deliberate activity, in this case, choosing a certain course. Students' relevance beliefs can be mediated by the mathematical content, but also by interactions with others. A different category of relevance beliefs is part of teachers' beliefs and pertains to a teacher's perception of the relevance of mathematics to their students.

In the Norwegian school system, students in upper secondary can choose among several mathematics courses with differing aims, scope and difficulty. Students make a selection while negotiating contradictions, such as those between the apparent irrelevance of school mathematics, and the image of mathematics that is drawn out in the media as a subject of paramount importance for the future economic development of society (Lange & Meaney, 2018; Valero, 2017). This duality puts the students who engage in the hardest mathematics in an interesting position: how do they reason about selecting and pursuing the most advanced mathematics course available to their age group? Once they are in this course, they encounter mathematical topics such as derivatives, integrals, and trigonometry. In the school system, they encounter little information on how these mathematical topics are useful out-of-school. The few situated tasks are quite inauthentic. Also, teachers of such courses, generally, have a background in university mathematics with little emphasis on the mathematics' use-value outside of the school context. Our research on students' relevance beliefs regarding school mathematics was operationalized by the research question 'what reasons do students provide for engaging in a challenging mathematics course?'

Literature review

The discussion on the reasons for teaching mathematics has developed over the past two decades. According to Heymann (2003), mathematics is taught as preparation for later life, for promoting cultural competence, developing an understanding of the world, developing critical thinking, developing a willingness to assume responsibility, as practice in communication and cooperation, and to enhance student's self-esteem. Ernest (2005) provides a similar list, although he differentiates between reasons to teach practical versus advanced mathematics. In either case, it remains questionable whether students get to 'see' these reasons. Also, it has been argued that the above reasons remain at the pupil's level without considering the social role of school mathematics. For example, Pais (2013) suggests that school mathematics is important not only for its intrinsic purposes (use-value, aesthetics, etc.) but also because it has exchange value, for example as a testing and grading device that gives some students access to prestigious positions in society, and other students not. In the public discourse, school mathematics is typically associated with socio-economic development, in particular with the development of advanced technology (Lange & Meaney, 2018) and economic parameters on the individual and national level (Valero, 2017). In this cultural-political tug-of-war, it seems that school mathematics is struggling to communicate the use-value of mathematics.

A crucial challenge is the dialectics of two processes, the mathematization of knowledge and the demathematization of society (Jablonka & Gellert, 2007). The first has to do with mathematics being increasingly important in social, economic and political issues, for example in dealing with complex data through modelling and visualizations. This mathematization process is accompanied

by a demathematization process where mathematics is hidden and trivialized, for example when software encapsulates mathematical practices and datavisualizations can be generated in standardized formats by a few clicks.

Various teaching approaches to mediate relevance have been proposed. For example, in a study with engineering students, Hernandez-Martinez and Vos (2018) used tailored mathematical modelling activities and an invited talk by a professional to demonstrate how mathematics is used and valued amongst engineers. They found that several students experienced these activities as relevant to their future career, but some found the extra activities irrelevant, because their primary aim was to obtain a passing grade for the course.

Theoretical background: Cultural-historical activity theory

To study relevance beliefs, we consider students as having different backgrounds (where they come from) and foregrounds (aspirations, opportunities). The term *foreground* was developed by Skovsmose (2005) as analytic construct for interpreting learning processes, and is framed within the students' current political, cultural and social context. Additionally, we wanted to capture students' engagement in activities (doing mathematical tasks), which take place within a community (a classroom, peers, etc.), in which there are norms and conventions (e.g. the answers must be correct), tools (incl. language and symbol systems). To engage into an activity, a person is driven by a motive. In order to capture how the student (subject) is connected to the community and the object (aim of the activity), we adopted cultural-historical activity theory (CHAT) (Engeström, 2015), in which an activity system is a basic unit of analysis, see Figure 1.

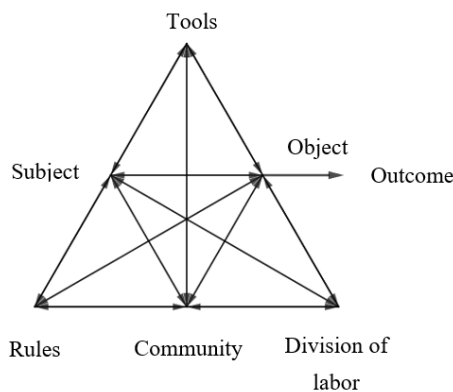


Figure 1: Engeström's (2015) model for an activity system

To analyse students' relevance beliefs, in particular their reasons for engaging with advanced mathematics, we assume that these can be affected by (1) the students' backgrounds (e.g. having a parent who uses mathematics in her workplace), (2) the environment in which the learning of mathematics takes place (the activity system of the classroom), and (3) the students' foreground (Skovsmose, 2005). This foreground can entail complex imagined activities, of which the student may not know much about; a student imagining herself as a future engineer may not know anything about the daily activities of an engineer, but nevertheless can aspire to become one. Thus, the activities envisioned in a student's foreground are not *realized activity systems* but *emergent activity systems*.

Method

To find participants, we contacted a teacher from an urban public upper secondary school. The teacher and the school were well-known to the first author, as he had previously worked there. The teacher agreed and informed the students in his class about the project in advance. Thus, students had time to consider whether or not they wanted to participate. When the interviewer visited the class, eight students (3 f, 5 m) agreed to participate. The interviews were conducted three days later.

The students were in grade 12, which in Norway is the second year in upper secondary school, and the year before the final exams. All had chosen the most challenging mathematics course available, referred to as *R1*, the name used in the local context. The students were interviewed in pairs for mutual support and comfort. All student names were anonymized, and the pairs follow the alphabet: A(ndré) and B(jørn); C(hristian) and D(aniel) and so on. The student pairs were interviewed for approximately 20 minutes on their back- and foregrounds. The interviews were semi-structured (Wellington, 2015) and the interview guide followed Kvale and Brinkmann (2015).

All interviews were audio-taped, transcribed, and analyzed using Skovsmose's (2005) constructs of back- and foreground, and the CHAT frame by identifying activity systems, particularly communities and associated objects and whether the activity systems were emergent or not. The statements were then interpreted in terms of relevance beliefs based on categories from the literature (exchange-value, use-value) and themes emerging from the data (Wellington, 2015).

Results

In the following, we present excerpts from the interviews. Due to space limitations, some answers very similar to others were left out. First, we asked the students why they chose the R1 course:

- Bjørn: I like mathematics and get good grades.
- Daniel: It's pressure from parents of course, and also some from my friends. Many of them are performing very well. I want to be on the same level, you know. Also, I suppose, career aspirations and further studies are... about having a relatively high-educated job which pays well... and is fun. I think that's very important.
- Fredrik: The reason I chose R1, it is kind of a continuation. I always performed well in maths ... and it went well in grade 11, so R1 was the natural choice.
- Gjertrud: I think math is fun. It's great fun when you get the same answer as the answer list. There aren't tons of pages about "it may be this", or "it may be that". It's great!
- Hilde: Because I want to keep the possibilities open because I don't know what to do next.

We see that students reacted very differently to this question. Two students, Gjertrud and Bjørn, answered to have chosen R1 because they liked mathematics, whereby Gjertrud emphasizes the clarity, and Bjørn likes getting good grades. Their answers are within the activity system of the present classroom, unlike the other students, who mention their background (e.g. parents' pressure, having been good in maths in the past), or their foregrounds (e.g. keeping options open, getting a

well-paid job). The second question asked the students explicitly about wishes and ambitions for future studies and career (foregrounds). They answered as follows:

- André: Likely that it'll be something related to science or technology. Or I'd study sports!
- Bjørn: I'm very unsure about further education, but probably I will do some university studies, and that will most likely be within science or technology. But I don't know much more than that, really, I'm a little unsure. It could be sports but it could also be social anthropology or psychology, those are things that I'm also interested in.
- Christian: I always had a dream of going into ... engineering direction for example ... be a marine engineer. That's what I have always wanted. But ... I don't know yet. I like to draw things, be creative, look at buildings, how they are built. And boats, how they break waves, how they manage to stay on water, not go down, like that.
- Emilie: I don't know what I want to become, but I'm taking IB [International Baccalaureate, a prestigious examination program] next year and then perhaps NTNU [Norwegian University of Science and Technology].
- Fredrik: I just try to keep all the doors open.
- Gjertrud: I think it will be something within science, like biology. But I also want to study psychology, I think everything is very exciting and I can't decide!
- Hilde: Nothing (...) I don't know.

The question on students' foreground showed that all students mentioned a future, but the range and focus differed. With the exception of Christian who had a clear goal, all were insecure and wished to keep options open. Many of them indicated future studies, most of which were within science and technology, and no one mentioned economy or business administration. Above, we see only Christian and Emilie mentioning a future profession beyond their studies, although for Emilie it was vaguer than for Christian. Towards the end of the interview, we asked why they thought they had to learn mathematics:

- André: I think [maths] is mostly about ... just having the foundation for further study.
- Bjørn: I think maths is really only about testing understanding and testing how the mind can assemble patterns and stuff. (...) it's about exercising the mind, IQ-testing ...
- Christian: ... ehh I think especially the maths we are learning now, for example, we will need it in physics. It is ideal for the ... calculations there ... to figure things out there.
- Daniel: I think a lot of mathematics we're learning is a little redundant. Of course, I see that many topics can be useful. Like what we're learning about now with differentiation, I think finding rate of change everywhere, can be relevant. But there are also the unnecessary things. Logarithms are actually one of the things that I'm not so sure of whether it is useful or not.

Emilie: I can help my kids, my little brother [with homework].

Gjertrud: I really feel that what we're learning is, like, further, that we're learning something we can use for ... Just like when you learned the multiplication table. Why do we need to learn multiplication? Now I use it all the time.

Most of the students considered their foreground. They mentioned that mathematics can be useful in future activities, for example in future studies. One student, Daniel, expressed concern that some mathematical topics may be useless. Only one student, Bjørn, considered the present activity system of the classroom when mentioning that the subject of mathematics has the purpose to train and test students' mental abilities. Emilie considered her present and emerging family activity system when she mentioned helping her kids and little brother. However, we must acknowledge that by first asking the students about their foregrounds, we primed the students to focus on their foregrounds thus biasing them towards focusing on the exchange value of mathematics.

Conclusion, Discussion, Recommendations

The present study on relevance beliefs was guided by the research question: what reasons do students provide for engaging in a challenging mathematics course, R1?. The interviews revealed that for some students, their backgrounds (parents, earlier success) and their present achievement and enjoyment in mathematics play a role. However, most students mentioned the belief that the R1 course is relevant for their future. Here, we saw different patterns emerging. For example, Daniel ("I want a relatively high-educated job which pays well... and is fun") did not have a concrete plan for his future and strived to "keep his doors open", he aspired a high-status job, possibly within engineering. Similarly, Christian ("I always had a dream of going into engineering and be a marine engineer") looked beyond the course. The object of their engagement in the mathematics classroom had an exchange-value for getting into some form of higher education that led to a desired job. Their image of activities in higher education and workplaces were emerging activity systems, rather than realized activity systems. So, two subsequent emerging activity systems are in their foreground, see Figure 2 (left). For other students, such as Emilie ("I don't know what I want to become, but I'm taking IB and then perhaps NTNU") and Gjertrud ("It will be something within natural sciences, everything is exciting, I can't really decide"), the R1 course was relevant as having exchange-value to enter some form of higher education and keep options open. They looked at a nearer future in higher education without concrete ambitions regarding professions. Thus, their foreground was one or more emergent activity systems at early stages, see Figure 2 (right).

Two students believed mathematics to be useful, for other subjects (Christian mentions physics) or in an undefined use (Gjertrud: "we're learning something we can use"). Not one mentioned usefulness for their daily life, nor did they say anything about how mathematics can be useful, for example in modelling, data analysis or data visualization. Others believed that some mathematics could be useless (Daniel: "logarithms, I'm not sure of whether it is useful"). They also mentioned the mental strengthening function of mathematics (Bjørn: "exercising the mind"). The most frequently given reason for choosing the R1 course was that they believed it keeps their options open, apparently knowing the hurdle function of mathematics. This exchange-value of mathematics overshadowed its use-value, as already indicated by earlier research on Scandinavian secondary

students (Nosrati & Andrews, 2017; Pedersen, 2013). This suggests that a demathematization of school mathematics has happened, where the usefulness of mathematics has become obscured, and beliefs about other social functions of mathematics, for example its exchange-value, have taken over.

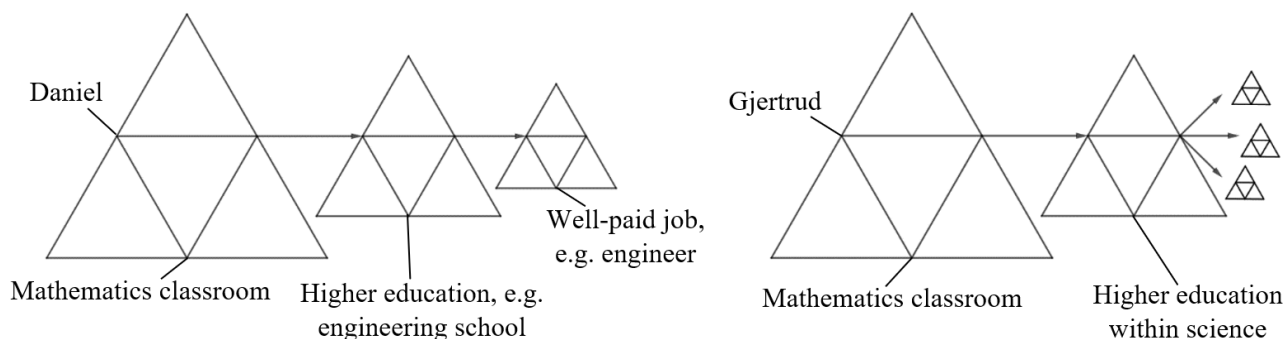


Figure 2: Students realized activity systems in the mathematics classroom, with emergent activity systems as objects; the case of Daniel (left) and the case of Gjertrud (right)

The networking of Engeström's (2015) and Skovsmose's (2005) theories proved fruitful in our analysis for connecting relevance beliefs to an activity (choosing a particular mathematics course). As a result of this, we found that for research on relevance beliefs regarding school mathematics, it is necessary to take into account students' (1) background, (2) current situation and (3) foreground.

Among the items on Heymann's (2003) list of reasons for teaching mathematics, the students on our study are clearly aware of its role in preparing for later life, although exclusively for further education and future workplace activities. The frequent reference to 'keeping all doors open' shows clearly that the students were aware of school mathematics' exchange value: a passing grade in this course is critical to many study programs that are otherwise not accessible. Furthermore, Daniel's assertion that the advanced mathematics course might lead to a "high-educated, well-paid and fun job" indicated an awareness of Pais' (2013) suggestion that school mathematics has a role in distributing prestigious positions in society. Based upon our research, we recommend, first, that beliefs may be divided into different categories, and 'relevance beliefs' regarding the usefulness of school mathematics is a separate category within students' belief system. Second, teachers, teacher educators and text book authors ought to create resources for students to inform them about the use-value of mathematics, not only within professions typically associated with mathematics (e.g. engineering and economy) but also its use-value in medical and social disciplines for purposes of modelling, analyzing, communicating and visualizing data. Clearly, many of the reasons for teaching mathematics mentioned in the literature have not reached the students.

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