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We focus on the perceived autonomy of mathematics students in their first semester at university. According to self-determination theory by Deci and Ryan (1985), students have to satisfy their need for autonomy in order to develop intrinsic motivation. Using two facets of autonomy, we analyse interview data to explore which situations foster or hinder the students' perceived autonomy. The main factors affecting students' autonomy are briefly discussed.

Keywords: Self-determination theory, autonomy, first study year.

INTRODUCTION

Students' interest is an important factor in learning mathematics, especially for deep understanding (Köller, Baumert, & Schnabel, 2001) end of Grade 10, and middle of Grade 12--in order to investigate the relationships between academic interest and achievement in mathematics. In addition, sex differences in achievement, interest, and course selection were analyzed. At the end of Grade 10, students opted for either a basic or an advanced mathematics course. Data analyses revealed sex differences in favor of boys in mathematics achievement, interest, and opting for an advanced mathematics course. Further analyses by means of structural equation modeling show that interest had no significant effect on learning from Grade 7 to Grade 10, but did affect course selection--that is, highly interested students were more likely to choose an advanced course. Furthermore, interest at the end of Grade 10 had a direct and an indirect effect (via course selection. However, in their first semester at university, mathematics students often experience motivational problems (e.g., Daskalogianni & Simpson, 2002), which form – at least in Germany – one major reason for drop-out (Heublein, Hutzsch, Schreiber, Sommer, & Besuch, 2009). Self-determination theory (SDT) by Deci and Ryan (1985; Ryan & Deci, 2002) postulates three basic psychological needs which are central to the support of interest: the needs for perceived competence, autonomy and social relatedness. In this paper, we focus on autonomy, investigating how German first-semester mathematics students experience the satisfaction of their need for autonomy at university. We have chosen autonomy because in our data, many students have a problematic autonomy experience despite possible positive influences at university (they study a topic of their own choice in an institution that gives many freedoms, e.g. minimal attendance requirements). After an explanation of the concept of the need for autonomy we state the research goals and describe the methods we have used. We then present empirical findings and finally discuss factors influencing students' autonomy.

This research is part of a PhD-project focussing on students' interest development.

THEORETICAL BACKGROUND AND RESEARCH GOALS

In SDT, the role of the basic psychological needs for the development of motivation compares to the role of basic physiological needs (food, water) for the development of our body: need satisfaction is necessary to thrive. A major difference is, however, that the satisfaction of psychological needs is a personal perception. Thus, even in the same situation, different persons may experience need satisfaction very differently. The term autonomy as it is used in SDT should not be confused with different usages like independence or influence on one's learning. The need for autonomy is described as referring "to being the perceived origin or source of one's own behaviour" and "concerns acting from interest and integrated

values" (Ryan & Deci, 2002). Following Lewalter (2005), we distinguish two different facets of autonomy of Ryan and Deci's description. The first one is the *perceived locus of causality* (PLOC) people feel when they initiate and control their actions (but not necessarily the outcomes, however). The second one refers to their *personal goals and values* (PGV). For example, one might compose music and feel a PLOC concerning the emerging ideas. In contrast, one might play music in an orchestra and give the initiative to the conductor but might still feel autonomous in the PGV sense if one's goal is to play music in an orchestra and one sees being conducted a valuable way to do so. Since studying mathematics includes external causations (e.g. choice of content, exams) one might or might not agree with, we expect the usage of the two concepts to give more detailed results. Based on SDT, Reeve (2002) stresses the importance of autonomy in educational settings and gives descriptions of autonomy-supporting behaviour like being responsive, supportive and flexible (e.g., giving students time to work in their own way). In contrary, using directives, evaluating students and motivating them through pressure hinders their perception of autonomy. Since motivational problems are known in the first semester, it would be interesting to see if and how the basic needs are satisfied. However, we could not find descriptions of students' autonomy experience in university mathematics courses.

Our first goal is to identify typical ways to have autonomy-related experience in the first semester. Our second goal is to find out in how far autonomy in studying mathematics may be perceived very differently across students. Since for the first two aspects, we distinguish two facets of autonomy (PLOC and PGV), our third goal is to analyse the relation between both facets.

DATA COLLECTION AND ANALYSIS

Our data is formed by 17 semi-structured interviews with first-semester students. Some were enrolled in a secondary teacher programme, others studied for a mathematics degree, but they all attended the same lecture on real analysis. The professor held the course in a rather abstract way and included only few numerical examples. The setting was typical for German mathematics or higher secondary teacher programmes: About 100 students attended the lectures where they had to hand-in a task sheet every week. The sheet was marked and then returned in a weekly tutorial where the solutions were presented and discussed. Only students who got at least 50 % of the maximum score were allowed to take the exam. Attendance was neither required in the lectures, nor in the tutorials. The lecture was based on definition and proof and also many tasks included proofs. Many students also attended a course on linear algebra in their first semester, which was more calculation-based in comparison to the analysis course. All students were asked to come for an interview in the lecture. They agreed in the scientific use of their data and were given the possibility to discontinue the interview or delete passages from the tape at any time.

The students were interviewed in the third or fourth week of their first semester and were asked to broadly describe their experience and learning behaviour at university. Subsequently, they were more specifically asked for their satisfaction of the basic needs including autonomy (e.g., referring to their narrative, the interviewer could ask for situations which were similar or very different from those which affected students' PLOC and for issues they did or did not agree with). The students were asked to include the linear algebra course in case they attended it, but happened to mostly speak about their analysis course. The interviews lasted 30 to 60 minutes and were taped and transcribed. To illustrate the very personal nature of need satisfaction, we picked out two pre-service teachers, whom we call Betty and Chris. We included one more interview with each of them which was conducted at the end of the semester in the same manner. They were chosen to maximise the contrast of autonomy experience: Betty experienced very little autonomy and Chris quite a lot.

Since need satisfaction is usually connected to emotions and may thus be remembered quite well, we assume that the students recalled large parts of their important experiences. We thus expect to cover a very broad range of need satisfaction. Students' statements in the transcripts were coded for PLOC and PGV concerning university mathematics anywhere in the interview, not only when the students had been asked for autonomy. As the interviews included both positive and negative experiences relating to need satisfaction, we distinguished positive from negative in our coding depending on students' reported emotions or evaluations. PLOC was coded when students either referred to themselves as source of their actions or

described situations where they were far from being the origin of their behaviour (having no idea what to do, feeling desperate). PGV was coded when students reported that issues were in accordance or in conflict with their goals and values. Coding one passage for both categories was also possible. We want to give some examples of our coding:

Positive PLOC

> For example today, I could calculate some things because I knew how to rearrange them. And that felt great, I was really proud since I knew, it was right. And it was my thought.

Negative PLOC

> I found the worst thing which frustrated me very much and still does: You shall prove or justify something but no one tells you how.

Positive PGV

> I find it a great thing, that you simply have a task sheet every week. For this reason I am confident that if I engage with the sheet, then my studies will work.

Negative PGV

> For me, it isn't right, that the lecture is so fast and you really can't follow and I find this really bad.

The codings of each category were then grouped into typical situations by the first author in a rather exploratory way. We believe the method to be sufficient to identify ways to experience or hinder autonomy, although there is no methodological control.

RESULTS

In order to answer the first question of how autonomy typically arises or is hindered, we present the main clusters according to the two theoretical facets.

For the PLOC-facet, 156 out of 204 codings were negative, which corresponds to most students' general experience of some frustrating first weeks.

- Each student felt pressure to hand-in the task sheets in time and get a sufficient grading, which was a rather permanent experience.
- On a situational level, they lost PLOC when they couldn't (immediately) understand the lectures and the pace was too fast for them, so they could only take lecture notes.
- The students also lost their PLOC when they did not know if they were mathematically right or wrong (e.g. if a proof was correct or complete, which argumentation was allowed) or missed explanations of mathematical objects.
- The most serious restrictions were experienced when the students worked on the task sheets. There is a frustrating feeling of being stuck which occurred in three different types of situations:
  - when students did not understand the task itself,
  - when they had no idea how to tackle the problem
  - and when they had an idea, but did not know how to write it down.
- Another autonomy restriction concerns the evaluation of the students' work. The marking on the task sheets, sometimes just the score, and the tutorials did often not provide the students sufficient information to understand in which parts and why they had been right or wrong. Sometimes, students even got different grades for the same solution, so they felt treated arbitrarily.
- When students positively experienced a PLOC, they mostly referred to situations contrary to the above mentioned ones (e.g. having ideas for the tasks). This especially related to calculation tasks.
- In addition, managing their resources like books, the internet or peers gave them feelings of initiative on an organizational level and thus autonomy.

For PGV, negative codings amounted to 65 out of 113 codings.

— Students did not agree with the way mathematics was presented (too few explanations and examples, the high pace in the lectures)

— and in general with a system that is so demanding that many students struggle.

— For the future teachers, another conflict was that the subject matter was perceived to be not appropriate for their future work.

— Positive PGV-experiences were reported with regard to the general aim of deeper understanding

— and in particular concerning the weekly task sheets, which made students work harder than they would have done otherwise and thus learn more.

In order to illustrate personal differences in need satisfaction, we now focus on the two students Betty and Chris who were enrolled in the teacher programme.

The case of Betty

After school, Betty did not immediately go to university but completed a vocational training as an educator and then decided to become a teacher. Her autonomy experience at university was mainly negative. On her first task sheets, she received far less than 50 % and thus reported enormous pressure and lack of time. Her experience covered examples for every negative PLOC category mentioned above. Especially, she did not understand why it had to be so hard. She could work on proof tasks only when the tasks were about proving that something satisfies a given definition. Once, she handed-in a solution copied from a book which proved an implication, where the task had asked for a proof of equivalence. She felt treated unfair since even the book's solution got a bad grading (affecting both PLOC and PGV). Asked for autonomy concerning her studies she confirmed that she knew she had autonomy, "but the feeling didn't show up". Despite her previous aims to fully understand the subject matter, she soon focussed on the minimal requirements and therefore merely worked on the task sheets without having time to review the lecture notes. Betty experienced autonomy using her resources like peers, books and the internet where she tried to get hints or solutions from. In the second interview she said that she had started copying homework although she did not like it. She was torn in her view on university mathematics. On the one hand, she characterised mathematics as "explaining simple things in complicated ways" and saw no use in it, especially in proofs since they would not have any application. On the other hand, she did not want to call university mathematics useless and gave it some importance since teachers should know what is behind the results. Her only autonomy experiences related to connections to school mathematics (PGV), managing resources (PLOC) and few numerical calculation tasks or examples (PLOC and PGV).

The case of Chris

Chris directly entered university after school, where he had reached the highest grades in mathematics. He felt pressure after his first task sheet was graded less than 50 %. He sometimes did not know how to tackle a task or write it down, but also solved some tasks so that positive and negative experiences balanced. Due to his partial success, he believed he could reach the necessary score so that fear and insecurity soon started fading out. He felt his autonomy restricted by having no guidance for proof tasks, getting no informing feedback on the marked sheets and having to do a lot for the tasks so he had less time for self-directed learning. All three aspects refer to both his PLOC and PGV. However, in principal he appreciated the task sheets since they make people work hard. Chris also readjusted his aims from getting good grades to simply passing and started using books and internet resources.

In the second interview, Chris still described some tasks as frustrating but he received sufficient scores and had developed confidence in eventually meeting this criterion. So although he still tried to solve every task, he did not feel pressure to do so. Chris also mentioned that he usually had several ideas and strategies for the sheets, including reviewing suitable parts of the lecture notes. He also highlighted his own evaluation of his solutions and his understanding in addition to the grading. Chris found having his own ideas was much more motivating than collecting information from different sources. Nevertheless, he sometimes searched for hint on the internet. When he found other interesting things there, he followed them for his own interest (PLOC).

Personal differences in autonomy experiences

It is clear, that different situations may lead to different autonomy experiences. Betty perceived very little

autonomy when she copied solutions for the tasks, whereas Chris could experience autonomy since he solved the tasks on his own. It is also clear that in similar situations, students may have similar experiences. Betty and Chris both feel pressure from the tasks sheets (PLOC) which they generally agree with (PGV), because they see the sheets as a good measure for their learning. They both appreciate that university mathematics aims at deeper understanding and they both like calculation tasks because they usually know how to tackle them. However, Betty and Chris also had very different autonomy experiences in similar situations:

They both believed that they would not need the university mathematics in their future work at school, but related this to their goals and values very differently. Betty said "Why? I do not want to become a mathematician but a teacher". Chris' reaction was rather opposite: "What else should we do then? They can't tell us again what we already learned in school!" In addition, they both had been looking for solutions in internet forums, but all they had found were hints. Betty disliked such posts and expected others to present the solution. Chris appreciated such posts as protecting him from copying something he would not understand (PGV). Differences also appeared for the PLOC-facet. When working on the tasks, Betty had mostly no idea what to do next whereas Chris often had several ideas and could then choose. In addition, Betty's only reason to work on the tasks was the score, since "I need the crap 50%". Chris, in contrast, saw things differently: "if I did it just for the external pressure, then I would tackle it very differently".

The relation between PLOC and PGV

Although the two facets of PLOC and PGV are connected, they turn out to contradict sometimes. While there was no situation where students had a PLOC but did not experience PGV, it happened that students' experienced no PLOC but felt their PGV were respected. Like Betty and Chris, all students (partially) lost their PLOC due to the pressure from the task sheets. However, this was mostly according to their PGV. A similar situation (no PLOC, but accordance with PGV) occurred when Chris could not find a solution for a task on the internet, but only hints. Concerning the content matter, Betty had very few PLOC experiences and was torn, struggling to connect the content to her goals and values, whereas Chris experienced both facets positively.

DISCUSSION

In our study, we analysed interview data concerning experiences of autonomy using the two different facets of PLOC and PGV. We could reach our first goal by describing typical situations of need satisfaction or dissatisfaction. We could see that studying mathematics at university provides rich opportunities to experience need satisfaction but also dissatisfaction which may cause serious problems for students' intrinsic motivation. Many typical situations could possibly also appear in other study subjects. However, especially those which refer to the task sheets (not understanding the task, having no idea how to tackle it or how to write down a solution) and proof (when is a proof correct and complete?) seem to be typical for university mathematics. Concerning the PLOC concept, autonomy seems to not only have heteronomy as a counterpart, but also feelings of being stuck and having no idea what to do next.

For our second goal, we compared the two cases of Betty and Chris, which illustrated that autonomy experiences strongly depend on both the person and the environment. Similar situations may foster the autonomy experience of some students and hinder the autonomy experience of others.

Concerning the third goal, we could see different, sometimes contradicting experiences for PLOC and PGV, although both facets origin in the same framework. Distinguishing the two facets helped analyse students' autonomy by revealing hidden tensions, where students feel no PLOC and yet experience need satisfaction in terms of PGV. In such a situation, the students may sustain their intrinsic motivation.

General issues affecting perceived autonomy

The *duty to get good grades* on the weekly task sheets clearly affects students' perceived autonomy, as it puts much pressure on them, violating Reeve's (2002) criteria for autonomy support mentioned above. However, to some extend most of the students appreciated the pressure which would eventually make them learn more. In addition, the case of Chris shows that students do not necessarily experience this duty as pressure if they are confident in meeting the criteria. However, like Betty, many students focussed mainly on the tasks and put their learning goals on hold.

Although the students did not express it, this might not meet their PGV.

Another major background is the *personal competence*. We could see that competence affects autonomy on different levels: First, content knowledge affects students' opportunities to tackle the tasks (PLOC) and also to evaluate their own mistakes (PLOC). As Chris' case shows, this ability can also be important to assess the personal work independent of external judgements like grades. Second, mathematical language is needed to even understand the task itself and to write down solutions (PLOC). Language can also affect the satisfaction of PGV, like in the situation where Betty misunderstood the task. A third level of mathematical competence refers to insecurities like how detailed proof needs to be or which arguments will be accepted. They may be described in terms of sociomathematical norms (see, e.g., Yackel, Rasmussen, & King, 2000) as normative understandings which are negotiated in the social context. It is clear to see that calculation tasks, which all students liked, do not address these problems apart from including difficult content. In turn, students may experience a PLOC based on their competence, e.g. seeing different ways to tackle a task or having their own ideas for solving problems.

Proof as a new concept fitted many students' PGV of heading for deeper mathematical understanding. However, students may have trouble to connect proof to their PGV because they do not see an application. In cases of proving obvious statements, they might see no use at all. Here, one decisive aspect is whether students see building a mathematical theory as part of their goals or restrict them to calculations and applications. In addition, *proving* as an activity may involve all competence-based problems mentioned above.

A very interesting point is the *questioning of the need of university mathematics for teaching at school*. The question itself is part of an open debate (e.g., Davis & Simmt, 2006) so there is no clear and simple answer. The students usually do not have teaching practice and see teaching often as "explaining". Taking this as basis, they need to trust in the university doing what is necessary for them. In our study, this did not always happen. We could see that students felt a conflict with their PGV only if they also had a PLOC-conflict. However, it is also possible that some students do actually not agree with the content but do not start to question it unless they start struggling. What we could observe is that the conflict reduced when connections to school were made explicit. Recent projects successfully provided such connections (Leufer & Prediger, 2007). In addition, the compulsory task sheets show that students may value things although they negatively affect their PLOC.

Unlike in school, university requires learning activities which are not explicitly assessed such as reviewing the lecture notes, monitoring the personal progress, searching for alternative explanations and examples or generating them. Students may not be aware of the new rules and experience these changes as "bad and too few explanations" affecting both PLOC and PGV. Such a mismatch of expectations can be described in terms of the *didactical contract* (Brousseau, 1984) which was highlighted by Hourigan & O'Donoghue (2007)the consequences of the 'Mathematics problem' are a source of concern for the education sector and governments alike. Growing consensus exists that the inability of students to successfully make the transition to tertiary level mathematics education lies in the substantial mismatch between the nature of entrants' pre-tertiary mathematical experiences and subsequent tertiary level mathematics-intensive courses. This paper reports on an Irish study that focuses on the pre-tertiary mathematics experience of entering students and examined its influence on students' ability to make a successful transition to tertiary level mathematics. Brousseau's 'didactical contract' is used as an intellectual tool to uncover and describe the contract that exists in two case mathematics classrooms in Irish upper secondary schools (Senior Cycle for the secondary-tertiary transition.

Some findings parallel the work of Sierpinska, Bobos, & Knipping (2008), who investigated "students' frustration" (which can be seen as contrary to autonomy) in prerequisite mathematics courses from an institutional point of view. Especially since both of us found critical elements like techniques of problem solving and learning strategies, rules and norms as well as the didactic contract, we hypothesise that these elements are generally important for autonomy in the learning of mathematics at university level and thus for students' motivation.

Implications

It seems that in general some conflicts with students' autonomy are inevitable. However, at some points help seems accessible, especially concerning aspects

which are typical for university mathematics. For instance, students expected to be guided more in their learning process. Making explicit new demands in strategies for learning and problem solving, sociomathematical norms and the mathematical language could possibly help students to experience more autonomy. Since many students seek for suitable resources, books addressing study skills (e.g., Alcock, 2013) and mathematical language (e.g., Beutelspacher, 2004) could be a good start. In addition, making connections to school mathematics more visible would help pre-service teachers to connect their courses to their PGV.

The German community should also question the task sheet system. For instance, students could have to hand-in documents of their learning process (e.g. a learning diary) rather than worked-out solutions only. They could then also be admitted to the exam for learning activities of their choice like engagement with the lecture notes.

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