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APPROACHES TO STUDY AND THE QUALITY OF LEARNING. SOME EMPIRICAL EVIDENCE FROM ENGINEERING EDUCATION

ABSTRACT. In the late 1990s failure rates in a first-year introductory calculus course at the Norwegian University of Science and Technology reached peak levels. This paper reports on findings from an action research project that was set up in 2002/2003 to improve the situation. The study confirms that students approach their tasks differently which contributes to qualitatively different learning outcomes. Furthermore, patterns of achievement in mathematics and physics in secondary education keep reoccurring in the calculus course, even though the teaching and learning contexts are different. The paper does not provide any definite answer as to why groups of students get involved in distinctly different learning processes, and it will take further research to decide the nature of commitment to the learning tasks. However, inspired by the notion of 'practices' this paper raises a discussion about the role of intentionality in learning processes. When doing mathematics, students are also in a process of being engaged in and developing a practice. It is a major challenge for academic staff to contribute to communities of practice that are conducive to learning.

KEY WORDS: approaches to learning, assessment, calculus, failure rates, quality of learning

INTRODUCTION

In the late 1990s, the Norwegian University of Science and Technology faced an increasing number of students who were less able to cope with the demands of the basic course in calculus. This course was obligatory for students enrolled in the engineering education. In the years from 1998 to 2002 the failure rate ranged from 21.5 to 39.2 per cent. The growing numbers of student failures at the exam contributed to concern for teachers as well as distress for students. High failure rates logically resulted in poor progression and reduced through-flow of students. This paper draws on data from an action research project that was set up to remedy the situation.

A recurring problem is that students use mathematical procedures, but with limited or no understanding of the underpinning concepts (Hiebert & Lefevre, 1986). Consequently, doing mathematics may be perceived as an activity with emphasis on the manipulation of formula. Accordingly, learning mathematics may take on a meaning of memorising facts and

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procedures. In line with that, some researchers claim that students' difficulties have to do with the ways in which they view mathematics (Oaks, 1990). A conception of mathematics as rote learning may easily contribute to poor conceptual and procedural learning, both of which are essential in mathematics (Hiebert & Carpenter, 1992).

There is a comprehensive body of literature on students' *approaches to learning*. This research tradition was initiated by Marton & Säljö (1976) in Sweden, but has later been followed up by a large number of researchers in the UK, Australia and elsewhere. Marton and Säljö found an interesting difference in learning outcome for students who focussed on the 'sign' as opposed to those concentrating on what was 'signified' by the sign. Understanding what is signified requires that students are able to recognise pieces of mathematics in different contexts and being able to reconstruct forgotten knowledge.

In this study, the exam questions in the introductory calculus course were designed to check students' understanding of basic knowledge and skills, and the awarded grades therefore represented a potential measure of in-depth learning. The study aimed at detecting how students approached their learning tasks, and how their study behaviours were related to awarded grades. We start by a short review of the mathematics education literature, and then move on to the methodology of the empirical part of the paper. After that we focus on the findings before we go to the discussion section, and, finally try to draw some conclusions.

THEORETICAL BACKGROUND

A review of the mathematics education literature reveals a variety of challenges that students encounter during their mathematics education. The concept of 'learning' apparently takes on different meanings for different students. Some researchers have suggested that emotions, attitudes and beliefs play an important role for students in their mathematics studies (Schoenfeld, 1992; McLeod, 1992). It is documented that some students even believe there is not any meaning in mathematics. Doing mathematics means manipulating with apparently meaningless symbols, and some students firmly believe that the key factor to success is memorising (Oaks, 1990).

Schoenfeld (1994) argues that problem solving might be a favourable way of teaching mathematics. This approach is based on the assumption that students develop their values and beliefs by social interaction. Schoenfeld (p. 61) argues that the problem solving approach is grounded on a particular *epistemological* view where the means are *social*. The problem solving approach serve as an arena where students work on selected aspects of mathematical practice, and where they come to learn the mathematical enterprise.

Vinner (1997) makes the point that providing problem solving situations is not always entirely straightforward. What is considered to be a learning situation for a teacher does not necessarily appear to be so for a student. Some students simply do not want to know something about a certain kind of reality. Rather, these students want to please the system by trying to acquire as good grade as possible, but with minimal learning. Vinner denotes these situations *pseudo-learning* or *pseudo-problem-solving situations*.

Students who primarily believe that learning mathematics is about memorising, are likely to pay attention to procedural knowledge in favour of conceptual understanding (Porter & Masingila, 2000). Mathematics teachers easily become aware of this when they are reading students' exam papers. Some students are apparently good when procedures are required, whereas they have less to contribute if they are asked to provide multiple representations, like drawing a graph or explaining the answer by their own words.

To meet this challenge, some researchers have suggested that doing more of writing in mathematics education would help remedy the difficulties (Brandau, 1990; Rose, 1990; Doherty, 1996). The underlying argument is that writing can be an effective way of learning. There is also research evidence to support this claim (Guckin, 1992). However, later research has suggested that it is not the activity of writing in itself that is important. Rather, these activities prompt students to understand what they are writing so that they are able to communicate their knowledge to others (Porter & Masingila, 2000).

Along the same line of thought some research indicates that the quality of learning largely depends on the nature of classroom discussions (Mcnair, 2000). These should provide opportunities for students to share and develop their knowledge so that they can further elaborate on emerging ideas and thoughts individually. The point is that classroom discussions need to be framed so as to promote desired learning. The discussions should be intentional in their nature. They should reflect a real effort to learn something that has proven to be hard to grasp for students.

Furthermore, Sfard (2001) argues that focussing on communication in mathematics education is likely to impact both the ways in which mathematics is taught, how it is learned and what is learned. A major point in her research appears to be that discourse is not reduced to mere language, but encompasses both perceiving and doing as well as speaking and writing. The language and the world spoken about are seen as mutually constitutive

(Sfard, 2000; Dörfler, 2000). This view draws on Wittgenstein's claim that the meaning of a term is synonymous with how it is being used. This mathematical learning can be viewed as a process of enculturation into mathematical discourse.

The challenge is to support students into particular mathematical activities that take place in a social context. This is commonly known as a *situated* approach to learning as opposed to the traditional *transmission* model of teaching. In the situated approach the major role of the teacher is that of a facilitator, where (s)he helps students develop emergent patterns of understanding. Gravemejer, Cobb, Bowers & Whitenack (2000) argue that one of the problems with the transmission model is that of negotiating meaning. Taken-as-shared interpretations might differ significantly, and the challenge often remains to bridge the gap between mathematical activities and their representation.

Furthermore, it is well known that students prioritise individually what to study and how to study within the given framework of a course, and empirical studies have confirmed that students vary significantly in their approaches to learning (Marton, 1981). Research in Sweden in the late 1970s brought evidence to distinguish between students who adopted a deep approach and those who favoured a surface approach. The original research was in relation to reading tasks in an experimental situation.

An approach is not the same as a skill. Rather, it is about the learner's intention. In the deep approach the learner is intent on making sense of what is written. The text itself is not an end. Rather it is a tool for the reader to make sense of phenomena in the world. When students adopt this approach they become actively involved in the learning material and strive to develop higher levels of competence, not just regurgitating factual content. They also devote themselves to personal exploration to discover meaning in texts and projects: 'I am really trying to learn something in this course. My objective is a deeper understanding. I'm not just learning for the exam.' (Gynnild, 2001).

In the surface approach the learner is simply trying to recall texts, charts or formulae with the intention of regurgitating content, e.g., at an exam. In an educational setting efforts are put in place to meet requirements minimally and they tend to reproduce essentials of the curriculum for assessment purposes. They also tend to be passive in the learning situation being very reluctant in getting involved in deeper learning. They rely on memorising and do not seem to be interested in gaining the essential meaning of a text or an exercise.

A third position, the strategic approach, has emerged from qualitative research in real-life teaching and learning (Entwistle, Hanley & Hounsell, 1979). A strategic approach denotes the intention to get good grades with as little effort as possible. Passing exams is the main objective so as to get the qualifications required for further study or for future working life. On the basis of empirical data our assumption is that students learn different things because they have different focus and intentions while studying. Another assumption would be that students learn different things because they have got different abilities to grasp a particular text fully. Graham Gibbs admits that different approaches sometimes involve differences in ability. However, he also argues that most often different approaches express differences in intention. Students are simply trying to achieve different things (Gibbs, 1992).

'Approaches to learning describe the relation between the learner and the object of learning within a particular context' (Bowden & Marton, 1998). A student may be described as having taken a surface approach to learning, but is not necessarily a surface learner because of that. Students may change their approach to learning according to the learning environment (Ramsden, 1984). The way in which students approach their studies is not something fixed or definite. Rather, it is largely a product of more or less conscious decisions at various levels of the university. The only way in which students will approach their studies differently is by changing the learning environment, and we already know a lot about how frame factors impact student learning (Gibbs, 1992).

There is now abundant evidence to claim that students taking a surface approach are less likely to get a good grade when understanding of a topic is required. Biggs (1990) summarised the literature in this field in the following way: '... studies ... show that a surface approach, almost without exception, leads to a quantitative outcome of unstructured detail, and a deep approach to an appropriately structured outcome.'

The current study extends the boundaries of the university in the sense that it also compares average grades in mathematics and physics from secondary education with grades in the calculus course. In particular, the following questions are addressed:

- How do students' approaches to study relate to their individual grade awarded at the exam?
- Are there patterns of study behaviour that characterise high versus low performers in the course?

In the following paragraphs the methodology of the investigation is presented, on the basis of which findings subsequently will be discussed and some conclusions drawn.

SETTING AND METHODOLOGY

The calculus course (SIF5003) was mandatory for all first-year students of the engineering education at The Norwegian University of Science and Technology. The overall aim of the course was to enhance students' knowledge and skills with a particular view to applications in engineering. The main teaching methods were lectures and tutorials. Lectures were arranged according to faculty belonging and tutorials were taking place in groups of 24 students with at least one learning assistant attending.

The lecturers were all well experienced in teaching, however, due to broader recruitment a number of students were entering university with lacking skills and knowledge in mathematics. Considerable efforts were therefore put into providing extra tutorials and learning resources to cover knowledge that previously would have been assumed. Grading was based on a dual assessment design. The end-term exam counted for 80 per cent towards the final grade whereas a mid-term test counted for 20 per cent.

High failure rates in the course triggered curiosity of the causes for this amongst stakeholders at the department, with the ultimate purpose of making interventions to remedy the situation. Furthermore, some issues of investigation were intentionally chosen during the design process with a view to subsequent research. Among the issues of interest for the enquiry were study strategies and study behaviours, aspects of the tutorials, questions related to why students failed and how this could be avoided in the future.

The action learning model provided a useful framework as for how the project could be conducted. Action research consists of a wide variety of research methodologies, however, the crucial point is to pursue action and research outcomes at the same time (Dick, 2000). Whereas learning often is assumed to take place on the basis of knowledge transfer, action learning requires learners to develop their insights more by learning and doing than by search for 'expert' recommendations. Normally, research participants using this methodology begin with little, or insufficient knowledge of the situation, on the basis of which they work collaboratively to observe, understand and finally change the situation. A commonly known model is that of Kemmis with the following steps: Plan – Act – Observe – Reflect ... (Dick, 2000). Action research is less suitable when there is a straight forward solution to be found more easily (Zuber-Skerrit, 2002). In this case there was no blue-print solution. No one really knew how to improve student learning in order to reduce failure rates. Rather, a broader knowledge base was required on which decisions could be made.

Although the research from the outset was based on well known concepts, such as 'deep' and 'surface' approaches to learning, it was of interest to identify further patterns of behaviour related to awarded grades. Therefore, the survey questions were a bit experimental in nature as there was no clear path to pursue from the outset. This way of doing research is inspired by grounded theory as presented by Barney Glaser (2001). According to grounded theory the core process in research is that of conceptualisation, i.e. generating concepts on the basis of emerging patterns rooted in data. The survey itself was undertaken in February 2003 and consisted of 43 items. These were grouped under one of the following headings: (1) Introduction, (2) Approaches to Learning, (3) Study Habits, (4) The Exercises, (5) Suggestions for Improvements, and (6) Section of Items for Students Who Did not Pass the Exam.

The total number of students enrolled for the exam in December 2002 was 1746, however, only 1368 actually sat the exam. The data gathering was conducted by means of an online survey to students who were attending the exam. The student sample was guaranteed full anonymity when submitting the form. The time span from the exam was undertaken to the survey represents a possible source of bias. On the other hand, this time might have helped students to reflect on their experiences more comprehensively.

The response rate was 41.7 per cent of the total number of students attending the exam. The majority of the survey items were quantitative in the sense that students were invited to respond to statements or questions on a scale ranging from 1 to 9. However, students were also encouraged to describe issues in further detail qualitatively.

No specific measures were taken to provide a representative sample of the group of students attending the exam. However, when comparing the distribution of grades of the survey group with those of the exam sample, there is reason to argue that our sample is reasonably representative. In Figure 1, 1 = F means failure, whilst 6 = A is the best grade.

Approximately 16.5 per cent of the students in the survey sample were enrolled prior to 2002; that is, they had already failed the course at least once. These students normally attended classes on higher levels and had less opportunity to follow the course in SIF5003. About 24 per cent had participated in a voluntary introductory course prior to the commencement of the semester (in August 2002). Finally, 80 per cent of the sample participated in a voluntary mid-term test that counted for 20 per cent towards the final grade. Only 20 per cent had a part time job outside university.

One specific aspect of the enquiry is emphasized in this paper: we examine how certain approaches to learning and study behaviour are related

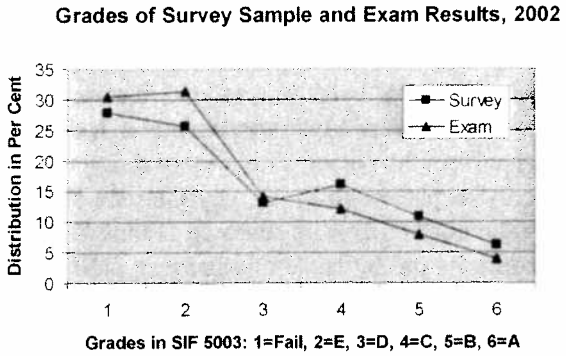

Figure 1. Distribution of grades in survey sample and exam results.

to the awarded grades. The particular phrasing of items for our purpose is shown in Table I.

In the analysis that follows, graphs are drawn with the mean score of each particular item on the Y-axis and the awarded grade for a group of students on the X-axis. In this study, some of the questions were posed in different phrasings so as to get as clear a picture as possible of the students view of a certain issue. To facilitate the reading of graphs, items with similar patterns are grouped together. It should be noted that the grouping of data was carried out after the data gathering was finished.

The Findings

As expected, the better grade in mathematics from secondary education, 3MX/3MN, the better is the grade in SIF 5003 (Figure 2, Series 1). Exactly the same applies for the physics course from secondary education, 3FY. The better grade in physics on entry to university, the better grade at the exam in SIF 5003 (Series 2). 'Series 1' and 'Series 2' refer to two different survey questions in the same class of students (see Table I).

The reader should be reminded again that the graphs in Figure 2 are based on mean scores. Table II displays the picture at an individual level.

The overall relationship presented in Figure 2 is recognised in Table II. Most high performers from secondary education do well in calculus. However, there are some surprising exceptions. Among the interesting features to pursue in further depth is the fact that 37 students with the grade '5' or '6' from secondary education failed at the exam.

Figure 3 displays scores on two different questions (see Table I). The responses to both questions seem to follow similar patterns. The better grade in the calculus course, the fairer students find the assessment. And similarly, the better grade in the calculus course, the more students think

TABLE I

Phrasing of items

Figure	Series	Phrasing of items
1	Survey	What grade did you get at the exam in SIF5003?
	Exam	(Displaying the distribution of grades for all students attending the exam.)
2	1	What is your average grade in maths from secondary education, based on class work?
	2	What is your average grade in physics from secondary education, based on class work?
3	1	To what extent do you agree that the awarded grade in SIF5003 was fair when considering your own performance at the exam?
	2	To what extent do you agree that the awarded grade in SIF5003 mirror the skills and knowledge you think you possess yourself in the subject matter?
4	1	To what extent do you agree with the following statement: I was only interested in getting a pass, and did not care whether I got a good or a bad grade in SIF5003.
	2	To what extent do you agree with the following statement: my ambition when doing the exercises was just to get an approval, without focussing on in-depth learning.
5	1	To what extent do you agree with the following statement: I was relatively passive and scared of not being successful in SIF5003. I was committed to being able to regurgitate content at the exam, and I was trying to memorise methods and techniques.
	2	To what extent do you agree with the following statement: I was facing severe problems when trying to understand *why* various methods in calculus work appropriately.
6	1	To what extent do you agree with the following statement: when I was doing SIF5003, I was intent on understanding concepts and underlying principles in the subject matter.
	2	I managed to keep up with the progression in the course.
7		How do you assess your own effort in SIF5003 (the exam preparations included)?
8	1	Did you attend the induction course upfront to the teaching of SIF5003?
	2	Did you attend the mid-term test in SIF5003?
	3	To what extent, in terms of percent, did you attend the lectures in SIF5003?

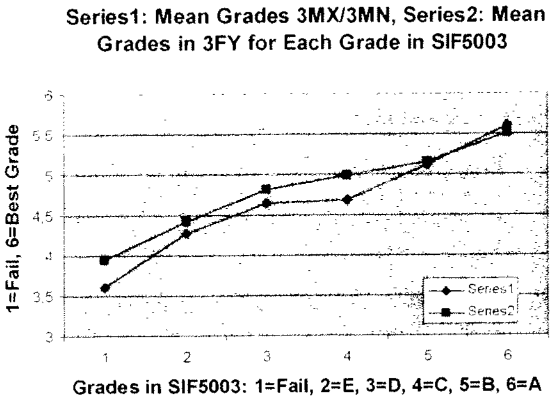

Figure 2. Graph showing the mean grades in mathematics and physics on entry for each grade in SIF5003.

TABLE II

$R \times C$ table showing grades in maths from secondary education and SIF5003

	Grades in maths, secondary education (6 = best)						
SIF5003	6	5	4	3	2	Other	Total
A	24	8	3	0	0	0	35
B	29	24	3	2	0	3	61
C	15	52	12	7	1	3	90
D	9	42	13	9	0	1	74
E	10	63	46	16	4	5	144
F	4	33	51	44	18	6	156
Total	91	222	128	78	23	18	560

the grade provides a proper picture of their competence. The results are hardly astonishing from a psychological point of view, but underscore the importance of the relative standards applied by students in these particular questions.

Figure 4 deals mainly with students' intentions while studying (see Table I). Responses to both statements display similar patterns. Students who got the worst results at the exam were the ones who cared least about the grade as long as they passed. And, the less intention of any in-depth understanding of exercises the poorer average grade the students got. This is not surprising, but it is illuminating to see the relationship in a chart.

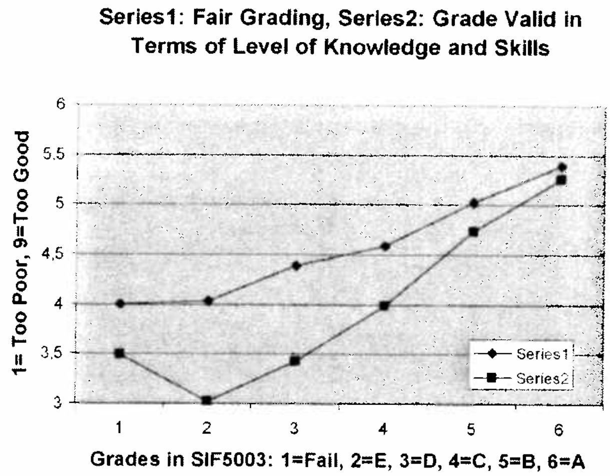

Figure 3. Students' views on whether grading was fair and valid.

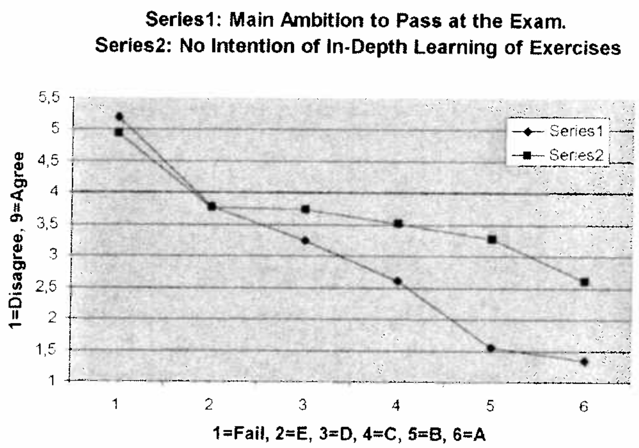

Figure 4. Students' intentions in the calculus course related to grade in SIF5003.

To further broaden the picture of this group of students, the chart in Figure 5 is helpful. The more passive and intent on just memorising factual content and techniques the poorer results they got (Series 1). Similarly, the greater the problems in making sense of the way particular methods in calculus work, the poorer results at the exam. This sounds reasonable as the course required understanding of concepts and principles. Just memorising methods and looking for standard solutions of exam questions would not be sufficient to pass, and definitely not enough for acquiring a reasonable grade.

The more students assumed they focussed on understanding of concepts and underlying principles (Figure 6) in the calculus course, the better grade

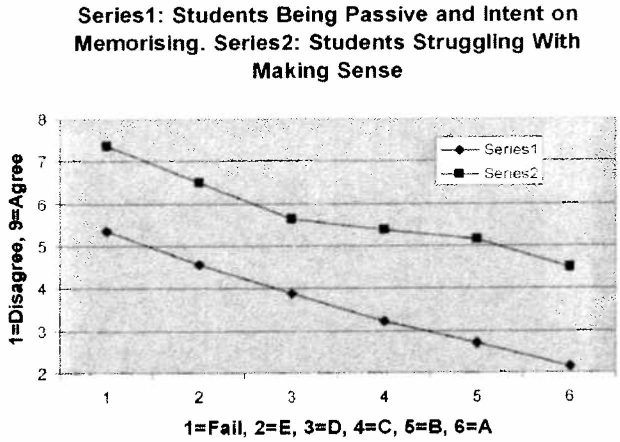

Figure 5. Students intent on memorising and struggling with making sense.

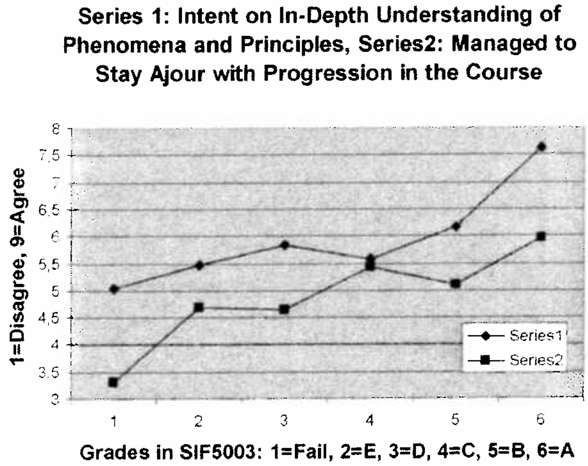

Figure 6. Students practicing in-depth learning strategies related to grade.

they got. And, the more they managed to keep up with the progression of the course, the better grade. This has obviously also to do with students' own effort in the course.

As the chart in Figure 7 shows, there is a striking relationship between the way students assess their own effort and the grades they achieve. Unsuccessful students put less effort into the course than those who pass. Students who achieve an "A" assume their effort to be better than for students achieving a poorer grade.

It was well known within the Department of Mathematical Sciences that some students simply lack basic knowledge and skills in mathematics when they enter the university. Consequently, they are likely to have prob-

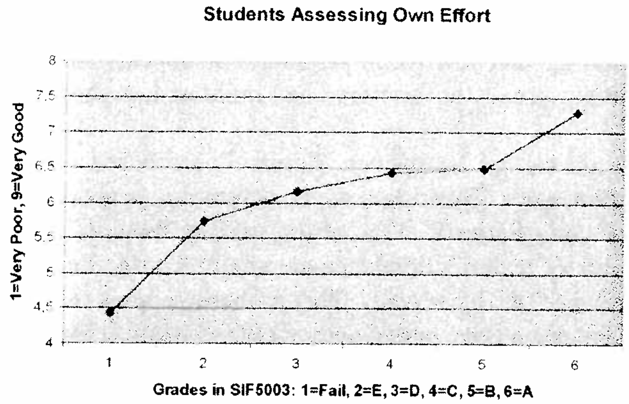

Figure 7. Students assessing own effort in the calculus course.

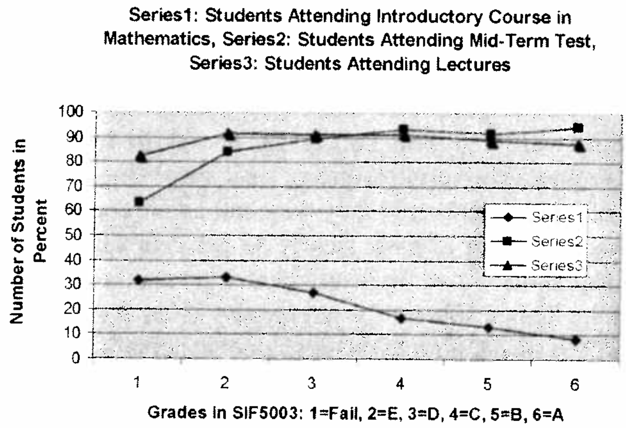

Figure 8. Students attending preparatory course, mid-term test and lectures related to grade.

lems to keep up with the progression in the course. Accordingly, a preparatory course in mathematics was provided upfront to the ordinary teaching term for those who felt the need for that. Also, in the autumn term of 2003 a mid-term test was introduced to make students work more steadily throughout the semester. This was also meant to serve as a diagnostic tool both for students and teachers.

We now want to focus on the extent to which students attended the introductory course, the mid-term test and lectures in general compared to the awarded grades at the exam. As can be seen in Figure 8, approximately 30 per cent of the students either failing or getting an "E" attended the introductory course whereas less than 10 per cent of those who got an "A" did so (Series 1). Series 2 displays a different reality. Those who got the best grades were most frequently attending the mid-term test (94.2 per cent), whereas students who failed were far less frequently attending that test (63.2 per cent). It appears that some of the weaker students already at this stage had more or less dropped out of the course.

The data on lecture attendance (Series 3) are based on estimates by students in retrospect. These data are therefore not as accurate as the data for 'Series 1' and 'Series 2'. One of the striking features is that the variations in terms of lecture attendance are small. Those who failed had the lowest attendance (82.1 per cent). This probably comes from the fact that this group contains a large percentage of older students that have failed the course earlier, and who are now busy with other courses. If we consider the group of students who passed, the differences in attendance at lectures are small, ranging from 91.7 per cent for those who got "E" to 87.7 per cent for students who got "A." The overall impression is that student attendance at lectures is high regardless of grade at the exam.

In the survey, some extra questions were posed to the group of students who failed. It was of particular interest to find out to what extent these students were aware that their knowledge and skills in maths would be insufficient to pass. The result of this is a bit surprising as approximately 37 per cent of 139 students said they were not aware that their knowledge and skills were too poor to pass. Nearly 33 per cent said they knew their knowledge and skills would be insufficient whereas the rest (31 per cent) were uncertain. This result can be interpreted as an argument for making the mid-term test mandatory so that all students get an opportunity to map their strengths and weaknesses in due time.

Furthermore, students who did not manage to pass the exam were requested to rank a number of causes for that according to their perceived relative importance. To handle the data quantitatively, the survey provided eight closed alternatives and one open. From this it appears that the main reason why students fail at this exam are that they are working in an inappropriate way. The second most important reason is inadequate effort, and the third reason is that their maths skills were considered insufficient on entry (Table II).

Table III is important in the sense that it points to potential ways of coping with the high failure rates. The most striking feature is that the considered top three causes all relate to students' own ways of dealing with the challenges they are faced with. Consequently, in the end it is largely up to the students themselves to remedy the situation.

TABLE III

Main causes why students failed at the exam ($N = 130$)

1	I approached the tasks inappropriately.
2	My own effort was just inadequate to cope.
3	My maths skills were inadequate on entry.
4	The exam questions were unexpected.
5	I simply had a bad day.
6	The lecturer provided too few examples.
7	The lecturer did not explain properly.
8	Unsatisfactory support from student tutors.

Discussion

As this paper is based on a case study in one particular calculus course, the authors make no claim to generalise findings beyond this sample. On the other hand, even though the response rate for the survey is moderate, there is still a solid data base that prompts questions about the quality of learning in calculus and across disciplines. In particular, what is the nature of mathematical *understanding*, and how can it be promoted in a situation when student numbers are growing, and when the student population is far more diverse than it used to be, both in terms of motivation and basic skills and knowledge.

This paper brings evidence that there is indeed a relationship between how well students perform in maths and physics in secondary education and how they perform in the basic calculus course at NTNU (Figure 2). Even though the learning contexts are different in secondary school compared to university, performance patterns are easily recognisable. In this case study, poor performers in maths and physics in secondary school are also poor performers in the calculus course, and vice versa, yet, we know that the learning environment is different. In secondary education, students are provided with more of individual support, and the pacing is slower than is normally the case at the university.

A key element for understanding learning processes seems to be students' approaches to learning. Figure 4 provides an example how similar phrasings to basically the same task generate nearly identical response patterns. The questions were not put together in the survey, so students were not able to copy their responses to the two questions. When students start focussing on passing the exam as an objective per se, they tend to lose focus on the real learning tasks. Similarly with the exercises: when the overall ambition is to get obligatory work done, the intended learning outcomes appear to be less important.

This study confirms that students' intentions do play a role for learning processes and learning outcomes (Figures 5 and 6) as has been shown through extensive interview studies (Marton & Säljö, 1976; 1984). When students can not keep up with the progression of the course, the major learning strategy appears to be memorising facts and procedures without deeper understanding (Oaks, 1990). This approach may not be desired in the first place, but emerges as a result of the lack of understanding. This fact triggers survival strategies simply to get a pass at the exam.

Even though the learning design of the course was created on the basis of the best of intentions, some students apparently failed to benefit from this. Vinner (1997) describes this as *pseudo-learning* or *pseudo-problem-solving* situations. Getting stuck in this situation, students often resort to providing the right answers to please their teacher or learning assistant. To get the exercises approved, there was no formal requirement in terms of real learning outcome. Only a learning assistant or teacher who expects learning will be frustrated in a situation like this. And the student might not even be aware that there was something wrong with the behaviour as (s)he had complied with expectations.

Furthermore, students come to university with the twin motivations of increasing their career opportunities and studying subjects which interest them. If the first one of these comes to dominate, it can lead to the adoption of instrumental behaviours as well. This creates a problem for the university as a place of learning because learning is often sacrificed by the instrumental student for the aim of 'getting through' a course and/or a degree. Students who are instrumentally motivated are likely to adopt a surface approach to learning, which does not lead to high quality learning (Biggs, 1999).

Instrumentalism, or technocratic rationality, is a form of rationality where education is seen as a means towards some end, rather than being valuable in its own right (Coxon, Jenkins, Marshall & Massey, 1994). Snyder (1971) found that engineering students at Massachusetts Institute of Technology in the 1960's had an instrumental approach to studying, and pointed out that:

> The instrumental student has a pragmatic approach to education ... Such students ask themselves how (or whether) the study of a text or the writing of a paper can help them to achieve a higher grade and thus further their specific career or life plans (p. 16).

The main goal for poor performing students seems to be to get through the course, but not necessarily to get a good grade. When examining qualitative data from the survey, it appears that poor performers in particular experience a challenge in going from the lectures to applying theory in practice. They try to remember facts and procedures rather than committing themselves to in-depth learning. Poor performing students are struggling with making sense of what they are doing. The worse grade at the exam, the more students turn passive, trying to memorise facts and procedures (Figure 5). And vice versa: The more intent on in-depth understanding, the more able were students to keep up with the pacing of the course. These were also the students with the best grades (Figure 6).

Comparing this with data from Figure 8 raises some intriguing questions. Figure 8 brings evidence that students with an "A" did not on the average spend more time on lectures then the rest of the students. Still, students with good grades consider their efforts to be 'better' than students with poorer grades (Figure 7). From Figure 8 we also see that the better students performed at the calculus exam, the less frequently they attended the pre-semester introductory mathematics course. This indicates that students on entry to the university were well aware that they needed to improve their skills in mathematics.

Furthermore, the crucial factor for in-depth learning is not lecture attendance per se, rather, how students approach their tasks, particularly outside the lecture theatre. It seems that some students perform better than others simply because they are more devoted to the learning aspects of the course. Successful students were trying to acquire a deeper understanding of what they were doing, as these students with an "A" describe:

I liked the course. I enjoyed very much doing exercises as soon as I had been through theory ... The calculus course was really well organised ... Excellent lecturer and very good coaching in the exercises ... (Student comments).

No one would dispute the need for students to perform a number of mathematical procedures. However, mathematical understanding also requires an ability to apply procedures appropriately, how to reconstruct forgotten knowledge and how to apply procedures, formula and equations in an unknown context. Students focusing on memorising procedures or templates do themselves a disservice as this approach is likely to generate hurdles for a deeper mathematical understanding. In their later career, surface learners are also likely to experience severe shortcomings when applying mathematics to employment. This would be an interesting issue to pursue in future research.

In this study, students failed for three major reasons: Their study approach, inadequate effort and lacking skills and knowledge in maths on entry. All of these can be viewed as a personal responsibility for the individual student. However, being a student is also being part of a learning community, and the university bears a particular responsibility for framing student learning. It follows from this that lecturers and tutors need to carefully revise learning objectives for the target group, and strategically align institutional 'frames' with desired learning outcomes. Examples of such frames are the selection of content, estimated work load, methods of assessment and teaching and tutoring strategies. Frame factors limit the variation in the processes, but there is no direct causal relationship between frames and processes (Lundgren, 1972). In the end, the important thing is how frames are being conceived of and used by the students themselves.

Learning mathematics as a research field has been significantly influenced by studies on *practices* (Boaler, 2002), a central notion to situated theory (Wenger, 1998). This approach has contributed to moving the focus from students' cognitive processes to the norms of classrooms, and the learning practices that shape knowledge in different settings. *Mathematical practices* refer to patterns of actions in which students engage, however, the main focus is not learning mathematics, but rather *doing* of mathematics. Wenger (1998) assumes that students develop identities through their practices, and that learning can be viewed as a process of engaging with practices.

Wenger (1998) views students' engagement in practice both as '... the stage and the object, the road and the destination. What students learn is not a static subject matter, but the very process of being engaged in, and participating in developing, an ongoing practice' (p. 95). This statement prompts some intriguing questions on how communities of practice are established, how they are nurtured and how students might change their identity by engaging in different practices. If the quality of learning is to be improved, there is hardly any escape from these challenges.

Concluding Remarks

Patterns of achievement in maths and physics in secondary education keep reoccurring in the calculus course, even though the teaching and learning contexts are different. In the calculus course, students approach their tasks differently which in turn contributes to qualitatively different learning outcomes. The paper does not provide any definite answer as to why groups of students get involved in distinctly different learning processes. Students apparently have different intentions, but when they are *doing* mathematics, they are also in a process of being engaged in and developing a *practice*. A major challenge for academic staff is to contribute to communities of practice that are conducive to high quality learning. Putting high demands on students without providing appropriate support is likely to promote practices that are not conducive to in-depth learning. It is the way in which students commit themselves to learning tasks outside lectures that really matters.

Findings in this paper prompt further research in the field. One of the important challenges will be to sort out what is happening when students are *doing* mathematics, and how that relates to the concept of *learning* mathematics. Investigating what constitute students' mathematical identity, might be one path to pursue along with studies of the dynamics of learning groups. How should these groups be recruited, and how can tutors act to suit students' needs in appropriate ways? Even though there is no simple solution to reducing high failure rates in calculus, a further emphasis on conceptualising what is going on inside and outside the classroom is likely to enhance knowledge that might help to remedy the situation. A key element should be a *process of theorising* in order to analyse daily practices so as to better understand why students approach their tasks the way they do. This kind of research can be undertaken also in cases where attention from academic staff most often is directed towards cognitive aspects of learning calculus.

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