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# The impact of giving different goals (to teach and being tested) on engineering students' approaches to learning

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*This paper investigates engineering students' approaches to mathematical learning (deep and surface) when set different goals (to teach and being tested). The inquiry is a part of a bigger project and only part of the data is presented here. This paper reports the case of one engineering student's approaches to mathematical learning using four different semi-structured interviews in different occasions. The results of three interviews indicated that setting the goal of teaching the content motivated the student to focus more during learning activities and prompted him to engage with concepts in more depth. Moreover, the student mentioned that having teaching experiences during the mathematics courses can be beneficial for engineering students and it would be helpful if they have teaching activities in group work.*

*Keywords: Approaches to learning, learning goals, deep, surface, engineering students.*

## Introduction

This paper reports from an inquiry into the relation between engineering students' mathematics learning goals and their learning approaches. Researchers argue that to foster more conceptual, deeper forms of learning, it is necessary to understand students' approaches to learning (Duff & McKinstry, 2007). Approaches to learning are students' intentions to studying and learning, and to the process of the learning which they apply (Lindblom-Ylänne et al., 2019). Approaches to learning are different from conceptions of learning, as the former refers to how students learn, and the latter refers to how students represent learning. One characterisation of the different approaches is deep and surface approaches (Marton & Säljö, 1976). A deep approach to learning refers to students' intention to understand information by making connections between ideas and using evidence. Students who adopt a deep approach focus on generating their own understanding of the topics (Lindblom-Ylänne et al., 2019). On the other hand, surface approach to learning is referred to using unreflective strategies, such as memorising the learning material and an intent to learn the facts to only pass a course (e.g., Spada & Moneta, 2012). Moreover, researchers reported that students who adopt a surface approach to learning mostly are not able to see the relationships between different concepts (Lindblom-Ylänne et al., 2019).

Approaches to learning are changeable and could be influenced by different factors in the learning environment (Diseth, 2003). Stimulating a deep approach to learning is quite difficult (Marton & Säljö, 1997). Many researchers have been trying to enhance students' approaches to learning towards deep and meaningful learning using different methods such as student-centred learning methods (e.g., Kågesten & Engelbrecht, 2007; Wilson & Fowler, 2005).

Given the arguments for the importance of students' approaches to mathematical learning, this study investigates engineering students' learning approaches when they learn different mathematical concepts with different learning goals (to teach and being tested). The question which is addressed in

this paper is: *How does an undergraduate student's approaches to learning unfold, when different goals (preparing for a test vs to teach) are set for his learning activity?*

## **Theoretical framework**

Deep and surface approaches to learning were first identified by Marton and Säljö (1976) in the late 1970s. They investigated the ways students tackle reading tasks and identified two various levels of processing. Students with surface-level processing concentrated only on the text and try to memorize it as much as possible, whereas students with deep-level processing focused on grasping the meaning of the text (Marton & Säljö, 1976). The approach to learning consists of the strategy and the intention, in which strategy refers to what students do while intention refers to the reasons, they do it (Marton & Säljö, 1997). Both quantitative and qualitative methods have been used to shed light on different approaches students adopt during the learning activities. Mathematics education researchers have reported that there is a relationship between approaches to learning and the nature of mathematics tasks (Maciejewski & Merchant, 2016). Moreover, approaches to learning can predict students' performance in mathematics, for example, Zakariya et al. (2021) found that students with surface approaches to learning performed poorly in mathematics courses while there was no statistically significant evidence that shows students with deep approaches performed any better in the mathematics courses. A deep approach is connected to students' conception of mathematics (Dart et al., 2000) and is necessary for learning mathematics conceptually (Maciejewski & Merchant, 2016). Therefore, undergraduate mathematics learning environments should help students to adopt a deep approach to learning.

## **A brief summary of empirical studies**

Many methods have been developed to stimulate deep learning and understanding, such as active learning, inquiry-based approaches etc. Some studies reported that applying student-centred methods can stimulate deep approaches to learning (e.g., Wilson & Fowler, 2005). Researchers reported a link between students' conceptions of learning and students' learning approaches such that students adopt particular learning approaches based on their conceptions of learning (Biggs, 1989). Researchers have developed and adopted several frameworks for conceptions of learning (e.g., Säljö, 1979; Dart et al., 2000). Säljö (1979) identified five different conceptions of learning (a quantitative increase in knowledge, memorising, the acquisition for subsequent utilisation, of facts, methods, etc., the abstraction of meaning and an interpretative process aimed at understanding reality) by interviewing participants ranging from 15-73 years. Another conception (developing as a person) has subsequently been added by Marton et al. (1993). Dart et al. (2000) reported that students with particular conceptions to learning (the abstraction of meaning, an interpretative process aimed at understanding reality and developing as a person) tend to adopt the deep approach to learning while those with other conceptions (a quantitative increase in knowledge, memorising and the acquisition, for subsequent utilisation, methods, etc) are likely to adopt the surface approach.

In summary, while published research indicates that approaches to mathematical learning can play a valuable role in students' mathematical learning, there is a lack of research, especially at the university level, on students' approaches to learning. This study, therefore, aims to explore whether giving different goals (to teach and being tested) to students can foster them to apply different

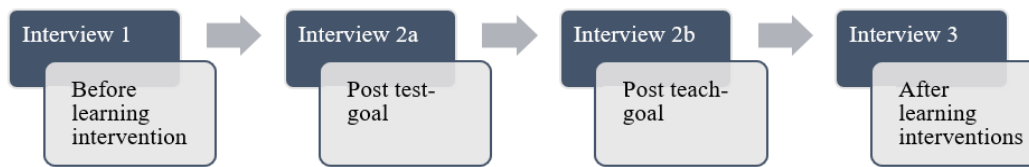
approaches when they engage in learning mathematics. The next section introduces the research methods used in the study.

## **Research methods**

The data of this paper comes from a larger project focusing on students learning higher mathematics with different learning goals. In this paper only the interview parts are presented. The present study takes a qualitative approach. To form an understanding of students' approaches to mathematical learning (deep approaches to learning and surface approaches to learning), engineering students took part in semi-structured interviews. Two different mathematical topics from the students' program Calculus 2 (partial derivatives and double integral<sup>1</sup>) were given to students and they were set the task to learn the topics for different purposes: they learned one topic, told they would be tested on it, and learn the other topic told they would be required to teach it to one of their classmates. The first author designed two separate contents (for double integral and partial derivatives) using calculus textbooks. The mathematical contents consist of the definition of the topics and two examples. The validity of the contents was checked by two senior lecturers in mathematics and two senior lecturers in mathematics education. The first interview aimed to explore students' approaches to mathematical learning in general and took place before learning interventions. Interview questions were based on students' approaches to one particular task, their approaches to studying and their conceptions of mathematical learning (e.g., *What do you mean by the word "learning mathematics"?* and *how do you go about learning mathematics?*). The interview questions were based on previous studies (e.g., Marton et al., 1997). After the first interview and each learning intervention, students participated in one semi-structured interview. In the interviews, students were asked to explain (or describe) how they went about learning the contents and whether different aims (learning a mathematics topic for teaching or being tested) prompt them to learn differently. Finally, in the last interview, students were asked about the experience they had when they taught the topic to their classmates (Figure 1). Each interview took maximum 45 minutes and were audio-recorded. Interview questions were piloted first with another student which helped the researcher to refine and change the questions. Using purposeful and convenience sampling, six engineering students from one University in Norway were selected for this study. Only one of the participants will be the focus of this paper and this student was selected randomly. He learned the double integral to be tested in it and learned the partial derivatives to teach it. Students' responses to the interview questions were analysed using thematic analysis (Braun & Clarke, 2006). In the first phase, words, lines, and segments of student's responses were read thoroughly and labelled (based on the definitions of approaches to learning and conceptions to mathematical learning). After initial coding, the most significant or frequent codes were considered, and different themes defined. After reviewing the themes, the main themes were identified (see Table 1).

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<sup>1</sup>These topics were chosen based on lecturers' recommendations. Moreover, the students had not learned these topics and they learned the topics during this project for the first time.



**Figure 1: Summary of the research method in this paper**

## Results

This section comprises the results of analysing the student's responses in four different interviews on different occasions.

In interview 1, the student was asked about his approach to one particular task, his approach to studying and his conception of mathematical learning. The aim of this interview was to gain a deeper understanding of what approach the student adopts to mathematical learning in general. Student's responses in each part of this interview were categorized and coded. Ten different themes were found in the student's responses (Table 1). In terms of the student's approaches to one particular task, the student chose one task from his mathematics course (calculus 1), and he discussed with the author the intention of choosing this task and how he went through this task:

Author: What did you do first for solving this task?

Student: Well. We have had many separate tasks where you have to solve small parts but then we get to solve the whole problem, so I started to solve the small parts of this task and then based on the results, I solved the main problem.

Regarding approaches to studying, several questions were asked to understand how student engages and studies mathematics:

Author: How do you read the material set for your mathematics course?

Student: I read what I sum up in the lectures. after the lecture like the five last minutes of the lecture, I will make a summary with the rules we've learned and then I will try to understand them. If I don't understand them from the lecture then I will go to the book and then read like the definitions and examples and then if I still don't understand them I will do the tests that are correlated with the examples and definition.

Finally, in the last stage of first interview, student was asked about his conception of learning mathematics:

Author: What do you mean by learning mathematics?

Student: If I learn mathematics, I would define it as being able to, well, not just learning it, but I would have to be able to actually understand it and be able to teach it to someone else. Then I actually learned it

Author: what do you mean by understand here?

Student: I understand. Well, if I just remembered the rules then I haven't learned it, I have to know how the rules work in the correlation.

Author: Can you give me an example? Like in a mathematical concept.

Student: For example, if I just remember like the rule for the derivation, for example that  $x$  squared derivative is  $2x$  like the rule, is that  $x^2$  end is equal  $2x$  up to  $n$  minus one. Then I haven't understood it because I'm just remembering why, but if I feel like, that derivative is the speed that the graph growth and that I can show that then I can actually prove why that rule exists.

In this interview, the student mentioned that learning for him is understanding, and he tries to figure out how the concepts are connected to each other. Moreover, the student pointed out that he

understands a topic when he is able to teach or explain it to someone else. In Dart et al.'s (2000) framework, there is a category named *learning as understanding* which students learn a concept to understand it and students with this qualitative conception usually apply deep approach to learning. Considering the student's responses to first interview and based on using previous frameworks in relation to approaches to learning (e.g., Säljö, 1979; Dart et al., 2000), this student is likely to apply a deep approach to learning when he learns mathematics.

In the second interview (2a), following a testing goal set to the student, he was asked about how he engaged in the topic. The student's responses were coded, and different themes were recognized (Table 1). As the student mentioned in the interview, he tried to understand the text and make a connection between his previous knowledge (definite integral) and the given topic (double integral). He also tried to make a connection between the examples and theory in this topic:

Author: How did you go about learning this topic?

Student: So first I just read through the entire thing and then I tried to look at the pictures and examples to understand how things worked in combination with each other. After that I looked at the examples to understand how you would use it then I tried doing the examples in my head without looking at and checking if it went correctly with what was in the example on the page.

Author: What do you mean by understand here?

Student: I mean how to use them. So I tried to figure out how I would use the information I learn from the text.

...

Student: what I knew from earlier here. Well, we had three-dimensional graphs at high school like this one so new 3-dimensional space and a new  $dx$  and  $dy$  that it would make regards to one or the other variable, so the only new thing is that it's an extra integral and these are.... I think these are two limits that are minus each other.

Moreover, the student mentioned how he tried to make sense of the concepts in the text. The student mentioned that he tries to understand the concepts and make connection between given information and his previous knowledge. Therefore, considering student's responses to this interview and based on using previous frameworks in relation to approaches to learning (e.g., Säljö, 1979; Dart et al., 2000) and definitions of approaches to learnings, this student is likely to apply a deep approach to learning when a testing goal is set for him.

In the third interview (2b), following a teaching goal set to the student, he was asked about how he engaged in this topic. Student's responses were coded, and different themes were recognized (Table 1). The themes which were found from students' responses in this interview were similar to themes from the previous interview. The student tried to understand the content and make a connection between different concepts in the topic and between the two given topics (partial derivative and double integral). The only observable difference was that the student spent more time learning this content and he mentioned that for this part he focused more during the learning process:

Author: How did you read this text? What did you do first?

Student: First, I just skim through it to get an overview, and then I think, I went to read it again in more depth and then I looked at the examples and tried to understand how the theory got connected with examples.

Author: Do you think that your way of learning for this topic differs from the previous topic like double integral?

Student: yeah, because I have to teach this topic and it changes the way you have to focus. Because you don't only have to learn yourself, you also have to learn a way to learn somebody else, teach somebody else so this actually makes me to focus more. I would think I focused more on the examples and how to explain them.

Similar to the previous interview, the student tried to make sense of the different concepts in the topic and make a connection between different concepts and also his previous knowledge. Therefore, considering the student's responses to the interview and based on using previous frameworks in relation to approaches to learning (e.g., Säljö, 1979; Dart et al., 2000) and definitions of approaches to learnings, I interpret that this student tended to adopt a deep approach to learning when a teaching goal is set for him. The only difference was that in this interview he mentioned that giving him a teaching goal motivates him to focus more during the learning activity and as he mentioned he tried to learn the topic in more depth.

**Table 1: Themes from three interviews with one student**

	Themes		
Interview 1	<ul style="list-style-type: none"> <li>• How to use the information</li> <li>• Learning as understanding</li> <li>• Make a connection between concepts</li> </ul>	<ul style="list-style-type: none"> <li>• Self-studying</li> <li>• Passive learning</li> <li>• Reasoning</li> <li>• Active learning</li> </ul>	<ul style="list-style-type: none"> <li>• Teaching or explaining the concepts to someone else</li> <li>• Mathematics as Visualization</li> <li>• Adopt different methods for learning</li> </ul>
Interview 2a [Testing goal]	<ul style="list-style-type: none"> <li>• Repeating the concepts and checking the information</li> <li>• Comparing the information</li> <li>• Put theory in practice</li> </ul>	<ul style="list-style-type: none"> <li>• Visualization</li> <li>• Do the examples</li> <li>• Understanding</li> <li>• Use the information</li> </ul>	<ul style="list-style-type: none"> <li>• Make a connection between concepts or different parts</li> <li>• Trying to figure out how mathematics works</li> </ul>
Interview 2b [Teaching goal]	<ul style="list-style-type: none"> <li>• Repeating the concepts and checking the information</li> <li>• Put theory in practice</li> <li>• Trying to figure out</li> </ul>	<ul style="list-style-type: none"> <li>• Focusing</li> <li>• Meaning making</li> <li>• Do the examples</li> <li>• Understanding</li> </ul>	<ul style="list-style-type: none"> <li>• Make a connection between concepts or different parts</li> <li>• How mathematics works</li> <li>• Use the information</li> </ul>

In the final interview (3), after the student taught the topic to his classmate, he was asked about his teaching experience he had. He mentioned that having teaching experience can be beneficial for engineering students and it would be more effective if lecturers include teaching activities in their courses:

Author: What do you think about teaching activities for engineering students?  
 Student: Well, teaching is more or less just effective communication when you're working in groups. I think engineering students will benefit from teaching each other, because when you teach something, not only others understand it better, but when you are teaching, you will understand the topic better as well. It would be beneficial for both sides the one who teach and the one who learn.

...  
 Student: I think if students teach in a group will be better because in the lecture you can ask questions, but in a group, it's not much stigma around asking questions, so you're more likely in a smaller group to get questions when you're teaching than when you're teaching for an entire auditorium.

## Discussion

The present study explored undergraduate students' approaches to mathematical learning when different goals (to teach and being tested) are given to them. The findings showed that giving students teaching goals might foster them to adopt a deep approach to learning. To answer the question which was mentioned earlier: How does an undergraduate student's approaches to learning unfold, when different goals (prepare for a test vs to teach) are set for his learning activity? Based on the result which was presented in this paper, when the student was asked to teach the topic, he focused more and tried to learn the topic in more depth compared to when he was asked to learn the topic only to be tested in. In both situations, based on student's responses in interviews and previous frameworks, he adopted a deep approach to learning but in the teaching part, he tried to learn the topic in a different way. There is a lack of research, especially at the university level, on whether giving different goals (to teach and being tested) might influence the adoption of different approaches but this result is consistent with the previous studies (Wilson & Fowler, 2005) which have reported that a student-centred learning environment can foster students to move towards a deep approach to learning. Moreover, the student mentioned that teaching activity for engineering students is beneficial especially if it would be included in group work activities. This result is consistent with previous studies (Kågesten & Engelbrecht, 2007) which have created a peer learning environment in which engineering students teach their classmates by making oral presentations in groups. They reported that students teaching each other can lead to deep learning for students and can motivate them to be actively engaged in the learning process.

To conclude, this study suggests that asking engineering students to teach can help them to learn better, therefore, it would be beneficial if mathematics lecturers can ask students to teach some topics of their mathematics courses to stimulate a deep approach to learning in students. Moreover, as the student suggested that teaching can be included in the group works and students can teach each other different topics in mathematics, therefore, it would be helpful for lecturers can include some group teaching activities in their courses.

There are some limitations of this study that need to be addressed. Considering only one participant was the focus of this paper, it would be beneficial if the number of participants could be increased. Moreover, the student in this study adopted a deep approach to learning (in general) and it would be helpful if a student with a surface approach to learning would be considered to see whether the same result happens. In addition, the student's declarations about his learning process may have been affected by the context of this study.

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