ADAPTING TEAM-BASED LEARNING IN A MATHEMATICS COURSE FOR COMPUTER ENGINEERING STUDENTS

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For computer engineering students, mathematics is fundamental. However, it is a subject with a high failure rate, and mathematics anxiety is common, also in STEM. To provide students with a working knowledge of mathematics valuable for a computer engineer, learning experiences should promote conceptual understanding of mathematical ideas and the ability to discuss mathematical problems and solutions. Collaborative learning may promote such learning outcomes. In this study, we investigate the use of a modified team based learning (TBL) approach in a second year mathematics course. The implementation aimed to promote collaborative learning through group work, but did not include formalized peer assessment and competition between groups. Six students were interviewed in depth about their experiences from the course. The study sheds light on the balance between providing flexibility to accommodate students' individual needs and preferences, and imposing the structure needed to achieve the intended collaboration. Issues of preparation, attendance and freeloading are discussed. As an implication for higher IT education, we propose the use of TBL in mathematics courses to encourage students' conceptual understanding through structured group work. We provide a set of lessons learned as advice for such implementation.

1 INTRODUCTION

For computer engineering students, mathematics is fundamental. However, some students approach it with apprehension, and the failure rate is high. Even in STEM (Science, Technology, Engineering and Mathematics) study programs, mathematics anxiety is found to be common, with no clear correlation between mathematical performance and mathematics anxiety (Dowker et al. 2016). To provide a working knowledge of mathematics valuable for a computer engineer, we tried out a novel approach in a mathematics course in the autumn of 2016.

With several approaches to collaborative and active learning to choose from, and a student group used to the format of traditional lectures followed by exercises, we chose a modification of Team Based Learning (TBL). The goal was to achieve learning experiences that would promote conceptual understanding of mathematical ideas and the ability to discuss mathematical problems and solutions. While the TBL approach has proven itself over several decades especially in the medical disciplines, it is less common in mathematics.

This paper reports on our exploratory approach to trying the modified TBL in a six-week discrete mathematics module in a mathematics course for computer engineering students. The lecturer wanted to try out flipped classroom along with the preparation tests and the group activities of TBL, with the objective to promote discussions and active learning in class. Our research objective was to answer the question: *How will the students respond to an adapted version of TBL in mathematics?* We approached this on the basis of students' responses to a short survey, interviews with 6 students and the lecturer's notes on the experience. The lecturer is one of the authors of this paper, but she did not participate in our data gathering.

Further guiding the research were a set of issues that the lecturer was uncertain about at the outset:
- How would the students collaborate in their new groups?
- Would the students see collaborating on mathematics problems as an unnecessary overhead, with the result that they just divided the work between them, working separately rather than together?
- Would a fairly structured teacher-led design like this be perceived as restrictive with respect to their usual work process, as the students are used to more autonomy?
- Would the tests lead to negative stress rather than the intended motivation to prepare?
- Would it be possible to design group activities that work well with the TBL setup, while also achieving the desired learning outcomes?

The paper is organized as follows. In Ch2 we provide some background on collaborative learning, challenges to organizing learning in groups along with the orthodox (evidence based) version of TBL and give an introduction to mathematics self-efficacy and mathematical anxiety with implications for group based teaching. In Ch3 and Ch4 the case and research method are described. The Results chapter outlines lecturer's experiences and key findings from the interviews with students. The discussion in Ch6 focuses on an overall evaluation of the outcome for students and staff, concluding with insights for further efforts with TBL-based approaches in mathematics or other subjects. Ch7 provides a brief conclusion.

2 BACKGROUND

In this study, we investigate the use of a modified Team Based Learning (TBL) approach in an undergraduate mathematics course. The implementation aimed to promote collaborative learning through group work.

Group work - challenges and rewards

Numerous studies have found that the use of small groups in STEM education at the undergraduate level can have positive effects, e.g. greater academic achievement and more positive attitudes to learning (Springer et al. 1999, Drury 2003 et al.). However, students' feelings about working in groups vary: while it can be fun and rewarding, it also involves overhead in organizing work tasks as opposed to performing them, perhaps disagreements on what, how and how much to do, as well as the common problem of fairness in effort and rewards (Kouznetsova 2009). While working and learning skills in groups readily makes sense to students in terms of projects in design and construction, this sense does not necessarily map on to other core subjects such as mathematics where individual understanding and performance is seen to be at stake. It is not unusual for a few students in a class to report, as cited here from a database course: " .. *would have enjoyed this class more if it included only individual (rather than teamwork) assignments*" (Kouznetsova 2009 p.31). Groupwork poses challenges of in terms of curriculum design, assessment and staff training, *".. as well as issues of the quality of student learning and their attitudes and perceptions towards group work"* (Drury 2003, p.77-8).

It is a challenge to get all students to see (Syh-Jong 2007) that knowledge can be seen as socially constructed (von Glasersfeld 1989). In the case of mathematics education, the social context includes the established knowledge of the field of mathematics at large, and the more local context e.g. of a student group building their own understanding through the presentation and discussion of individual explanations and solutions. Viewing learning as a process taking place in a zone of proximal development (Vygotsky 1978), group members may support each others' learning as more capable peers guide less capable ones. Talking and writing may stimulate the students to construct knowledge and be more active and open-minded toward learning (Syh-Jong 2007).

Team Based Learning

Group work in an educational context may be more or less structured, with some level of scaffolding (Wood et al 1976) provided by the teaching staff. Collaborative knowledge construction can also be scaffolded (e.g. Weinberger and Fischer 2006, Koshmann 2003). Team-based learning (TBL) offers a comprehensive systematic approach to group work which scaffolds the students learning by supporting a complete active learning process.. TBL involves curricular preparations through flipped classroom, individual and collective activities of reflections and decision making, collaboration on a problem/project with accountability to team members, motivated by an element of gaming through competition amongst the teams. Resources on TBL may be found online at www.teambasedlearning.org. Developed over a number of years, Michaelson and Sweet (2011) sum up with four basic principles as essential for a successful use of TBL. A course usually has 5-8 units. Each unit of a TBL based course must address:

1. **Strategically formed, permanent teams**, aimed at "*achieving collaborative learning as students sinking or swimming together, students working interactively, students having a goal to learn and a goal to help other students in their group, students learning how to cooperate effectively, and the teacher holding students accountable."* (ibid. p.43, based on Petty 2006).
2. **Readiness assurance** for the upcoming group activity, as a four-step process of **i) pre-reading** on their own, **ii)** doing a multiple-choice on the pre-read material as an individual Readiness Assurance Test ***(iRAT)*** as the first item on the agenda in class, **iii)** immediately after delivering the iRAT, the team (t) does the same test together in class (**tRAT**). They need to achieve consensus and choose the answer on a scratchcard which supplies immediate

feedback to their discussion and reflection (correct, partly correct, wrong), **iv)** For incorrect answers the team may write an **appeal** to the teacher, arguing the case for their own answer based on a) a clear argumentative statement, or b) evidence cited from the pre-reading material. Finally, the teacher gives a short clarifying lecture for the questions still not clear, given any remaining faulty answers of the i/tRAT and appeals.

3. After the clarifying lecture, **4-S Application activities** that promote both critical thinking and team development by using that which was learned in the Readiness Assurance Process. The students now put their learning to use in activities that work best when they: 1) address a **Significant problem** that demonstrates a concepts usefulness. 2) make a **specific choice** among clear alternatives (best example, most agree, most important ..). 3) all teams work on the **same problem. 4) Simultaneously report** their decisions in class so that everyone can see the answer. This is the competitive gaming element that contributes to motivate discussion and engagement.
4. **Peer evaluation** to provide students with formative and summative feedback of their performance in the current unit, which will also inform the following unit. Each team member gives anonymous feedback to their individual teammates, in a standardised form delivered via their teacher, on what they appreciate, and what they would request on: preparation, contribution, gatekeeping (help others contribute), and flexibility (listen to other arguments).

Table 1: Four basic principles for successful use of TBL. Michaelson and Sweet (2011)

Is teaching mathematics different?

Kraemer (2017) reports on using TBL in a course involving system development, comparing its effects to the traditional lectures with exercises. Kraemer finds that the students discuss and engage with the theoretical concepts and their application to a much greater extent than in previous classes. Kraemer made slight adaptations to TBL, of note is their peer evaluation: each student shared out 100 points to their team members, affecting the grade the students received. The TBL RATs were also included as part of their final grade, along with a final exam. A class of 120 students were divided into groups of eight, based on their personal choice of teammates. For immediate feedback, including collective anticipation, scratch-cards with 4 options were used. Kreamer notes that the content of application activities and RATs should be designed backwards, by starting out with the learning goals of the course. And, they learned along the way which tasks worked better than others for this setup. Two students interviewed by the Campus News mention that they appreciate the enormous effort put down by the professor in switching the course to TBL (Mikkelsen, Universitetsavisa, 2016).

Paterson et al. (2011) describe some of this experiential journey for teaching staff developing their understanding of constructing suitable tasks in a TBL based course in discrete mathematics. They focus on the 'unspoken curriculum' of mathematical thinking that they want the students to perform. *"The style of thinking labeled mathematical is pertinent whatever the content to which it is being applied. It is mathematical not because it is thinking about mathematics but because the operations on which it relies are mathematical operations."* (Burton 1984 p.36, cited by Peterson et al. 2011 p.879*).* They want open-ended questions where the students need to investigate (ibid p.887) and make sense of problems, 'play' with them, and overcome their obstacles by working with them. They claim that TBL at this point is not much used in the quantitative sciences.

We were inspired by Kraemer's (2017) and Kraemer and Lillebo (2016) reports on using TBL. For a first trial of TBL in discrete mathematics, we kept it simple. Designing application activities and the readiness assurance process would take time and need trying out in a flipped classroom setting. Given the teaching professor's experience that getting discussions going in class was difficult, the possible presence of mathematics anxiety was an issue. Several reports on the implementation of TBL, also in mathematics, state that task and question design, which the 4-S criteria aim to support, needs careful consideration and is something the teachers develop and refine over time based on evolving experiences (Paterson et al. 2011, Kreamer 2017, Vasan et al. 2009).

Self-efficacy and anxiety in mathematics

Cited by May (2009), mathematics self-efficacy (MSE) is defined as an individual's beliefs or perceptions with respect to his or her abilities in mathematics. The concept is based on the Self-efficacy as coined by Bandura (1977, 1997), and has four main sources: mastery experiences, vicarious experiences (of others), social persuasion and physiological states. Bandura suggested that students with high SE are more motivated to learn, and more likely to persist. May explored MSE further in connection with mathematics anxiety, by building on previous works on, amongst others: mathematics anxiety (Richardson & Suinn 1972; Cates and Rhymer 2003), how career and majors choices are affected by MSE (Betz and Hacket 1983), and especially in regards to anxiety towards mathematical tests (Rounds & Hendel 1980) and the time limits given to complete tests (Walen and Williams 2002). Students' perceptions of internal versus external locus of control in learning will affect how students behave in terms of their own learning and various learning approaches (Schunk 2004).

The relevance of anxiety to performance in mathematics as described in May (2009), and the acknowledged presence of some socially less adept students in the early years of their studies, gives us grounds to tread carefully when moving to change course and learning design in mathematics.

Students' positive view of TBL as a learning approach may be unrelated to grades. However, based on a survey among medical students in a TBL based anatomy course the analysis reveals that those that do better, appreciate TBL more than the others. On the teamwork itself, the students were positive regardless of grades (Vasan et al. 2009).

Based on experiences in medical education, Parmelee et al. (2010) provide useful, well explained specific tips for carrying out effective TBL. TBL shifts the instructional focus from knowledge transmission to knowledge application, and supports gaining and evaluating professional competencies that cannot be done through a lecture-based approach. Their tips pertain to the process of designing a TBL course, starting with the desired learning outcomes; transparency for the students on the whys and hows, what to do when, and how they are doing; Why the 4-S are important for assignment designs and the effects of leaving some of the 4-S out; as well as a team focus through peer evaluation, accountability and constructive feedback to fellow students.

3 CASE

This study was performed in TDAT2002 Matematikk 2, a second year mathematics course. It is the second of two consecutive mandatory mathematics courses, both full year courses with an exam at the end of each semester. Working both in structured teams and more informal groups is already an integral part of the study programme and included as a learning goal. In their first year, the students in our study have completed two software development projects as well as informal group work in other subjects. The course consists of three modules, namely discrete mathematics, vector calculus and numerical methods. The third semester Christmas exam includes the first two of these. We tried out our modified TBL in the discrete mathematics module only.

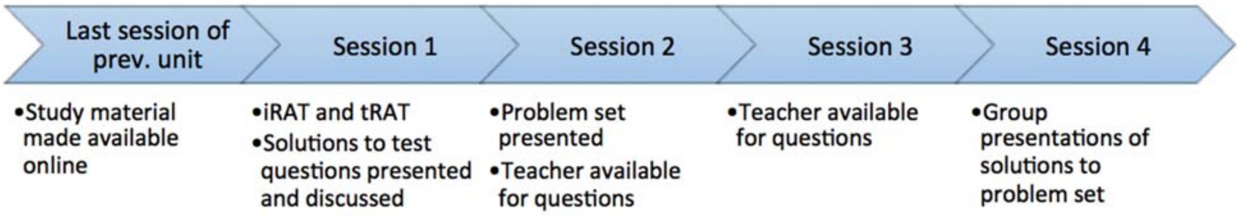
The delivery of the mathematics courses in this programme can be described as traditional. Typically, there is a lecture and an exercise session each week. The students are given problem sets to solve, and two thirds of them need to be satisfactory ("approved") for the student to be allowed to take the exam. In the exercise session, the lecturer and student assistants help with solving problems, and go through and approve the students' solutions to the problem sets from the previous week. Students are encouraged to collaborate on solving these sets, though some choose to work alone (or at least go through the approval process alone).

We adapted TBL as follows: There were three TBL units of two weeks each. Every week had two in-class sessions, giving a unit four in-class sessions. In what continues we will refer to these as the sessions of the unit. The first week of the semester was not part of a TBL unit, but was used to explain TBL, administer an "example iRAT" and give a repeat lecture on some essential topics from the previous year's curriculum.

The students were split into random groups of six, and adjustments were made to assure more heterogeneous groups with respect to gender and ability. In addition, some special requests from students were accommodated. An iRAT/tRAT (individual/team Readiness Assurance Test) and a group assignment activity was prepared for each unit. For the complete TBL-based three-unit module, each student needed approval for two thirds of the iRAT/tRAT sessions and group presentations.

The group assignment activities were adaptations of existing course assignments. Some problems were made more open, encouraging creativity, and more guidance was given on some of the more difficult problems. Some problems were unchanged. This means that the activity did not adhere fully to the principles of TBL. This was done because the lecturer found that the nature of the curriculum made it hard to formulate a group activity, lasting two weeks and being focused around a single concept, without it either becoming too complex for the average student to succeed with or it not covering the learning objectives of the course sufficiently. Another adaptation was that in two units the assignment activity included an individual digital test delivery that covered "in-between material", that is, material considered too advanced for the RATs, but that still should be completed individually (such as gaining basic proficiency in modular arithmetic). The groups were encouraged to collaborate on these too even though the delivery was individual.

Figure: Timeline of a TBL unit. The discrete mathematics module consisted of 3 two-week units.



Before the first session of a unit, learning materials such as videos, references to the syllabus book, multiple choice tests and lecture notes from the previous year were made available online. In the first session, the students completed the iRAT (on a paper handout) and then did the same test again in their group as a tRAT. To get a RAT session approved, the iRAT either by itself or the combination of the iRAT and tRAT had to be answered in a satisfactory way. This meant that a poorly prepared student could be "saved" by their team. The questions were designed to test if the students had read and understood the main points of the learning material, but did not require deep understanding. Next, the solutions were presented and discussed in class. We did not use scratch cards as suggested in TBL.

In the second session of the unit, the assignment activity was presented. The lecturer then remained in class, available for questions and help. In the third session, the lecturer would also be available to help, and it was the deadline for any individual delivery in the assignment activity. In the final session, group presentations took place. Three groups would meet the lecturer at a time. Giving feedback, discussing, and helping each other out by pointing out ways to improve solutions or figuring out why an answer was wrong was an important part of the session. Note that we did not frame the group presentations as a competition and did not appoint the best solution given, as is suggested for TBL. The reason for this was to keep anxiety at a minimum, and because it can be difficult for students to judge the solutions of other students to difficult mathematical problems, on the fly without preparations and/or guidelines.

4 RESEARCH METHOD

In endeavouring to evaluate a lecturer's attempt to improve students' mathematical thinking by trying out flipped classroom through elements of TBL in her course design, we made a case study of the implementation. Both qualitative and quantitative explorations of its starting point and effects were carried out. Alongside the TBL initiative in class, described in Ch. 3. Case, the students were asked to participate twice in a simple survey on self-efficacy in mathematics (MSE). Two months later, this was followed by semi-structured individual interviews with six students. Respondents were carefully selected to cover a range of how their MSE score altered during the progress of the course. Nine (9) students were invited for a follow up interview. Three declined, giving reasons of busy schedules with exams. A third survey was attempted later, after the exams, but attendance was low.

Three (3) researchers were involved in this project, one of which was teaching the TBL-based part of the course. This researcher did not get access to the data until the students had completed the school year. The researcher is no longer involved in teaching courses to these particular students. Students were assured that their teacher would not see the anonymized results before the year and grading was well over. The project has complied with the terms, and acceptance, of the NSD (Norwegian Centre for Research Data).

The interviews were fully transcribed by one author, then analysed and coded by another of the authors through a process of thematic analysis (Braun and Clarke 2006). Most of the coded data was translated from Norwegian to English. All the authors discussed the material with respect to salient themes, connections and the meaning of specific pieces of data in light of the research questions.

A 12-question survey with a 5-range Likert scale (1=never; 5 =usually) was implemented in our learning platform (LMS). All the questions had a positive angle to topics indicating a value of confidence or belief. The survey questions, all except one, and a modified one, were drawn from May's MSEAQ-questionnaire (1997, p.70-1). Questions given were: MSEAQ #: 1, 4, 7, 9, 10, 12, 13, 19-21, 29; and L: «I think mathematics can be fun». The class had 65 students, of which 58 completed at least one survey.

We also report on the lecturer's own evaluation and experience with using TBL in the discrete mathematics part of the course. As she has taught the same curriculum six times previously, she has grounds for comparison, albeit not of a systematic nature. We have no grounds to compare grades between them.

This research project does not attempt to generalize. Rather we report on the thoughts and perceived outcomes of a small but representative number of students taking mathematics in the second years of their Computer Engineer BA-studies. The discussions touch on Self-efficacy in mathematics; on the flipped classroom/TBL teaching approach, including the rearrangement of effort over time necessary for TBL to work, for both staff and students; on working and discussing in groups with fellow students; the overall debate climate in class, and on personal self-assurance as a general backdrop to performing as a student.

5 RESULTS

In this chapter, we present key findings from the interviews with the students. As a backdrop for the students' views on the TBL-part of the mathematics course, we start with the lecturer's perspective.

5.1 The lecturer's perspective

The lecturer's experiences are based on her reflections prior to, during and after the TBL part of the mathematics course, and on the interaction that she as lecturer had with the students throughout the course.

In the beginning, the lecturer experienced resistance among some of the students towards the TBL. There was some anxiety about the test, the term "test" seeming to evoke a few negative reactions. Some students assumed that the preparation material covered a substantial part of the course material and the test was made to assess their understanding rather than to prepare them for further work. This calmed down after the first unit, as the students got experience with how the TBL-arrangement worked.

There were only a few problems during the weeks of TBL, but on several occasions, some teams did not show up for classroom activities that did not include RATs or presentations. On three occasions, individual students did not pass one of the RAT sessions. When the lecturer talked to these students, they all explained that they had not prepared. The group presentations generally went well, but a few times problems were not properly solved by any of the present groups. Some presentations were not well prepared. The feedback given between groups was generally quite superficial, which can be expected as they did not have the possibility to prepare, and sometimes their understanding of the problems and solutions was lacking.

After the TBL part of the course the lecturer was contacted by a student who explained that TBL had been very stressful for some of them. Anxiety made it hard to perform in a group with others who they did not know well.

Overall, at the end of the weeks of TBL, the lecturer perceived the discussions during the group presentation sessions as successful, but she was at the time unsure about the success of the i-/tRAT and the collaborative learning. To improve on the design for a second time around, she would in particular consider structuring the group work more, for instance by requiring deliveries on the group work itself in addition to the mathematics. She would also try to make the assignment activities more true to the ideas of TBL, for instance by making fewer, but more complex problems with suggested "paths" through them.

In what follows, when we refer to "TBL", we will be talking about the way TBL was implemented in the Mathematics 2 course as described in the Case chapter. "A." is the lecturer of the course.

5.1 The students' views and experiences

In this section we present findings from the student interviews. We have given them pseudonym names.

The students' relationship with mathematics

The students interviewed in our study express enthusiasm about mathematics. This is maybe to be expected in an engineering study program for which a high school specialization in mathematics is required. Alex likes mathematics "at least when he succeeds with it". Ben likes putting two lines below the answer, and says he typically starts solving a task without reading it properly, because he gets so engaged when he encounters a problem and understands how it can be solved. Carl feels that he can manage mathematics fairly well if he does some reading. He likes algebra but is not fond of statistics. Dina is good in mathematics and explains that she learns very fast. She finds discrete mathematics and logical thinking easy, but considers it hard to learn formulas and learn by cramming. Frank likes seeing how mathematics can be applied; it makes him understand and motivates him. He believes mathematics involves a lot of "free thinking"; real life problems do not come with a mathematical formula. Regarding the type of interest in mathematics that makes you solve puzzles e.g. in the newspaper, the students differ - Alex, Ben and Carl does not have that interest, but the others do.

Ben reflects about his classmates' self-confidence in mathematics. He thinks many worry about mathematics and have little self-confidence about what they can achieve, thinking that they will not master much of the university mathematics (only need to survive it!) as they struggled a bit with mathematics in high school.

The students are generally happy about TBL and understand its key elements

Asked to explain how the TBL part of the course was organized, the students stress slightly different things. Alex explains that there were tests that the students had to prepare individually, and then the same tests were taken in groups afterwards, so that they got to discuss the problems. And then there were presentations, to the larger groups. Ben considers TBL to be about "learning through collaboration with others". "We were divided into groups. Every second Tuesday we met to have a test.", and every other Tuesday and Thursday they had a presentation. Carl says TBL is about "showing up for the lecture when A. presents what we will be working on. She goes through the presentation, solves some tasks on the blackboard. [..] It was test and lecture every other time. It was divided into teams, which was quite okay really. Because then you are maybe a bit more forced to work, really doing what you are supposed to.". "Preparation sheets were available on [LMS], if I remember correctly. [..][If] you read through it, you were sufficiently prepared to get those tests approved." Dina was pleased with the TBL, as she liked to have tasks first, which helped her understand what to look for, and then read about it afterwards. She explains: "First there was in theory a reading part all alone, which I was not very good at, but [..] it worked out anyway. Then it was the testing part. It was a very simple test of basic concepts. And then it was working in the team on real tasks. A bit more advanced tasks." Emma says TBL is about having less focus on a teacher lecturing and talking to the students, and more on their actually working with the material. Also, that you can watch video lectures at home and then go to school and get help with what you need help with, and be able to cooperate with others and work together. Finally, Frank liked the way exercises were organized in the TBL, and explains: "I think the individual and group tests that we had in the beginning was a very good way to become motivated, to read and start with the material before we had, in a way, the real exercise, which was the presentation."

About the reactions of the class to TBL, Alex says most were fine with it; nobody questioned it or complained. Asked whether all students took the tests, did the tasks, prepared, contributed, Alex says: "Yes.. when we discussed around afterwards it seemed it had worked well with everyone". "I think everyone had prepared."

Regarding what might be the idea of TBL from a teacher perspective, various aspects are mentioned. E.g., Carl thinks that TBL gives better monitoring/follow-up, as you do not have the approval of exercises only in groups (which is common in the study programme and sometimes leads to a single group member doing a lot of the work). TBL ".. is a way to find out a bit more about where the individual person stands and make sure they actually work. Get some more opinions into the picture."

Having tried TBL might change students' perspective on the more traditional form of lectures and exercises. Frank says that when they started with TBL, it was new and "not the usual rhythm", which made it more stressful, "because you were not used to the way it was done. So then I looked forward in a way to having just normal exercises again." But with traditional exercises in all of the courses, "I missed a bit having organized group work and deliberate discussion around it. That is not <the same as> just [..] group work" Asked what he thinks about the outcome of the TBL for the entire class, Frank says: "I think there are very many who need [..] a kick in the ass where you have to work, start working. That is why I think this <TBL> way of organizing exercises was very good. I think it was good for a lot more people than just me."

On working in teams

The informants are happy about working in teams. Ben says: "I never learn as much as when I sit and work in a group, whether it is in a lecture or not does not matter much". "if you do the tasks in a group, you kind of get used to ..always listening to others, right; [we are] thinking completely differently about most things". Carl appreciates that TBL offers a kind of safety-net for those who were not prepared. Sometimes people have reasons not to be prepared, he argues, but it makes sense that they can still participate in the group discussion about how the task was done, so that they can learn it anyway. Dina says TBL worked well in her team "because we all tried." With different opinions, they "figured it out, more or less, sometimes. Sometimes we thought incorrectly", but by and large they found the right answer. And they always agreed on something that could be communicated when the presented. "There was no one who was not heard in my group, I think." Emma's group tended to divide the work between the team members and assemble the result for the presentation. However, she says: "at the times when our group worked well together, with the first two exercises, or at least with the first one [..] we talked well together and in a way discussed things and collaborated on it. Then I learned things I did not understand and, yes, explained things to others, things they did not understand." Emma would have preferred mandatory attendance in the group work sessions to ensure collaboration in the team. Frank thinks TBL, through the work in the team, created more discussion than in traditional teaching

Learning strategies and preferences in context of TBL

The interviews demonstrate that the students are reflective about how the elements of TBL fit their learning strategies and preferences, including what they see as their strengths and weaknesses.

Alex sees the organizing with the tests as useful because it made him prepare well the day before the tests and made them go through the material after the tests. He thinks this made him spend a bit more time on the course than he would otherwise have done.

Asked about when learning takes place in TBL, Ben says: "It is [..] on your own in the sense that you need to prepare for the test. But if you had something different from the others then it was in a way the discussion after the test. I think I learned the most from that." Also, "you realize more easily that you have got it wrong if you get it explained then and there, in a way, when it is in your head." Ben thinks he "always managed to learn from the others in the <TBL> team", and that he learns a lot from teaching others; telling something to others is the best way to repeat the material. He also thinks he learns from both tests and presentations. Furthermore, Ben is fond of lectures, explaining that the syllabus of the TBL, discrete mathematics, to him was a bit difficult in the beginning, as it was different from the mathematics he was familiar with (derivation, integration etc.). Even with the available written lectures and videos, he feels it helps him "to hear it from someone knowledgeable. .. This is probably just the way I am used to learn." He thinks being in a lecture can help you learn, whether you have prepared or not. If you have read and understood the material "then I can ask questions about things that seem unclear to me." But also: "if [..] you arrive totally blank in a lecture, then you learn something new all the way." What Ben missed in TBL was some lectures.

Carl also explains that he likes: "People like me like to turn up at lectures and get things from there. " He says he usually does not read at home.

Dina says TBL worked well on her part, because she does not attend lectures that often. Having slides available is enough, "and then we can just do the tasks and then you have handed it in and then you do not necessarily have to be there to look into it even more.” For her, the testing part of TBL went well: “it was only the most basic things, so that if you had just slightly read the sheets, it went well. It was not difficult to understand.” But Dina adds: “I have heard from many who say that it does not work for them, that they would have liked to have more lectures.” Also she knows that others use the videos and other learning material to find out how to solve the tasks. She thinks others on her team used these resources actively: “At least they read on the night before!”

Emma appreciates watching video lectures, e.g. on a Sunday evening, and would have wanted to have more of them. She has had some health issues, and by use of the videos, she can get back on track after missing a lecture. She can watch difficult topics several times and skip the trivial parts. In lectures on campus, she tends to lose concentration if it becomes too simple: “I easily get bored and just zone completely out.”. Emma sees work in groups as motivating with regard to attendance, considering it easier to find motivation to show up on campus when you know you have an appointment with the team. About the group work, she points to the issue of work often being divided between the team members rather than being done collaboratively: “If each person solves just one task, you only get to solve part of the syllabus.”, leaving the rest of the syllabus aside and giving priority to work with other courses in a generally busy semester. Emma would have preferred mandatory attendance in the group work sessions, not only for the presentation. Having mandatory attendance only for the presentation goes against the intentions of TBL, in her opinion. She thinks the intended talking and discussing about mathematics needs to take place during collaborative work. Regarding the presentations, she did not get much out of them: “[I]t was mainly I who talked (laughs). And the others were standing there..”

Frank explains about the tests, tasks and presentations: “[Y]ou did not have to do a lot to prepare enough for that test. And then, the presentations I don’t know if I liked that much really. But I think the tasks were very good. And I think I learnt a lot from solving them.” Compared to traditional teaching and exercises, he is unsure what he prefers: “Maybe I would have wanted an assignment to be handed in. Maybe as a group, or not, but.. Then you don’t get the same discussion platform in the presentation, so I don’t know.” “For me, motivation is important, and group work is a good way of getting it. Because discussion increases, or it tickles your curiosity. So you start exploring a topic in a way among yourselves instead of just sitting and reading in the book and looking at it yourself.” Franks likes applied mathematics and thinks he learns the most when he himself does the work. “I learn very badly when I am just told things. So, I function rather badly in a lecture. But I see the value in a lecture because you get the structure of the material, and you have the hooks when afterwards you work on your own.” Regarding the presentations, Frank says: “I am in many ways happy that we had the presentation, because you in fact learn a lot better if you explain material that you already know..”

Plenary sessions: self-consciousness and reluctance to ask questions

The informants generally characterize their class as quiet in the sense that the students are not eager to raise hands and ask questions during lectures. Five out of our six informants mention (although we did not ask directly about it) that the students tend to be afraid to say something wrong or make fools of themselves. Especially, asking questions feels scary if they have not prepared. The informant who is most convinced about his classmates’ self confidence with regard to asking questions, is Carl: “I’d say that if people are wondering about something, there will be a question. People do not sit around wondering about things they do not understand.” However, Carl, too, admits that discussions during lectures are rare. Frank thinks that the class is too big a forum for questions and answers: “That is why smaller groups <in TBL> were nice.”

Mathematics is, borrowing Dina’s words, a “geeky” subject in a “geeky” study programme. We might speculate that given the importance of mathematics to students in computer engineering, the stakes are especially high with regard to revealing a possible lack of comprehension in class.

The students see TBL as fit for different types of students

Alex thinks TBL fits both strong and weak students. “Yes, I think so. [Y]ou get to discuss in the group afterwards. I think everyone has something to learn from that.” Carl says: “[S]ome students like to work a bit on their own and read through [the material], while students like me like to show up in the lecture and get it from there.”

Dina says that she herself is better at logical thinking, whereas her friend is better at cramming. She says: "[P]eople master mathematics in very different ways, really. And [..] you can see a lot from how people learn, what part of it they master." "Because people who master logical thinking, master [it] when they solve tasks, whereas those who need cramming usually prefer to get it explained [..], in a way." Dina sees the logic vs, cramming distinction as a question of approaching mathematics through practice vs. theory, somehow considering the use of logical thinking as a form of practice. When helping others with mathematics, she thinks it is necessary to find out what is their starting point, how the other person understands mathematics. Regarding lectures, whereas they do not work well for Dina, she says there are many "who need to be in a lecture and listen and ..get it explained, really" She proposes to adapt TBL to fit the different preferences: "I would have tried to mix it together in a way. Had a small lecture before, and then made available the slides so that those who do not necessarily need or want to would have the option not to [attend]".

Emma also proposes to adapt to different types of students, if she were the mathematics teacher: "if I were to think of only myself, then, as I said, I like video lectures, and maybe at the same time have both, have a bit shorter lectures at school and video lectures [..] for some of the theory, combining it. I know there are many who like to have lectures, because they feel they get much out of it, and who are not using those videos."

Asked if TBL worked for everyone, Frank replies: "Yes [..] I think at least it worked better for more people than the traditional solution works. You will never find a solution that works best for everyone, unless you adapt to them personally."

On the TBL presentation sessions

With regard to TBL, Ben explains that there is indirect feedback through the fact that the team discusses the test and the lecturer goes through it afterwards. You may ask questions in class, but he thinks there generally is a fear to say something wrong in front of everyone. Through the feedback on the presentations "you get it directly in your face" if there is something wrong. The lecturer addresses it and "shows how". Ben says: "But this is the best kind of feedback, because, then, ok, it was really wrong.". The fact that different groups in the room present different tasks (randomly drawn), means there are many different solutions, so you get questions there also from people sitting in the room. "This is another great thing, because [..] totally different ways of thinking about the same task usually gives the same answer". As all teams in the room have done the same tasks, "you typically ask about the task you have knowledge about."

Who are these students?

Having read some of the students' thoughts, some more background information is relevant. The 49 respondents in the first survey (class had 65 students), are between 19 - 35 years old, with a mean age of 21,9 yrs. Their mean grade in mathematics in [secondary school/ high school] was [4.8/4.2] where 6=A; 1=F, implying that most of them have done fairly well in mathematics – B or better. Our pseudonym informants are aged, in rising order:19, 19, 20, 21, 22, 27 yrs. The gender balance in class is approx. 1:3, giving us by chance the same gender balance of informants.

We report only briefly two surveys of the students' mathematics self-efficacy, i.e. their beliefs or perceptions with respect to their own abilities in mathematics. We measured MSE as a mean across 12 questions with a scale: 1 *never*; 5 *usually*. The total mean score in class for the first survey was: 4.0, (range: 2.6 - 4.9). This was reduced to 3.6 (range: 2.7 - 5.0) in the second survey, timed two thirds into our TBL module. The mean MSE-scores of our six interviewees ranged in the first survey: 2.7 - 4.9 and in the second survey: 3.7 - 4.9.

Alex put a low score on the question of *feeling confident enough to ask questions in class*, but raised it one point in the second survey. Ben put a slightly lower score than the rest first on the question of *doing well in a mathematics test*, but later on another question: *I think I can solve all the problems in a mathematics course*. Carl put relatively high scores, but improves on the question on *understanding the content in a mathematics course*, but reduces on the question of *being the kind of person who is good at mathematics*. Dina and Emma both put high scores on questions of *performing mathematics outside of class*, and especially low scores on *asking questions in class,* however both put significantly higher scores in the 2nd survey. Frank is also lower than average on *asking questions in class*, and in the second survey he increased *on Mathematics can be fun*.

For the whole class the issue: *«I feel confident enough to ask questions in my mathematics class»* has the lowest MSE-score of all the questions: 3.4 in the first survey – in between *sometimes* and *often.* While the highest scored question was*:* 4.6 in the first survey - in between *often* and *usually "I feel confident when using mathematics outside of school"* This serves to confirm that there is a common nervousness towards sharing potentially stupid questions with the class.

6 DISCUSSION

In this chapter we consider how the implementation of the adapted version of TBL actually worked out, in 6.1 examining our results in light of the initial questions of the course lecturer. We next, in 6.2, formulate a set of lessons learned. Finally, in 6.3 we discuss our insights with reference to TBL-related recommendations from other research, pointing to what we see as our main contributions to the research field.

6.1 How did the TBL turn out in light of the lecturer's expectations and worries?

Considering our results in light of the lecturers' questions presented in Chapter 1, we get some insight about how the TBL turned out in our case.

How would the students collaborate in their new groups? Our students appreciate the work in groups in TBL. The value of structured collaboration as a key idea of TBL seems to be understood. The students see the benefit of having various points of view brought up, learning from hearing what the others have to say and from explaining to others. Disagreement appears to trigger learning. The students see advantages to working with people they already know, but appreciate the perspectives, task focus and work discipline that follow from working with new people. Attendance, preparation and division of work are often mentioned as issues affecting the collaborative work. But even if participation is not always optimal, much of the intended collaboration takes place. The collaboration in the TBL groups may also be seen in light of the students' reluctance to ask questions in plenary, which makes the groups all the more important as arenas for feedback and discussion. Being wrong is not only safer in a smaller group; challenging others' solutions and opinions is even part of the TBL design. We may speculate that this makes the students more willingly accept the structure imposed by TBL.

Would the students see collaborating on mathematics problems as an unnecessary overhead, with the result that they just divided the work between them, working separately rather than together? Regarding the work on the assignments, it seems that many TBL teams did divide tasks between them and assemble the result (especially when putting together the presentation) instead of actually collaborating. Whereas this can in some ways be effective from the point of view of producing a shared outcome, it does not promote collaboration, and it also seems to lead to somewhat fragmented presentations. It thus seems that the learning potential of the presentations and the preceding group work is not fully exploited. Some students accordingly express that they would have preferred mandatory attendance in the collaborative work sessions. Whether the collaboration on assignments in TBL is seen as unnecessary overhead, is less clear from our results. What we do know is that the students, who regularly engage in work in groups in most of their courses, are used to dividing work between them whenever they find it convenient, and without mandatory attendance in the TBL group work sessions, it is up to the team to decide how to organize their work.

Would a fairly structured, teacher-led design like this be perceived as restrictive with respect to their work process, as the students are used to more autonomy? At least taken from the interviews, the students do not see the TBL as overly structured. Rather, a wish for *more* mandatory attendance is expressed by some informants, especially in relation to groups having problems with attendance. We see that some students skip the group sessions when they have not prepared, and these students might object to mandatory attendance.

Would the tests lead to negative stress rather than the intended motivation to prepare? As addressed in the Results chapter, the lecturer got some reactions from students who thought of tests as scary. Overall, however, it appears that once TBL is understood by the students, e.g. that they become familiar with the format and purpose of the iRAT and tRAT, the readiness preparation testing is seen as structuring of the learning and collaboration process rather than stressful test situations. Preparation for the tests is addressed by several informants in our interviews. There seems to be some motivation linked to social pressure to do one's part in the team, and awareness that you will not be able to participate and contribute in the same way to the group discussion of you have not prepared well individually. At the same time, we note the considerations about freeriding, which can be seen as a degree of acceptance of not always being prepared: If you do not prepare well, you contribute less, but at least the rest of the group gets to discuss more, and it benefits their learning. The group discussion can serve as a kind of safety-net; you get something out of it in any case. The occurrence of freeriding as well as acceptance of this behaviour is likely to vary among teams. A certain flexibility in this area might take some of the pressure off the test situation. Of course, lack of preparation on part of some students means that the change in workflow ('flipped classroom') intended in TBL is not complete.

Would it be possible to design group activities that work well with the TBL setup, while also achieving the desired learning outcomes? Taken from our interviews, the students perceive they learn equally much or more from TBL as from a traditional course design. This was not systematically explored in our study, but was implicitly addressed in the interviews. It can be seen from the students' reflections about their learning that even though they like mathematics, they tend to experience challenges with certain areas (e.g. statistics; formulas) or approaches (e.g. cramming), or even with completing a mathematics course (e.g. concentrate, be motivated to prepare sufficiently for the exam). This might be about self confidence or about self-insight about one's strategies, preferences, strengths and challenges. Nothing indicates that our students consider TBL as less adequate for strong or weak students. The differences between students warrant a course organization that allows various approaches. It seems that the different learning resources and the combination of individual and collaborative work in our TBL design allowed for different approaches. On the other hand, the issue of attendance during teamwork sessions points to the possibility that some students did not get the intended benefit of collaboration. Whether this has had an impact on learning outcomes, cannot be concluded from our study, as too many factors vary between the different instances of the mathematics course. We do know that students in several of our interviews tell us that they believe TBL and in particular group discussion helped them learn.

6.2 Lessons learned

Based on our study, we identify some lessons learned that can be seen as advice to teaching staff who consider implementing TBL in mathematical subjects. Our insights might also be relevant in other courses.

1. One can still get a lot of the benefits from TBL by implementing only parts of its design, for instance the competition element can be left out.
2. It is necessary to inform the students well both of the intentions of TBL and the practical organisation. Note that flipping the classroom is a part of TBL, and changing the rhythm of listening, reading and doing from the traditional order to a flipped work process is demanding for the students.
3. The use of terms is important in communication with the students. For instance, the word "test" can be a bad combination with mathematics anxiety.
4. Some degree of freeriding might be acceptable, as it creates flexibility for the students.
5. The design should adapt to students who are different with regard to preferred learning approach and learning material, for instance by offering a variety of learning resources and some influence on team composition.
6. When designing TBL group activities for a mathematics course, it can be difficult to design a cohesive activity that requires collaboration to complete, is not too difficult to solve and also not easy to split to divide amongst team members. Still, we think that almost any mathematics problem is suitable for collaboration as long as it is not trivial to solve.

Table 2:Lessons Learned

6.3 What is our contribution to the use of team-based learning?

While we have largely followed principles of TBL as presented in the literature, and taken heed of the advice on implementing TBL as we have understood it, amongst others that of Michaelson et al. (2011), we made our own adaptations. We find that our Lessons Learned 2. and 3. on wording and explaining TBL to the students, correspond well with Parmelee et al.'s (2010) Tip 6: Orient the class to why you are using TBL. We also heeded their Tip 11: Create teams thoughtfully also correspond with what we did. Some key issues are given below.

Task design and the accommodation of curriculum that does not properly fit TBL: We did our own take on the task design. Parmelee et al., in connection with their *Tip 1: Start with a good course design,* recommend a tight integration between instructional strategy and course design. However they also state: *"It can be the primary mode of instruction or work alongside other learning activities, i.e. focused lecture, service learning, self-directed online tutorials."* (ibid. p118) and mention a short period of TBL as an option. Our TBL period was short, but we also included some individual deliverables as part of the units, encouraging the groups to collaborate on these too. Individual assignments makes it more likely that each student gets some practice on their own. For an average student to be successful, assignments should not be too big and difficult.

Providing flexibility for the variety in the student population: Students are different with respect to their abilities, learning strategies and preferences. Through our study, we have found that this can be accommodated through providing some flexibility within a TBL design, given the availability of a variety of pre-reading materials. We have not seen this addressed in existing guidelines and principles for TBL and consider the insights from our study in this are to be a unique contribution. We have proposed allowing group tests to serve as a safety-net and accept that groups have various ways of handling different levels of contribution, including freeloading. When it comes to students who have special needs due to challenges e.g. with social situations, TBL might provide some adequate solutions for instance by enabling individual preparation through various learning resources, but other aspects of TBL may less adequate.

Reducing peer evaluation and competition among teams: We did not include the competitive part of the TBL design or focus on team building. Thus we perhaps lose out on getting the groups to collaborate all the way through the units. Effectively, we skipped Michaelson et al.'s (2011) Essential principle 4: Peer evaluation and their described feedback form addressing preparation, contribution, gatekeeping (help others contribute), and flexibility (listen to other arguments), or giving points to fellow students (Kraemer 2017). There lies accountability embedded in the concept of peer assessment in the teams. We also left out appointing winning solutions. Several issues discussed by Michaelson et al. (2011) and formulated as tips by Parmelee et al.'s (2010) are salient here, such as Tip 5: Do not underestimate the RATs, Tip 7: Highlight accountability as the cornerstone of TBL and Tip 12: Low budget props, such as flagpoles for the winning solution, in particular address this issue. Finally, we did not formalize Tip 8: Providing a fair appeals process, but appeals were part of the discussions in sessions and in connection to presentations. While these can be seen as limitations to our approach, we chose to leave out the competitive aspect in order to have mathematics centre stage rather than a nervousness that might result in students not attending the sessions. Some students did feel a kind of competitive effect anyway, as the interviews show. Our students were asked to give feedback to each other (limited, informal, sometimes superficial). In retrospect, a bit more attendance would have been beneficial. Asking for a reflection note on the group work might be a way to achieve this. Limited competition might be a good idea, though our lecturer prefers focusing on creativity and comparison. Mandatory participation in all the sessions, as suggested in our interviews, might compensate for this.

7 CONCLUSION

Through our study of TBL applied in a mathematics course in higher IT education we have found TBL to be a positive experience for both students and faculty. We implemented a modified version of the approach, with limited peer assessment and without competition among groups. Taken from our in-depth interviews with students, our TBL approach still leads to collaboration and learning through individual preparation and group discussions. Limited requirements for attendance offered flexibility to the students, accommodating individual differences and acknowledging that groups may occasionally serve as a safety-nets for the individual. Our findings relate to a certain type of course and study programme, and one particular class and educational institution. Our students have a tradition for great freedom in choice of which activities to participate in, and what you do on your own at a different place and time than lecturers might plan in their course designs. This is a challenge to implementing collaborative learning activities. Other courses and contexts might not share this characteristic. Further research along this line of work might implement our approach in similar or different courses and contexts, to challenge and/or strengthen our insights about applying and modifying TBL.

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