Team-Based Learning: A Practical Approach for an Engineering Class

Frank Alexander Kraemer, Ph.D. NTNU, Norwegian University of Science and Technology

We describe the framework of Team-Based Learning and its application in an engineering course at NTNU. We present the process of applying TBL to a new course, discuss the results on the course outcome and close with some recommendations.

1 THE FUTURE OF LEARNING

The days of traditional lectures are numbered. Once a necessity because books were a scarce resource, lectures are not an exclusive source of knowledge anymore [1, 2]. We also know now that active learning methods increase student performance [3]. Similar arcane artifacts are exams at the end of the semester. While they may be a convenient and safe form of assessment for the teacher, they do not optimally support learning, as argued in [4].

So, with two of the most prominent educational products of universities turning stale, what will the future of learning look like? Will students learn exclusively from online resources instead, watch video recordings and increase knowledge retention and track progress by solving quizzes? Will they study alone, whenever they find time?

For me it seems obvious that an optimal learning environment consists of more than just learning resources, whichever form they may have. Optimal learning must be structured around what the student actively does [5]. For that, interaction with peers is fundamental. Learning requires application of knowledge, juggling with ideas and an arena that allows to try out new things. Universities are still in the best position to offer such optimal learning environments.

Team-Based Learning (TBL) is a learning and teaching framework that keeps students active, implements principles of flipped classroom and utilizes teams for organizing learning activities. This makes it a much better learning framework than the arcane and passive combination of lecture and exam. But while that is reason enough to get to know TBL better and apply it in courses, there are two specific properties that make TBL interesting for the future of learning:

- Team-based learning is practical. It is precise and specific, but also fits for many courses and into different environments and can be combined with existing material. It is also possible to just try out TBL for a week or two.
- Team-based learning transforms the teacher as much as it transforms the student. After introducing TBL into a course, it is unlikely that a teacher will go back to passive lectures, so dramatic are the differences when instructors see how much more active their students become.

These properties make TBL a catalyst for change in education. Will the future of learning be an exact implementation of team-based learning? Probably not. What is more likely is that frameworks like TBL bring us as teachers into a position from which it is much easier to see what the future of learning actually looks like. But until we get there, applying TBL is the next best thing.

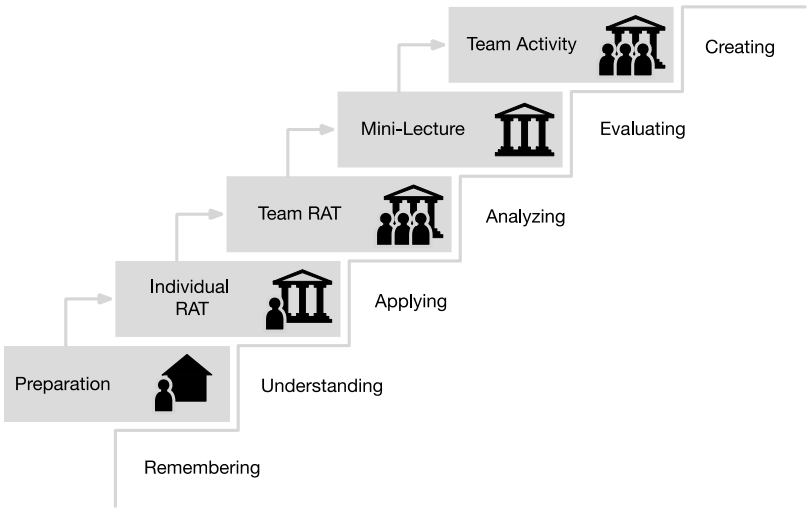

Fig. 1: The different activities within a learning unit

2 TEAM-BASED LEARNING

Team-based learning was developed by Larry Michaelsen [6, 7]. Since there are several books, articles and lectures on team-based learning, we'll just give a brief introduction in the following. A course is divided in five to seven units, each taught over a period of one or more weeks. A university semester with approximately 15 weeks can therefore be divided into seven two-week units. Students are organized into teams, consisting of five to seven students each. It is important that students do not form teams on their own, since this often leads to homogeneous teams. Instead, the instructor forms the teams based on, for instance, gender, nationality (resident vs. exchange students) and study directions. Even random division leads to better, that is, more heterogeneous, teams than if students choose teams on their own. Each learning unit is structured into a sequence of different phases, illustrated in Fig. 1 and explained in the following.

Preparation Phase and Readiness Assurance Tests

Each unit begins with the students reading through the curriculum on their own, usually at home. Teaching at university begins with a *Readiness Assurance Test* (RAT), a closed-book test, formulated as a multiple-choice test. The students solve the test first individually and hand in their results. The students will then solve the same test again, this time within their teams. They will start to discuss and explain parts of the curriculum to each other when arguing for the right answer. Using special scratch cards, they can immediately check if they found the correct answer. The teams hand in the team result, which also contribute towards the individual grade of each student. Teams may also come forward with formal appeals if they disagree with the answers.

Mini-Lectures

The instructor can go through the results of the tests and highlight questions that turned out difficult, and present material in mini-lectures. The word *mini* emphasizes that this part should be short.

Team Activities

After the tests and mini-lectures are complete, students solve tasks in teams. These tasks are called *team activities*, and TBL recommends that these tasks follow the 4-S criteria, meaning that tasks are *significant*, the *same* for each team, and that they require a *specific* choice that is presented by all teams *simultaneously*.

The different phases roughly follow the different cognitive levels in Bloom's revised taxonomy [8]. The lower levels of understanding and remembering are covered by the individual studies at home. The RAT is the first chance to apply the new knowledge. The team activities address the higher cognitive levels.

Peer Evaluation

TBL also recommends a peer evaluation within each team. This lets students anonymously evaluate each other. The result of this evaluation is taken to adjust the final grade.

3 TBL FOR AN ENGINEERING COURSE

In the following, we explain how we applied TBL to the course TTM4115 - Design of Reactive Systems 1. The 7,5-ECTS-points course is mandatory within the M.Sc. of Telematics and the M.Sc. in Communication Technology at NTNU. It aims at second-year students, but students from other study programs (Cybernetics, Computer Science and Electronics) can select the course at different times. The course is usually attended by around 75 students. The curriculum is about the development of distributed communication systems and covers modeling languages, system architectures and development processes. The learning goals of the course are related to mastering large development projects. Since software development is usually done in teams, the course included a semester project done in teams already in the years before we introduced TBL. Apart from this, the teaching techniques were traditional, with weekly lectures (about two hours), guided exercises and an exam at the end. The semester project counted 25% towards the final grade. The introduction of TBL in the course happened in two stages: For the spring semester 2016 we introduced TBL, but kept a final exam that counted 50%. For the spring semester 2017 we replaced the final exam by individual deliveries throughout the semester.

Learning Units

The course is divided into eight learning units. Creating this unit structure was the most difficult task, which has probably less to do with TBL but course design in general. The strategy for the unit design is the following:

- Establish the *launch day* in the final week as the course goal, imitating product launches as motivation from work life.
- Designing learning goals and formulate them based on the project development.
- Use backwards design and constructive alignment to develop the units based on the learning goals.
- The units need to be self-contained, yet be clearly connected to each other. We selected to go through the idealized stages of a software development process, from requirements engineering, use case specification towards the detailed design.

Readiness Assurance Tests

The creation of the readiness assurance tests requires a considerable amount of work. It is hard to prepare ten multiple-choice questions from one or two book chapters. The questions need to be reasonably fair and reward preparation, but at the same time not be trivial. It is impossible to create new questions for each semester, also because the potential for questions from a given curriculum is limited. We therefore use the same RAT each year, require students to return the tests, and strictly forbid copying of questions. Students can, however, view their tests under supervision. Each test takes 20 minutes. During the team-test, student assistants read in the results of the individual tests, so that detailed statistics are immediately

available for the beginning of the mini-lectures, where difficult questions can be discussed further. We use paper version for the tests, with a simple result box at the top to make reading the results efficient. The tests are formatted by a custom software for this course that generates an individual version of the test for each student. In these versions, questions and answer alternatives are shuffled, to prevent the most basic attempts of cheating.

Mini-Lectures

During the mini-lectures after the RAT we go through subjects that build on the preparation material. For instance, the preparation for the unit on sequence diagrams introduces the notation and examples with a book chapter. The mini-lecture then explains the deeper semantics. The length of the mini-lectures varies between the different units. In some cases, 20 minutes are sufficient to provide the additional material needed. In other cases, we use more time, effectively switching to a traditional lecturing style where material still requires it.

Team Activities

As explained above, the team activities should follow the 4-S principles. While all activities are significant and the same for all teams, we did not manage to build team activities that require specific choices and allowed simultaneous delivery. Instead, results were more complex, for instance in the form of a newly created diagram.

An example for a team activity is the following: Students receive a real product sheet describing the use case of a system to regulate watering height in Malaysian rice fields. The teams then create a deployment diagram based on the product sheet. The problem was hence significant and all received the same task. This first phase takes around 35 minutes, after which all teams upload their solution. Then, each team is assigned another team's solution, and they should compare it with their own result and comment on it. This takes another 20 minutes.

Semester Project

The semester project is not part of TBL, but we see it as an important learning means for this engineering course. Already from the beginning, students are introduced to the semester project that they must solve within their team. The teams need to come up with an idea for a system that they want to build. Apart from some technical requirements, the system needs to be useful and provide value to a user. The semester project culminates in the production of a short video that presents the system. The benefit of the videos is that they can be shown to next year's students as motivation. All videos are presented during launch day at the end of the semester. Before the video, the teams must prepare two deliverables, the first specifying the requirements of their system, and the second detailing their implementation. These deliverables correspond to deliverables in industry, and are handed in during the semester.

Grading

In 2016 we still kept a traditional final exam. Towards the end of the semester, however, it became apparent that this is not an ideal solution. Instead of focusing on the semester project, students divide their attention between the project and the exam, and the two do not mutually support each other. The exam requests more attention on notational details, but the semester project is more focused on the application of problem-solving skills. For this reason, we decided to remove the exam entirely and replace it with individual deliveries throughout the semester.

The final grade consists of the RATs, the semester project and the individual deliveries. The grading of the RATs is simple; each correct answer yields 10 points, which means the maximum score of a RAT with 10 questions is 100 points. Despite being a multiple-choice

test, we do not punish wrong answers or subtract 25 points that correspond to an average result achieved by pure guessing. This is justified by the nature of the answer alternatives: Each alternative sounds plausible, and figuring out the best answer is not trivial. Since the RATs require physical presence, only the best 5 out of 8 tests count, to handle case where students cannot show up. The final component for the RATs for each student consists of 30% of the team's RAT result (acquired with the scratch cards) and 70% of the individual result from the first round.

Individual Deliveries

To replace the exam, we introduced individual deliveries in 2017. These deliveries are prepared by each student, and take the team deliveries as input. Each student compares their own team's solution with that of another one, and reflects on the learning goals of the course. Each student receives therefore a unique combination of two team projects, which helps preventing copying results from each other. Suggestions and comments are then forwarded to the individual teams and serve as feedback.

Peer Evaluation

We perform a peer evaluation twice during the semester, after the second and after the final delivery. Students distribute 100 points among the other members of the team. This distribution is used to calculate a factor that is multiplied with the grades for the team deliveries. Experience from 2016 shows that students are careful and considerate when evaluating each other. Most students distribute points evenly, and the clear majority of students gets between 95% and 105% points, leading only to minor corrections.

4 EVALUATION

Evaluating courses is difficult, both regarding what should be measured and how to obtain good data. To get some at least some impression, we compare the course after the introduction of TBL in 2016 with its earlier years. Since 2016, the introduction of TBL was not the only change. In addition, the course has a new course responsible and part of the curriculum were changed. However, there is enough overlap with the previous years to at least get some indication. The data is presented in Fig. 2.

Regarding the global evaluation (1), students are more satisfied with the course in 2016 when TBL was introduced, with a score of 4,1, on a scale of 5 for *very satisfied* to 1 for *very unsatisfied*. The level of difficulty (2) compared to other subjects was perceived slightly less than in the previous years. Significant is the workload (3). Compared to the previous years it was considered with 4,1 as much higher than that of other courses.

Fig. 2 (4) shows the attendance rate during the first nine weeks of the course in 2017. The attendance rate is higher during weeks with RATs (92% on average) than compared to weeks without RAT (65%).

Figure 2 (5) shows the average of grades of the course over time. In 2016, the average was slightly better (2,5) than in previous years. In 2016 we observe a low percentage of student dropout (6), i.e., students that fail the exam or cancel the course. In 2016, these were only 3,2% of registered students.

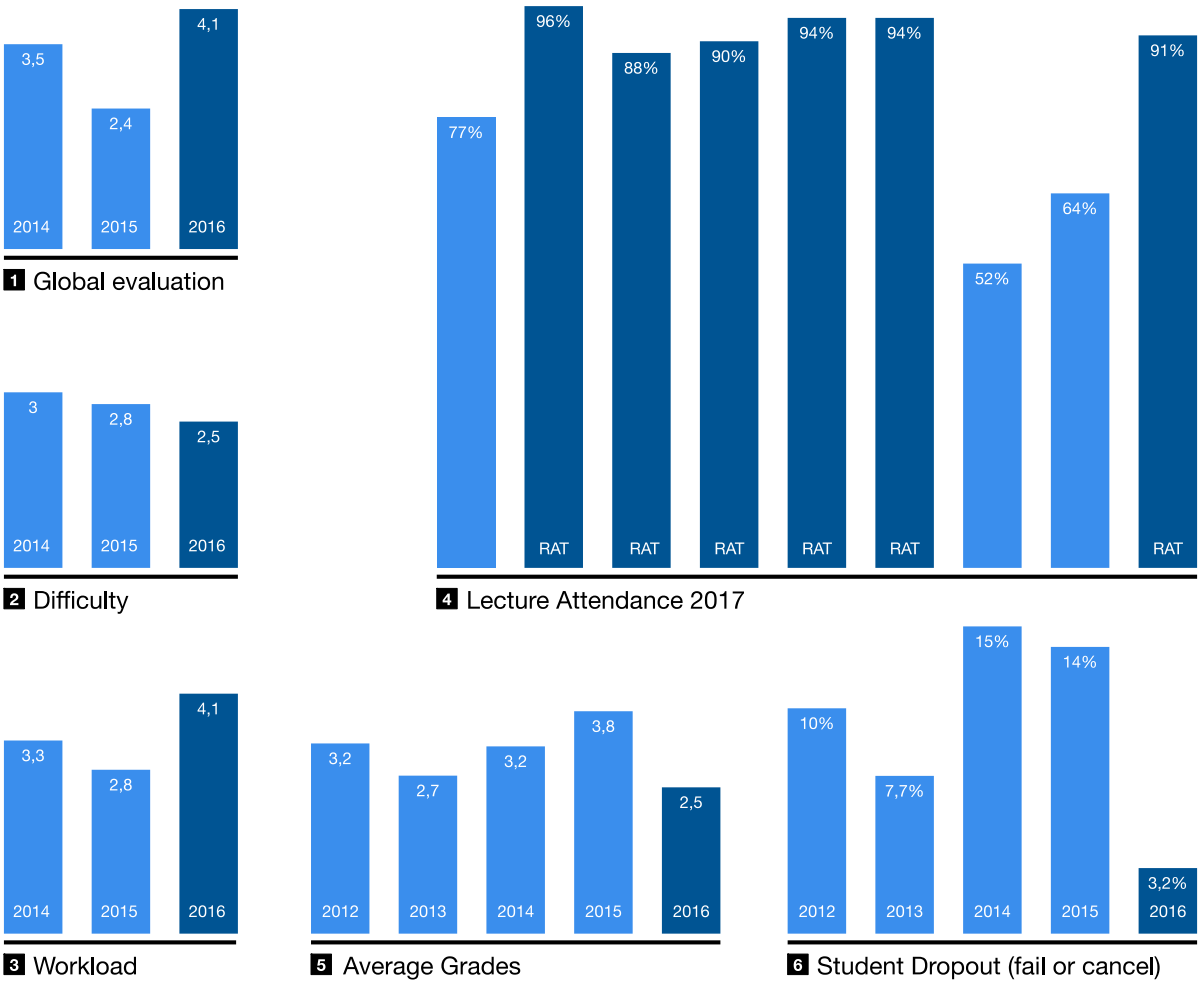

Fig. 2 Comparison of the course to earlier years and lecture attendance.

5 EXPERIENCES

Traditional Lecture Halls

In 2016 the course had 120 students and we used traditional auditoriums. The initial auditorium had 130 seats. It turned out that for writing the RATs, at least double the capacity is needed, to allow space between seats. We therefore booked another, larger auditorium with room for 300 students. During mini-lectures, less space is required, and during team-activities students often find alternative working rooms in the surrounding buildings. In 2017, we used a new learning room (Smia on Gløshaugen campus) with dedicated seating for teams. Unsurprisingly, such dedicated rooms are superior, since they encourage teamwork and make it easier for the instructor to walk among the teams. We need more of these rooms.

Weekly Emails

Students receive their preparation material via email a week before the RAT. Initially, we used the last 15 minutes of the previous learning unit to introduce the next unit. This, however, did not work well since students are tired at the end of a learning unit and less receptive for something new. Instead, the emails turned out to be a suitable reminder about the course which also reaches students that missed the current lecture.

Course Schedule

The course is scheduled weekly from 8:15 to 12:00. This combines the traditional hours for lecture and exercises. The consecutive hours allow to do the RAT, mini-lectures and team

activities all in one session. The RATs take 20 minutes each for the individual and the team version of the test, so that they fit into the 8:15 to 9:00 slot. After the RATs, a longer break is scheduled until 9:15. This gives some additional time for correction of the RAT. The RATs are then usually discussed until 9:45, followed by mini lectures or a more traditional lecture introducing more advanced concepts. The time from 10:00 to 12:00 is mainly used for the team activities, with breaks whenever needed.

6 CONCLUSION

Team-Based Learning may appear as an innovative, but also rigid and laborious method for teaching. However, it is possible to apply team-based learning only partially, beginning for instance with a single learning unit. A minimal unit consist of some part of the curriculum that is easy for students to read at home. Students should be coached on team-based learning, for instance by showing them some of the videos about team-based learning. The RATs for a single unit are not too laborious, and grading in such a test phase is not an issue. Usually, the biggest difference to traditional lecturing becomes visible during the team-version of the RAT. Students start discussing the questions of the test and dive into the curriculum on their own. This is usually the first revelation for a teacher used to traditional lectures: Your students become active.

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