Aalborg University
University Pedagogical Program

Design of interactive student sessions for full-day teaching

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1 Introduction

The majority of teaching at a university is lecture-based [Tronchoni et al., 2022], a method where a lecturer presents the learning material to a large group in a lecture theater [Exley and Dennick, 2009]. Classically, lectures are a form of passive learning, as the students engage with the lecture by listening to the lecturer and taking notes of the material. (Note taking is nowadays even less of an activity students engage with, especially when the format is an online lecture, see Morehead et al. [2019].) More recently, the use of active learning during a lecture is becoming more popular, as active engagement of students in activities as discussion and problem solving has been shown to encourage better learning [Bass, 2012, Darling, 2017].

Problem-based learning (PBL) is a teaching philosophy that heavily builds upon active learning of students. In Barrows [1996], Dochy et al. [2003], seven characteristics of PBL are given to define PBL: student-centered, small groups, tutors are facilitators, problems before study, problems are a tool to achieve knowledge and skills, self-directed learning, and representative problems. While it has been shown in Solomon [2020] that lecture-based learning is more effective than PBL for immediate surface knowledge, PBL increases the deep-learning of students [Du et al., 2019]. Hence, PBL universities often still apply a mix of courses and projects, where lectures are still the main activity in courses. These lectures might be supported with small semi-structured, yet real-world based, problems or cases in courses to enhance knowledge management or critical understanding [Chen et al., 2021].

Using Bloom's Taxonomy [Anderson and Krathwohl, 2001, Bloom et al., 1956, Krathwohl, 2002], lectures are typically targeting the factual and conceptual understanding of students (dimensions Remember and Understand) [Exley and Dennick, 2009]. Even though students often have positive opinions on lectures [Bates et al., 2018, Buchanan and Palmer, 2017, Solomon, 2020], their effectiveness to deliver the desired learning is often debated [Freeman et al., 2014, Kramer, 2017, Lambert, 2012].

Regarding lecture length, its duration is often dictated by the university's schedule. For example, blocks might be scheduled to take 45 minutes plus a 15 minutes break. Then this block can be repeated every hour, hence making scheduling easier. A teacher then gets assigned two such blocks for a single lecture. But research on optimal lecture time does not directly support such a schedule. In Johnstone and Percival [1976], Stuart and Rutherford [1978][1] it was first established that concentration span of students is about 20 minutes, while Exley and Dennick [2009] argues that it is nowadays probably even shorter. But Bradbury [2016] argues that most research on student's attention span, including the heavenly cited studies of Johnstone and Percival [1976], Stuart and Rutherford [1978], have methodological design

[1]The study of Johnstone and Percival [1976] is cited numerous times, but retrieving the actual paper was not possible.

flaws, thus disputing the ubiquitous mantra of the 15 min attention span.

2 Problem description

In 2020, the Software Engineering education started at AAU's campus in Copenhagen. This education is supposed to be the same as the Software Engineering education at AAU's Aalborg campus. While the department in Copenhagen has grown over the past years, insufficient teaching capacity and subject matter knowledge is still an issue. Therefore, some teachers from Aalborg have to teach occasionally in Copenhagen.

The first generation of Software Engineering students has reach the 6^{th} semester in spring 2023, and I have been asked to teach (parts of) the course Models and Tools for Cyber-Physical Systems (MTCPS) at this semester. Even though all teachers for this course (Copenhagen and Aalborg version) are based in Aalborg, the head of department has requested that on both campuses all teaching should be in-person. Therefore, the sessions at Copenhagen have been scheduled to be once every two weeks, 8-hour long, while at Aalborg the usual weekly 4-hour sessions are used, divided into 2-hour lecture and 2-hour guided exercise.

Teaching such an 8-hour block posses challenges. One might immediately think about how students and teachers can 'survive' such a long session, i.e., the fear that such a long session is detrimental to the attention span and energy levels of the participants. But I believe that such a long session also provides opportunities to increase the learning outcome for the students by organizing teaching differently. Therefore, the following problem is stated.

Which opportunities provides a full day teaching session for learning compared to a standard 2-hour lecture + 2-hour guided exercise session?

Due to the timing of the MTCPS course (spring semester) with respect to the University Pedagogy Course (spring semester and fall semester), ideas have to be implemented before a solid theoretical foundation is established for those.

The MTCPS course in Copenhagen is taught by two teachers: one starts the course with sessions 1, 2, and 3, while I was responsible for teaching sessions 4 to 7.

3 Lecturing at a PBL university

The PBL model relies heavily on student activity for their learning. As stated by Savin-Baden [2020], PBL "should be about meddling with uncertainty, underpinned by wisdom so that students are encouraged to wrestle with difficulties that arise from the knowledge put before them." This aligns with AAU's basic principle that problem-based project work of groups must be exemplary, meaning that learning outcomes achieved during the project should be transferable to situations in students' future careers [Aalborg University, 2015]. And during ones career, all different kinds of uncertainties and difficulties will be encountered.

Looking in more detail to what is expected from the students in AAU's PBL model [Aalborg University, 2015] regarding their active learning, it is stated that

- students develop, throughout their studies, strategies for project cooperation as well as project organization and the management of learning process,
- students are motivated and take responsibility for implementing the problem-based approach in their studies,
- students are motivated to create synergies between different cooperation cultures by collaborating with external partners and engage in interdisciplinary learning environments, and
- students support one another in their academic work and contribute to a strong culture of cooperation in their studies.

AAU's basic principle on courses states that courses have a supporting role for the project work:

> In order to ensure that they become familiar with a wide range of theories and methods which they can use in their project work, students will participate in obligatory as well as optional courses. The courses require a large amount of student activity, including lectures, workshops, seminars and exercises. Aalborg University [2015]

As can be seen, the lectures are considered to be a student activity. While in practice one could doubt whether students are really active during a lecture. According to Edgar Dale's Pyramid of Learning, reading text and hearing a lecture are the least effective methods for knowledge retention [Dale, 1969][2]. (Note that Dale's Pyramid of Learning should be treated with caution, as Masters [2013] shows that there is actually no substantial evidence from original sources on this pyramid, its percentages, and its conclusions.)

The AAU Study Activity Model [Aalborg University, 2023], a collection of types of activities that fit the PBL model, mentions several student activities related to teaching, i.e., organized by the lecturer and discipline oriented: lectures, classroom instructions, E-learning, laboratory experiments, exercises, and others. Again, lectures are considered one of the possible student activities, aligning nicely with AAU's basic principle on courses.

Both the AAU PBL model as well as the AAU Study Activity Model lack in exemplifying how these aims should be put into practice, especially for course lectures.

4 Adapting the MTCPS lectures

Before joining the teacher team for the MTCPS course in spring 2023, this course had been running for three years only in Aalborg. The setup of this course is a classical setup, where each week one session of 4-hours is organized for the students consisting of a 2-hour lecture (including breaks) and a 2-hour exercise session. If I would take over this setup and the existing teaching material, an 8-hour session of MTCPS in Copenhagen would look like the one depicted in Figure 1. A 2-hour

[2]The study of Dale [1969] is cited numerous times, but retrieving the actual report was not possible.

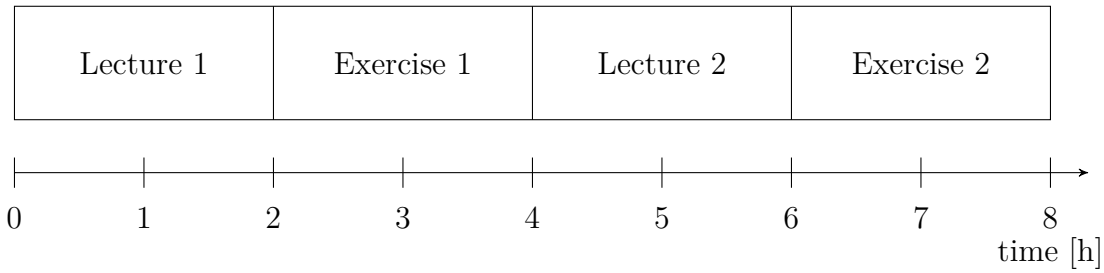

Figure 1: Schematic overview of a session design following existing content from previous year, including small breaks but excluding lunch.

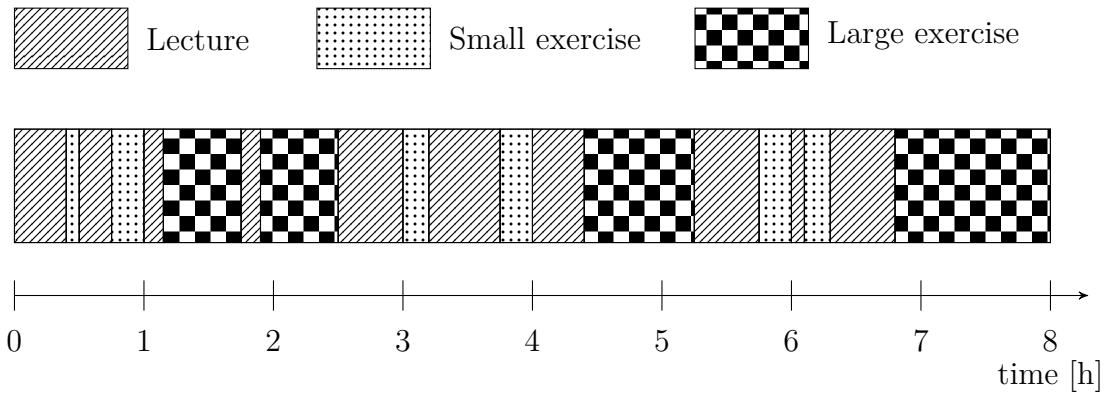

Figure 2: Schematic overview of a redesigned session, including small breaks but excluding lunch.

lecture would be followed by a 2-hour exercise session, again repeated by the second 2-hour lecture, and the day would end with the second 2-hour exercise session. Even though such a schedule for a single course is not typically done within university education, such a schedule for a student might still exists where the second lecture and exercise sessions are from a second course, i.e., one course occupies the morning and another one the afternoon.

The main idea behind the redesign of the structure of the session is to intertwine lecturing more often with (relevant) exercises. This creates a more dynamical session with students that allow them to reset their attention span, switching between the passive mode of listening to the lecture and the active mode of doing exercises. Therefore, this resembles more like full day sessions organized for professionals in continuing education or trainings. Unfortunately, no literature could be identified that analyzes the question how to best design such full day sessions in continuing education or training.

Figure 2 shows the schematic overview of a redesigned schedule reusing the existing material for lectures and large exercises, but scheduled in a different way through the day. (The presented schedule is from the fourth session in the course.) Instead of having two separate lectures (Lecture 1 and Lecture 2 from Figure 1), the original lecture material is split into smaller parts. Yet combined, they still cover the same topics as the original material.

In between the lectures are exercises, which can be classified into two categories: small exercises and large exercises. The small exercises are designed for the students

to quickly test their understanding of concepts just presented in the lectures. Hence, these exercises can be classified as simple problems in the Cynefin framework [Snowden and Boone, 2007]. An example of such an exercise is the following one. During the lecture, the students have been presented with several small examples of a model capturing the behavior of a light bulb to illustrate a new modeling formalism. Then the students were asked to change the model such that it exhibits slightly different behavior. Answers of the students were collected in a Miro board and then discussed in plenum. By including small exercises into the lecture allows the student to quickly check whether they understand the material presented to them. From the teacher's perspective, this also allows for fast feedback on the students' understanding of the material. A couple of times I explained misunderstood concepts after a small exercises instead of continuing with the prepared material.

The large exercises originated from the exercise sheets from previous years, where each exercise is designed to take 30-40 minutes for an average students. But instead of having two unstructured exercise sessions, the exercises were put closer towards the related part of the lecture. Furthermore, these exercises often fall into the complicated problems category of the Cynefin framework [Snowden and Boone, 2007]. Students have to analyze the exercise to figure out how the presented material can be applied. For example, during the lecture student were introduced to formally verifying whether a schedule exists for a particular scheduling problem. Then the exercise asks to find a schedule with the minimum completion time[3].

Comparing the two schedules from Figures 1 and 2 shows that the total duration of the lecture is approximately the same (the same material is being presented to the students), but exercise time for large exercises in the original schedule has been partially replaced by exercise time for smaller exercises in the redesigned schedule. That also means that several large exercises are left to the students to solve as self study.

5 Evaluation and reflection

Having a full day session provided me as a teacher the opportunity to mix and intertwine several student activities together, like lectures and small exercises. This creates a more dynamic session for the students where passive listening is combined with actively applying the material. Furthermore, it provides the teacher means to get fast feedback on the students' understanding of the material *and* the opportunity to address any issue before moving on in the prepared material.

The ability to execute a session planning as shown in Figure 2 is conditioned on the availability of a suitable physical location. In Copenhagen, the complete session was planned in a single room, which means that no room switching was necessary. Hence the content of the session can fully guide the planning. In Aalborg though, exercise sessions are typically planned, at the computer science department, under the assumption that students will do the exercises in their group rooms.

The redesigned session format was evaluated with the students ($n = 9$) after my first session with them (session 4 in the MTCPS course). Using Padlet, I asked

[3]The solution is to use binary search on the completion time such that for any smaller completion time no schedule exists.

them to answer four questions:

1. “Today I learned the most about...”,
2. “After today I should practice more with...”,
3. “Today I really liked...”, and
4. “For the next time I would change...”

The answers to the first two questions were almost uniquely ‘UPPAAL’, the tool introduced that session. More importantly for the redesigned session, the majority of the students answered that they liked the (number of) exercises in between the talks. There was only one response to question 4 of a student that wanted to go to single lectures. This evaluation is consistent with the semester evaluations held throughout the semester by the semester coordinator. In the first evaluation, held after session 1 and 2 of the MTCPS course delivered the ‘traditional’ way, students liked that teaching was physically, but they complained about the long session and problems with concentrating for such long. In the second semester evaluation, after session 5 of the MTCPS course and thus having experienced twice a redesigned session by me, the students mentioned that it works much better by switching more often between lecture and exercises.

Students’ grade could also be an indication on the effectiveness of the learning outcomes of the redesigned sessions. At the normal written exam, only 4 students passed out of the 18 that participated. At the written re-exam, 6 students passed out of the 13 that participated. That means in total 10 out of 18 students passed the exam, which is a 56% passing score. This is, after the re-exam, a reasonable passing score, but, since this was the first time MTCPS has been held in Copenhagen, no comparison with previous years is possible. Though the scores are lower than the ones from Aalborg, which has a 90% passing score. But, based on the comparison of exam scores between Copenhagen and Aalborg, one cannot conclude whether the redesign caused the difference. There are several other potential confounding factors that can explain this difference. First, the fact that 8-hour sessions were scheduled in Copenhagen could explain the different regardless of the delivery method of the content. Second, only the teacher of sessions 1, 2, and 3 were the same in Copenhagen and Aalborg; the part I taught in Copenhagen was taught by two others in Aalborg. Also, since this first generation of Software students in Copenhagen is a small group, they could have been more used to oral exams instead of written ones, as teachers tend to opt more for oral exams when the number of students is smaller. And oral exams result, on average, in higher grades than written ones [Huxham et al., 2012]. The fact that many more students passed the re-exam than the original exam, even though both were written and were similar of style, also with previous years, might suggest that students were unprepared the first time. Finally, teachers from other courses have the impression that this first generation of students in Copenhagen was weaker than expected from the education running in Aalborg. But there exists no strong evidence for this argument though.

6 Recommendations for improvements

The first generation of Software Engineering students participating in MTCPS was a small cohort (about 20 registered students, maximum 13 students present during any session at any point in time). This makes it relatively easy to adjust the pace of the

session on the spot. But for larger student cohorts, following a redesigned schedule approach with mixed lectures and exercises might become more challenging, as such a schedule might not fit well for very strong or very weak students. The redesigned schedule requires students to work more or less with the same pace.

Another pitfall with this design that should be managed well is the period in-between the sessions. By activating the students more during the contact session with the teacher, students might get the impression that they worked enough for this session, and thus no self-study is being done by the students until the next session. Especially at a PBL university, students might allocate there time to the project instead of finishing the exercises from the course.

On the other hand, this idea of mixing several student activities within a session could be developed even further. Based on the philosophy behind flipped classrooms [Rotellar and Cain, 2016], teachers should think consciously about how to use their contact time with the students the best such that the learning environment fits all kinds of learners [Lage et al., 2000]. With the presented redesign in this report, the lectures still cover material explained in the accompanied book. Therefore, even though students were instructed to prepare for the classes by reading sections from the book, no real incentive was in place for students to actual read the book as preparation. If parts of gaining basic knowledge, as explained in the book, could be offloaded from the contact session, the contact session could be used for different student activities focusing on skills that cannot be learned from a book, like how to capture the behavior of a cyber-physical system into a model. Since good modeling can be considered a form of art, having a long session with students could be used to demonstrate and discuss with the students on how to develop a model in an iterative manner, switching between pair or group work and activities in plenum.

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