Testing the impact of active learning in first year undergraduate natural science courses

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ABSTRACT: The last years have seen an increasing debate about the role of the lecturer in undergraduate courses. Recent investigations suggest that an instructional approach which can in a short term be phrased "active learning" is more effective than traditional lecturing, even for large size classes. However, there are only a limited number of investigations available, partly due to the practical difficulties of splitting the class to create a control group. Here we present an investigation, where we test the effect of an active learning approach without splitting up the class. Two first year undergraduate courses: classical mechanics and introduction to molecular biology are covered. In addition a "standard" experiment with a control group class was carried out for an introductory chemistry course. The students were taught for either 2 or 3 x 45 minutes with traditional lecturing and then for a similar time with active learning. The learning effect was tested with two multiple choice questionnaires (10 questions each), which the students had to fill out after completing each set of classes. The students were also asked to do a short survey questionnaire. We received a total of 351 answers. For all three courses the average score was slightly better for the active learning session questionnaire, but the participation was much lower (also in class attendance), further: individual students showed no significant improvement between the two questionnaires. This result is in clear disagreement with previous results in the literature. We suggest two possible reasons for this: None of us are experienced active learning teachers and this may have affected the result. Further, as stated in the literature, for the active learning approach to work properly, the students need to have studied the course material to be discussed in class in advance. In the survey-questionnaire the students were asked if they had prepared for the class. For all three courses a considerable fraction of the students answered "no" to this question.

1 INTRODUCTION

In the early days of universities when books were not easy to get hold of, lecturing was essentially a way of transferring the text material to the students. The lecturer would talk and the students would copy down what was said. Nowadays textbooks and video recordings of brilliant lectures are readily available for most undergraduate level courses, so does it really make sense to continue classical lecturing at this level? A further disadvantage for undergraduate level courses is that the classes tend to be large, making it difficult for the teacher to interact with the students on a personal level.

Active learning is a new approach to address this issue. The term "active learning" was first described in detail by (Revans 1971). The term "*active learning*" is defined by (Gogus 2012) as the instructional techniques that allow learners to participate in learning and teaching activities, to take the responsibility for their own learning, and to establish connections between ideas by analyzing, synthesizing, and evaluating. According to (Wieman 2014) the main aim of the active learning methods is to get students working on tasks that simulate an aspect of expert reasoning and/or problem-solving while receiving timely and specific feedback from fellow students and the instructor that guides them on how to improve. As summarised by (Wieman 2014) and (Freeman 2014) it is increasingly evident that active learning methods achieve better educational outcomes especially in science, engineering, and mathematics (STEM) subjects. Broadly put the idea of active learning is to make the students participate actively in a teaching session, rather than just listening and taking notes. The student involvement is achieved by asking multiple choice questions and discussions with classmates in the classroom, which the students then reply to using an electronic device. The answers are immediately accessible to the whole classroom. A few years back a so called "clicker" was mostly used, now often mobile devices are used with programs like kahoot or similar. One of the pioneers in active learning, Erik Mazur, extended this idea with the "peer instruction" approach (Mazur, 1997). Here the students first reflect on a question individually and then discuss the questions in groups. Finally the group submits one joint answer.

As we see it, the purpose of the active learning is twofold; first it serves to “wake up the students” as concentration level decreases after approximately 15-20 minutes (Wilson & Korn, 2007). Several studies, including NMR brain research investigations, suggest that learning is improved by a challenge that requires an active response rather than a passive intake. The second purpose of active learning is that it serves as “check up” for the teacher that the students have really understood the topic that is being explained. Failing understanding or misunderstanding in a large fraction of the classroom can be revealed by the multiple choice replies and if a large fraction of the students has answered wrongly the teacher has a chance to expand on this topic before continuing with the next point on the agenda (targeted in-class instructor feedback).

Several studies have shown an improved short term learning using active learning. According to (Armbruster 2009) implementation of active learning to undergraduate introductory biology course led to a significant increased academic student performance. In traditional lecture-based courses students are less active and more a passive recipient of information and there is little or no demand of personal involvement from the students giving lower learning output (Freeman 2014). Opposed to this, active learning with more student involvement, as well as instructor taking a facilitator role, has shown to increase learning as shown on better exam scores (Freeman 2014, Wieman 2014, Deslauiers 2011, Zhang 2017, Kovac 1999).

2 OUR ACTIVE LEARNING EXPERIMENT DESIGN

In this experiment design we test the active learning approach in a slightly different manner than what has previously been done in most studies. Usually the same topic is taught in two different ways (classical lecturing and active learning) to different groups and the learning effect tested afterwards with one set of multiple choice questions, handed out to both groups. Here we tried a different approach: we taught two different topics within one course in different ways to the same group and then tested the learning effect by comparing two different sets of multiple choice questions (10 questions each, 4 possible answers). The questionnaires were made available via the student teaching portal ("MittUiB") immediately after the lectures and kept open for one to three days so that the questionnaire for lecturing was closed before the active learning lecturing began. The experiment was carried out in this way for two different courses. A further course was tested in the "standard" manner using a control group and one set of multiple choice questions. In addition to the multiple choice questionnaires the students were asked to fill out a survey with 7 questions.

The advantage of the one group approach is that it is simple to implement practically because you do not have to find an additional classroom and an additional teacher, something that can be quite challenging in the middle of term. An interesting aspect is that it is possible to test individual progress of students, between the two tests. A further advantage is that it is the same teacher doing the whole course, so that we can exclude an effect due to one teacher being better than the other. That said, it should be mentioned that all of us practised "active learning" teaching for the first time for the purpose of this experiment, and in that sense, there may still be a teacher effect, since we are much more experienced in classical lecturing.

The disadvantage of the one group approach is that there might be a topic-related learning effect, which we will not see. We have to assume that the two different topics are equally difficult for the students to grasp and that the two set of multiple choice questions are equally difficult.

We designed our experiment as follows: First the students were given two or three lectures (each 45 minutes) over the course of one week using traditional lecturing. Then followed the same amount of lectures using active learning following roughly the layout presented by (Deslauiers 2011). We used student-student discussion questions, small-group active learning tasks and targeted in-class instructor feedback. Time was taken to clearly explain to students why active learning was being used and that research showed that this approach would increase their learning. In the physics course the students were presented with the Deslauiers paper. Unlike Deslauiers we did not provide any pre-class reading quiz. The students were told well in advance that it was particularly important that they came prepared for the active learning lectures.

The University of Bergen evaluation system did not allow us to reward students who filled out the questionnaires such as it is done in the Deslauier and other investigations. As an incitement, we told the students that two of the 20 questions would appear in the final exam. For all courses, there were significantly more students signed up for the course than were actually present at the lectures.

3 RESULTS AND DISCUSSION

The first course taught without control group was the molecular biology course MOL100. It is mandatory or recommended as a first-year course for students who will continue studies within the field of molecular biology, biology, nanotechnology, and bioinformatics. This course is taught in the spring semester. This year 5 different instructors have participated in the teaching of selected topics. The number of students enrolled in this course this year was 299. The topic chosen for lecturing was prokaryotic gene regulation and for active learning the topic was eukaryotic gene expression.

The second course taught without control group was the classical mechanics course Phys111. It is mandatory or recommended as a first-year course for students who will continue studies within the field of physics, petroleum technology, geophysics, oceanography and nanotechnology. The course is taught in the spring semester with the same instructor for the whole course. The number of students enrolled in this course this year was 178. The topic chosen for lecturing was angular momentum and the topic chosen for active learning torque.

The third course, which was taught with a control group, was the chemistry course KJEM110 (Chemistry and energy). It is a mandatory course for chemistry students, but is also mandatory or highly recommended for students within various other programs (pharmacy, biology, process technology, etc.) The course is taught both semesters with the one instructor for the whole course. The author BG teaches this course in the autumn term. For this experiment the regular instructor for the spring term carried out the traditional lecturing, and BG carried out the active learning. The topics covered were within the field of quantum mechanics, which for many students is hard to grasp.

An overview of the results of is presented in the two tables below. Note that for the Molecular Biology Class there is actually more answers to both questionnaires than there were students present in class, which means that some students have filled out the questionnaires, who were not present at the lecture. It was not possible to prevent this and it was not possible for practical reasons to keep record of the name of the students who attended the lectures.

One remarkable result that can be found from table one, is that the student attendance decreased by up to 62% (Chemistry course) in the active learning session. The smallest decrease was for Classical Mechanics (26%). In Molecular Biology the attendance decreased by 42%. This finding is not in agreement with the result from (Deslauriers 2011), where the student attendance for the experimental section increased by 20%. Could the low attendance that we observed in our active learning section be due to student resistance against trying out new teaching methods? An indication of this, can be seen in the fact that the change in attendance was smallest in the Classical Mechanics course. Up to the point of the experiment this course had been carried out as a mixture of classical lecturing and active learning, so that the students already had some experience with active learning. This also ties in with the fact that the decrease in attendance was by far the biggest in the Chemistry course, which was carried out with a control group setup. Here the students experienced the biggest change: change of teaching method and change of lecturer at the same time.

In all cases, there is a slight improvement in the average score for the active learning questionnaire, however, much fewer students took the second test and one might reasonably speculate that given a reduced attendance, it will have been the more enthusiastic students that stayed and this is the reason for the improvement. This is confirmed by the fact that on average no significant improvement in the performance of the individual students between the two tests was found.

Table two presents the results of the survey. Only a relatively small number of students filled out the survey. For the students who filled out the survey there was a general enthusiasm for active learning. The enthusiasm was strongest in Classical Mechanics, where the students were more familiar with the active learning concepts. Here more than 50% stated that they would prefer active learning as a teaching method.

The students were also asked in the survey, what they learned the most from. Here the answers were quite equally distributed between different aspects of active learning, suggesting, as also pointed out by (Deslauries 2011), that there is not one particular aspect of active learning that is most important, but rather one must see it as a combination of several aspects.

Quite revealing was the fact that a large proportion of the students admit to having not prepared in advance for the lectures. It is pointed out in several places that it is particularly important for active learning that the students have prepared in advance. This could be an explanation why we do not see the positive effect of active learning that has previously been reported.

Course	Students present lecturing	Students present active learning	Questionnaire results lecturing	Questionnaire results active learning
Molecular Biology	About 120	67	147 answers Av. score: 4.5/10 (s=7.71)	88 answers Av. score: 4.8/10 (s=6.14)
Classical Mechanics	65	48	58 answers Av. score: 4.3/10 (s=2.53)	38 answers Av. score: 4.4/10 (s=2.27)
Chemistry and Energy	40	15	7 answers Av. score: 4.3/10 (s = 3.64)	6 answers Av. score: 6.0/10 (s = 1.10)

Table 1: Overview of student participation and multiple choice questionnaire results for the three courses. The questionnaires all had 10 questions.

Course	Answers	Did you Prepare for the lectures?	Would you prefer active learning?	What did you learn the most from?
Molecular biology	35	Yes: 27 No: 8	Yes: 16 No: 19	Discussion with other students: 12 (34%) Solving Problems: 8 (23%) Response from Instructor (43%)
Classical Mechanics	17	Yes: 7 No: 8 No reply: 2	Yes: 10 No: 6 No reply: 1	Discussion with other students: 4 (23%) Solving Problems: 5 (29%) Response from Instructor: 5 (29%)
Chemistry and Energy	4	Yes: 3 No: 1	Yes: 3 No: 1	Solving Problems: 2 (25%) Response from Instructor: 3 (75 %)

Table 2: Overview of selected results from the survey questionnaire.

4 CONCLUSION

No significant improvements in student performance were found after this experiment. The reasons for this may be manifold, but it is striking that many students report that they did not prepare for classes. The active learning approach demands more from the students, and in a society where higher education is easily accessible, the dedication and commitment from the students may sometimes be less than optimal. In our experience encountering unprepared students is not uncommon. One may speculate whether students to a larger extent needs to be schooled in active learning for it to be more successful.

The implementation of active learning for the chemistry class differed from the implementation in the other two classes, as the class was split in two. The turnout was disappointingly low for the active learning group, but it was still about one third of the turnout in the traditional class. This may reflect student resistance to change, and a tendency to prefer the familiar. The results for the chemistry group was also different, as the active learning group performed better than the regular group (60 % vs 43 %). Still, this may be explained by the larger variance in the regular group – both the best and worst responses were collected from this group. This, combined with the small sample size, makes the difference in performance not statistically significant. It may be interesting to note that for the chemistry class a third group existed. Many students did not attend any of the lectures, but seven of these did do the multiple-choice test. The results were strikingly similar to the active learning group: A score of 60 % with a standard deviation of 1.63. Maybe we should just skip lecturing altogether?

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