30

Improving learning in large classes with online quizzes

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Abstract
In this project I address the problem of teaching mathematics to a large class of first-year students in life sciences. I focus on the introduction of quizzes during the lectures (clickers) and online quizzes for self study. The motivation to introduce quizzes is discussed, the practical aspects of the implementation is presented, and their effect on the students' learning is assessed.

Formulation of the problem and hypotheses

Course and class description

The project concerns the course *Mathematics for Biologists*. This course is a first year course of the bachelor in Biology at the University of Copenhagen, consisting of about 3,75 ECTS. The course is part of a 7,5 ECTS course called *Mathematics and Statistics*. The statistics part runs independently of the mathematics part. However, the students obtain one mark for the combined course and they need 50% of the points in the combined exam to pass the course. That is, they are not required to pass the exam in mathematics and in statistics separately.

There are about 230 registered students, and a prerequisite is to have passed mathematics at A-level in high school.

In the course 2014/15, the subject was taught for 7 weeks, with two 2-hour lectures (except for the first two weeks, when there was only one

2-hour lecture) and one 2-hour exercise session per week. In the exercise sessions the students were divided into smaller groups and were given time to work hands-on on some exercises related to the content of the lectures and lecture notes.

Foreseen problems

I taught this course for the first time in the course 2014/15. Therefore, my understanding of the challenges with the course was based on collected information from the experiences of the teachers of the previous years and from dialogues with other first-year teachers of the bachelor in Biology.

The foreseen problems with the course can be summarised as follows:

(i) Lack of *engagement*, *motivation* and understanding of why it could be relevant for them to learn mathematics. The self-reported time dedicated to the course in the previous years was on average far from expected.
(ii) Lack of *mathematical skills*, specially on basic arithmetics learned in primary school.
(iii) Lack of *understanding* of the new material.
(iv) Lack of independence in learning and responsibility over their own learning.
(v) Lack of awareness from the teacher perspective of the student's learning.

Engagement and motivation in the classroom is associated with increased learning (see e.g. (Fredricks et al. 2004) for a study concerning learning in schools). The first day of the course the students were asked to answer three simple questions, aimed at verifying the extend to which problem (i) was a problem.

Questions:

(a) Are you happy about learning mathematics at the university?

Yes:	51%
No:	22%
Indifferent:	26%

(b) Do you understand why you should learn mathematics at the university?

Yes:	86%

No:	6%
I don't know:	9%

(c) What is the grade you expect to obtain in this course?

0:	5%
2:	12%
4:	18%
7:	31%
10:	18%
12:	15%

My interpretation of these results is that, *a priori*, the students were more positive about the course than what I would have thought. It was surprising to me to see that the expected grade actually follows a normal distribution.

Although it is not the university the place where problem (ii) should be fixed, it poses clearly a real problem when learning new mathematics. Therefore, it cannot be completely ignored under the excuse that *this is not my problem*. However, the content of the course cannot be changed to simply cover things the students should already master.

Problem (iii) stemmed partly from problems (i) and (ii), but I believed that it could also be a consequence of the format of the teaching activities, mainly the lectures. The students are not used to mathematics being taught in a lecture format and find it hard to relate to that[1].

Achieving independence in the learning process (problem (iv)) should be one of the learning outcomes of any bachelor. Hence it is a skill that should be trained in all subjects of the bachelor. However, I considered that independence in learning mathematics is not an expected skill of any biologist. Therefore, instead of focusing on helping them to be independent, I focused on removing the necessity of independence to master my course.

Finally, problem (v) is expected when teaching large classes in large auditoria, where direct contact with the students is reduced to small conversations during the breaks and the teacher can hardly get a clear picture of how the class is progressing.

[1] Some students expressed they could not believe that this is the usual way of teaching in the bachelor in mathematics as well.

Introducing quizzes

The course was reformatted in content and teaching approach. In particular, I introduced quizzes in two formats: during the lectures and online for self study.

Evidence on the benefits of IT-learning are diverse and documented (see (DeHaan 2005) for a summary). For this specific project, the rationale behind the introduction of quizzes during the lectures and for self study to address problems (i)-(v) is the following:

- For problem (ii): Questions involving basic mathematical skills can be introduced in quizzes for self study, thereby helping the students refresh their knowledge from primary and high school and, at the same time, not interrupting the flow of the lectures or exercise classes for the students that have the required background.
- For problems (iii)-(iv): Quizzes during the lectures are a way of introducing active learning in the classroom, an aspect known to increase learning outcomes (Freeman et al. 2014). Quizzes also help the students focus on relevant aspects of the lecture's contents. Quizzes for self study help them get a deeper understanding of the content and evaluate their own learning, for instance by realising aspects they have misunderstood. They provide also a *to do list* for students that require clear instructions on how to achieve the learning outcomes (that is, the non-independent students).
- For problem (v): Quizzes during the lectures provide direct feedback about the student engagement and understanding of concepts in real time. Quizzes for self study provide feedback about how much the students work on the subject, the level of understanding of the content of the course, and when they work on the course, e.g. do they work equally distributed along the block or mainly the week before the exam?.
- For problem (i): Motivation and achievement go hand on hand (Rea 2006, Robinson 1996). Motivation and engagement is positively influenced by activation during the lectures, the level of understanding and the confidence in one own's achievements (Rea 2006). Therefore, I considered quizzes to be also relevant for addressing problem (i). Additionally, I believe also that the format of quizzes for self study is appealing to the students that do not feel like putting aside e.g. two hours to learn math. The hidden hope is that the students start doing a quiz thinking it will take 10 minutes, but they get trapped with some question they do

not understand, and that this leads to them spending time reading the lecture notes and trying to understand some aspect of the course.

In what follows I describe how the introduction of quizzes was performed and evaluates how it might have affected their learning outcomes.

Implementation

Quizzes during the lectures: clickers

We used the online tool *Socrative* (http://www.socrative.com/) for the quizzes during the lectures. With this tool, the students can answer a multiple-choice question using internet connection from the phone, tablet or computer. I gave them 3-4 questions in each 2-hour lecture.

An example of one of the questions posed to them when learning about complex numbers is the following:

Question: Solve the following equation

$$x^2 - 4x + 5 = 0$$

The students were given some minutes to solve the equation. During this time I walked around the auditorium and answered questions, helping with problem (v). Afterwards, they answered online the following multiple-choice question (two of the options are correct):

Question: Which of the following is a solution to the equation $x^2 - 4x + 5 = 0$?

(a) $2 - i$
(b) $2 - 4i$
(c) $2 + i$
(d) I couldn't solve the exercise.

I could follow in real time how many of them had answered and what they had answered. The amount of time I spend in clarifying the answer and the given details were adjusted to the outcome. The practical aspects worked surprisingly fine and Socrative could handle the about 100 students that would answer the questions.

The tool by itself does not help addressing problems (i)-(v) above, other than introducing variation during the lecture. The tricky part is to choose the right questions and think carefully about the questions being asked.

Taking into consideration the recommendations in (Mathiasen 2011) on the choice of questions, I tested out questions of the following type:

- Application of a result
- Repetition
- Short calculations
- Interpretation of graphical objects (important for biologists)
- Intuition inviting
- Discussion inviting.

The choice of questions was adjusted as the course progressed. For example, I thought it would be a good idea to introduce small bits of "inductive" learning. To this end I gave them questions that showed some situations and examples and asked them to figure out a rule. However, the students got very confused and unmotivated with this type of questions and I dropped them later on.

As the course evolved I moved towards questions based on repetition of the topic being covered and involving short calculations. That is, I would introduce some result, exemplify it with some exercises, and then ask them to solve a small exercise. This seemed to work fine and most of them were actively working on the exercises during the lectures.

Socrative provided not only a tool for the students to follow the lecture, but also gave me a clear picture of what was going on in the room. A typical day would start with most of them answering the questions, but by the end of the lecture only half of them were answering. I suppose they were getting lost and stopped listening, but this is definitely an aspect one has to address and avoid. One possibility why this happened is that I planned the lectures such that knowledge was being build as the class developed. Although this is a typical approach in mathematics, it means that when a student gets lost, there is no way back in. Therefore I think that next time I teach the course I should plan the lectures with "catching points", such that the students that get lost in one step, can get back in after a short while.

Quizzes for self study

There were a total of 9 optional online quizzes and 1 obligatory quiz (although it was not obligatory to pass it). To motivate them to take the quizzes

and to align the learning tasks with the assessment of the course, they were told that half of the exam would be multiple-choice based, with questions similar to those in the quizzes.

After taking the quiz, the student would only know whether his/her answer was correct, but in case the given answer was not correct, the correct answer was not given to the student. However, the students were allowed to take the quiz as many times as they wanted. The goal with this strategy was to give the students time to think why their answer was wrong.

I suggested them to take the quiz right after the lecture to assess the learning outcome of the lecture, and then again after having studied the material and done the corresponding exercises. A very small group of students followed this suggestion.

I combined easy questions based on repetition with questions that required a deeper understanding of the topic. I also added a few questions addressing typical misunderstandings.

The overall participation in the online quizzes was not as high as I would have wished. As of July 2015, the participation in each quiz is the following:

Fig. 30.1. The overall participation in the online quizzes.

Evaluation

Evaluation of the effect of the quizzes in the students learning and in particular in handling problems (i)-(v) is performed based on the following points:

- The students' comments in the course evaluation survey (45% of students answered the survey).

- The final grade.
- Focus-group meetings: three times during the block a group of student representatives meets with the teachers of all the subjects in the block and discusses the progression of the course. A summary for each meeting is produced.

The self-reported time devoted to the course increased, with the percentage of students working between 15 and 25 hours per week on the course raising from 43% to 61%.

Although the student's evaluation of the quizzes in the survey is not necessarily correlated with how much they learned, it is still an important measure. For a course in mathematics in the life sciences, I consider it is extremely important the overall satisfaction of the students with the course, because that is the main motivation they have to learn.

Final grade

About 205 students took the final exam in January. The final grades for the combined subject Mathematics/Statistics are distributed as follows (the distribution is not that far from what the students expected):

0:	15,6%
2:	5,9%
4:	20%
7:	28,3%
10:	19%
12:	11,2%

If we consider exclusively the mathematics part, then the pass percent is at about 72%, which is 10 point higher than the year before. Of course the group of students changes every year and comparisons cannot be easily done. One could also argue that maybe the exam was easier, but I do not believe this was the case. On the contrary, the use of multiple-choice questions allowed me to evaluate more aspects of the course in the exam.

The students grade cannot be taken as a direct indicator of the effect of quizzes in the students' learning, because other changes not discussed in the report were also introduced to the course. However, combined with the students comments, it is fair to assume that they contributed positively.

About Socrative

Socrative was generally well received by the students, to the degree that the two subjects they take in parallel to mathematics (*Statistics* and *Population Biology*) are considering to use Socrative from next year on.

The students valued the tool positively because it introduced variation in the lectures, and because it made them think about the content that was being discussed. Here are some specific citations (in danish):

- "Socrative var en rigtig god måde hvorpå man fik mulighed for at sætte sig ind i kurset og tænke over mulige svar - så til næste år, bliv ved med det!"
- "Når man engang imellem i det sene timer har siddet og faldet lidt hen og mistet koncentrationen, kom man da lidt med igen ved at bliver involveret i form af spørgskemaer på Socrative."
- "Brug Socrative, holdt mig vågen og opmærksom!"

For many of them, Socrative meant variation during the lecture and hence it helped them keep concentration, in agreement with the studies on student activation (e.g. (Freeman et al. 2014)).

Some students expressed though that Socrative took too much time during the lectures. The time variable is definitely a critical aspect of the use of clickers during lecturing (Mathiasen 2011). It seems impossible to find the right time, such that all students learn optimally. To me, for large classes, the question is to decide whether there is a gain when looking at the class in average, and not at the individual learning. In my particular case, there seem to be enough evidence that the students valued the use of Socrative.

About quizzes for self study

The students expressed that they liked the questions in the online quizzes because they helped them follow the course. They specially valued the obligatory quiz, which forced them to really take things into matter and work on the subject. The suggestion they gave me was that there should be more obligatory quizzes!

Here are some specific citations (in danish):

- "De ekstra quizzer i matematik har også været rigtig rare, da man føler sig mindre lost, når man har lidt svarmuligheder at gå ud fra. Den obligatoriske opgave var faktisk også en positiv oplevelse! Jeg selv, og andre jeg har snakket med, fik et meget mere afslappet forhold til tanken om en eksamen, efter at have taget testen med gode resultater."

- "Quizzer i matematik var godt, så man fik en fornemmelse af hvor man lå."
- "Det var super med obligatoriske quizzer (...) Gerne flere af dem, så man bliver tvunget til at få styr på tingene undervejs (og så underviserne let kan se, hvor det halter...)"

Conclusions

Overall I think that the use of quizzes, both during the lectures and for self study, have contributed positively to handle problems (i)-(v) outlined above. They helped in creating a good atmosphere during the lectures and in the course overall, in that the students felt they had enough structured material to work with and that they were guided towards what they should learn.

Changes need to be made in the type of questions being addressed during lectures. One also needs to think about ways such that the faster students do not have the feeling of wasting their time while waiting for the rest of the class to finish the small exercise. The fail of inductive questions was disappointing, but maybe the error was on the specific questions being asked, and not on the fact that they were inductive. I will definitely try to introduce them again, after reconsidering what might have gone wrong.

The survey and the focus-group meetings point at that the students found the type of questions in the quizzes useful, but they did not take them as often as desired because of deadlines with another course. Considering that the average time the students devote on the course is still a bit below expected, the possibility of more obligatory quizzes needs to be considered. This is in principle against the idea that the students need to be responsible for their own learning, but, as discussed above, maybe it is not this subject the place to achieve this.

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2015-8/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/

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