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Large-scale flipped classroom with a single lecturer

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Abstract

The flipped classroom is a setting for blended-learning courses which is generally considered to be effective at a small scale involving many teaching assistants. This paper describes a flipped classroom concept for large classes which can be conducted by one single lecturer while keeping the quality of teaching high. A core pillar of this approach comprises well designed threads of single and multiple-choice questions which have the potential not only to check learning objectives but also to foster deeper learning.

1 Introduction

With the rising availability of technical devices, instructors are able to distribute their learning materials freely and without depending on the physical presence of students. The flipped classroom (FC) is a teaching approach in a student-centered instructional framework which aims to use contact time more efficiently by placing the learning steps which require direct feedback in the classroom, whereas self-directed and individual learning steps like reading book chapters, watching instructional videos and taking automatically graded quizzes are conducted by students on their own (Tucker, 2012; Bishop, Verleger, et al., 2013).

It is generally considered challenging and labor-intensive to set up FCs for large groups of several hundred students (Brewe, 2018). Some people (e.g. Spannagel, 2018) deny outright their feasibility with 500 or more students. The main topic of this paper, however, is the large-scale FC approach developed by the authors. It is based on clear instructions for self-directed studying combined with didactically designed threads of single and multiple choice (SC/MC) clicker questions which can be administered by a single lecturer. While using SC/MC clicker questions is far from groundbreaking, it was important for us to not lower our standards concerning breadth and depth of learning. We developed a storytelling approach for threads of SC/MC questions.

In the final section we present feedback and evaluation results from students and lecturers.

2 Challenges

Typically, teaching in FC mode poses several problems as the class size increases. It becomes more difficult to oversee which questions and problems the students encountered in their individual preparation. In a small scale setting, the lecturer would read written feedback, take individual questions at the beginning of the physical lecture, or even have teaching assistants roam through the class and find the muddiest points of understanding. All these approaches rely on a limited class size below 100 students, with the amount of help involved increasing. Since teaching staff is often costly, if available at all, we aimed at finding a single-lecturer solution.

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Furthermore, one usual effect of blended learning is a trade-off between increased quality and reduced quantity of content. It was our goal to find an approach which does not sacrifice content.

Finally, students might not be used to blended learning approaches where they first encounter new material without a lecturer explaining it.

3 Our single lecturer solution

In two one-year undergraduate calculus courses for engineering students, both involving several hundred students and normally taught through direct instruction, we set up an FC intervention lasting for two weeks to teach complex numbers. This topic was chosen for several reasons. Swiss high school students have no central final exam; some will have learned about complex numbers in their mathematics classes, but others not. This knowledge gradient enables peer instruction to work efficiently. Further, the topic is also largely independent of the other course content and is not crucial for the final high-stakes course exam.

Students were given an interactive online script containing reading material, interactive exercises, narrated video explanations and interactive GeoGebra visualizations. Before each class, they received a so-called "road map" consisting of carefully designed instructions on which sections to read and which online quiz questions to answer, together with guideline notes for the class. Here's an example:

> For the Monday class, you should finish chapter 4. In this part, we will learn more about polar coordinates and use them to find complex roots. You can find the PolyBook at: `https://wp-prd.let.ethz.ch/WP0-CIPRF9961/`
>
> - 4.3 to 4.7, more about polar coordinates:
>   - Read the text and play around with the applets to get a geometric understanding of multiplication and division.
>   - The video in section 4.7 reviews what we've just learned.
>   - As always, if you need more examples, try to make up your own! At this point you might want to go through the clicker questions asked in the previous classes again.
> - 4.8, trigonometric identities:
>   - This rather short section tells you the secret on how to find your own trigonometric identities in case you need them!
> - 4.9, complex roots:
>   - This section is the most important part of this road map! Work through it carefully, watch the videos, use the applets.
>   - Subsection 4.9.2 on square roots is not vitally important, but it provides some helpful context. If you want to know more, watch the fascinating Mathologer video!
>
> As usual you can solve some introductory questions in EduApp. We will review them on Monday.
>
> Have fun and see you on Monday!

Classroom time was then spent on going through threads of SC/MC clicker questions of increasing difficulty and complexity. The next section has more details on threads.

A regular exercises session with student teaching assistants based on direct instruction with formative assessment are always part of these courses, but they were not altered to match the intervention and took place in the classical fashion.

4 Storytelling through clicker threads

SC/MC questions are generally considered useful for low complexity tasks. While it is feasible to ask difficult questions in homework, settings with narrow time limits such as classroom clicker sessions nudge lecturers towards asking simpler questions. In this section, we present clicker threads to enable deeper learning instead of disjoint problem-solving exercises.

Our experience shows that storytelling is an effective way to foster deeper learning. We imagine the learning process as a path composed of clear stages; in this way, it is like a story. The lecturer's task is to lead the students through these stages and to illuminate the path leading them towards mastering a certain concept. Every stage of teaching therefore needs to be a chapter of the story, with a clear narrative arc linking the different steps of the learning process.

Stories start at the beginning. In our setting, we ask simple and low-complexity homework questions, setting the frame on what to think about, and how. Classroom clicker questions then do not just illustrate the reading material, but explore the world we created in a deeper and more adventurous way, still asking SC/MC clicker questions following the story arc we designed, but with higher complexity.

Let us demonstrate this method using an example. The following problem appeared in the original tradtional lecture while the topic of complex conjugation was taught:

> Assume that $(3+4i)^{15} = A + iB$. Compute $i(3-4i)^{15}$ using the given A and B

To solve the problem, the students need to understand the following steps:

- The link between multiplication and conjugation
- The link between power laws and conjugation
- The influence of multiplying by *i* on the real and imaginary parts

In a traditional lecture these topics are taught separately, and when we reach the above example we have no means of verifying that each of the topics or steps have been successfully mastered by the students. We hope that by explaining the solution, the students will be able to identify and connect these different components or learning stages, leading to mastery of the concept of conjugation. Unfortunately, our experience shows that a large portion of the students remains confused even after studying the solution to the problem.

	Didactical goal	The question we asked
1.	Verifying basic multiplication	Compute $(5+3i)(4-8i)$
2.	Combining complex conjugation with multiplication Discuss $\bar{z}\bar{w} = \overline{zw}$ in class	Compute $(5-3i)(4+8i)$
3.	Verifying power laws, anticipating $\left((1+3i)^2\right)^2$	Compute $(1+3i)^4$
4.	Combining complex conjugation with power laws	Compute $(1-3i)^4$
5.	How is the real part of a complex number affected by conjugation, power laws and multiplication?	True or False? $\mathrm{Re}\left((3+i)^4(5-7i)\right) \stackrel{?}{=} \mathrm{Re}\left((3-i)^4(5+7i)\right)$
6.	The original task	Assume that $(3+4i)^{15} = A + iB$. Compute $i(3-4i)^{15}$ using the given A and B

Creating a story arc for our FC setting requires us to break down the original problem into steps which can be asked as single SC/MC questions. We first check if students have a basic understanding of complex multiplication, real and imaginary parts, and power laws. The thread of questions will add one more component with each question, allowing the lecturer to see precisely where students struggle, even in large classes. It also enables most students to solve the problem independently and understand its solution steps.

The sequence we designed uses the original question to develop the knowledge and understanding required for its solution step by step. It also makes sure that several basic concepts have indeed been assimilated through the students' independent preparation. Finally, it leads the students to successfully integrate the acquired insights (cf. Bloom, 1956, and Krathwohl, 2002). Almost all of the students were capable of answering the last question correctly, which shows a high level of understanding of the material, with the students able to put together the different methods and ideas learned in order to reach the final answer. The lecturer can steer the learning process in such a way as to create a story arc, and to use this arc to draw attention to all the important step, leading towards mastery of these concepts.

5 Findings

As the topic is only a small part of the entire course it was not possible to do any quantitative measurements of the exam results. From a survey among students we came to the conclusion that student opinions were very diverse. Still, most had the impression of having deepened their understanding. It was mentioned, though, that this setting is very time-consuming.

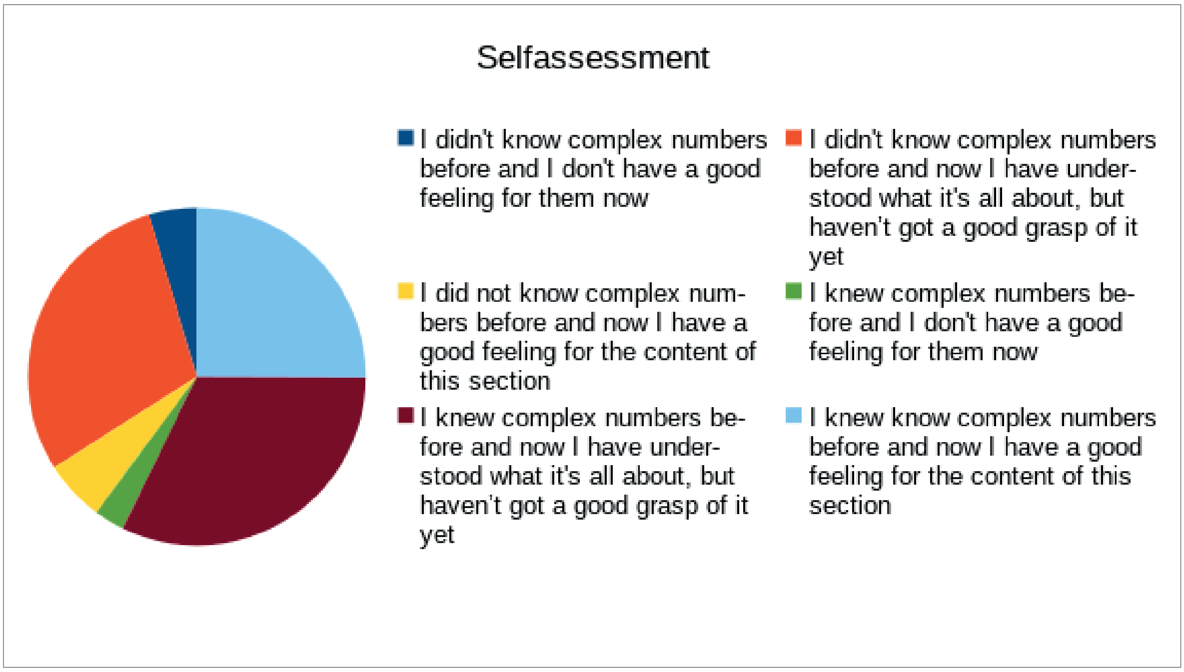

Figure 1

However, the results regarding time spent for preparation are on the levels we aimed for. We are not sure if we are actually overburdening students as the written feedback suggests, or if they simply invested less time in a traditional setting than we would have expected. This might also explain the mixed popularity of our approach.

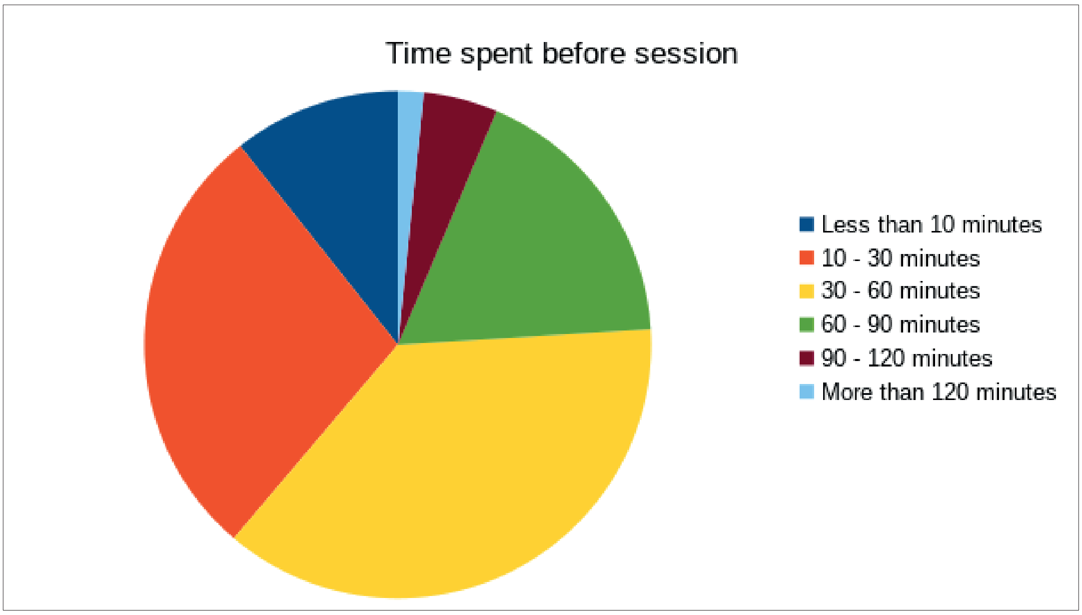

Figure 2

As lecturers this experiment gave us a much deeper insight into the student's learning process: difficulties were quickly identified and discussed. FC enhanced interactivity and peer instruction can very fruitfully be integrated.

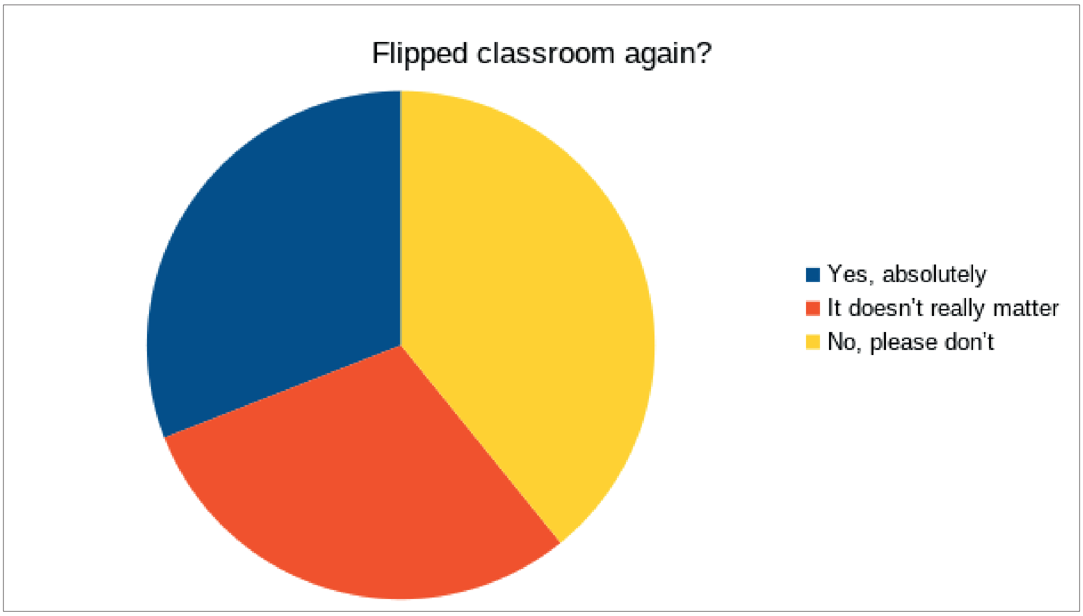

Figure 3

6 Conclusions

To summarize, we can positively answer the two questions posed in the introduction. Yes, the FC is possible in large classes with up to 700 students. It needs careful preparation in terms of both content and logistics, but then a positive learning situation can be created. Through the concept of threads of questions we managed to deepen the students' understanding more than in classical lectures.

However, we think that in our setting it does not make sense to teach the whole one-year course in FC mode. Our teaching and examining relies on a long revision period in the summer where much of the material is studied and understanding is deepened. The FC would, time-wise, go beyond the scope of what is possible during the semester.

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