28

Evaluating Interactive teaching on conceptual understanding on medium enrolment classes

Nikos S. Hatzakis

Department of Chemistry
University of Copenhagen

Abstract

Interactive learning is increasingly being valued as an ideal environment that promotes critical thinking, conceptual understanding, intellectual development and success. The beneficial effects of interactive lectures though very well established for small classrooms are often debated for larger classes. My hypothesis is that interactive lectures can easily be introduced to large classrooms and that students' engagement understanding and academic achievements can be greatly improved by constructively aligned interactive lectures. The purpose of my project is to evaluate the effect of interactive teaching on students' engagement, conceptual understanding, as well as academic achievement and performance on medium enrolment (~55 students) classes. This is particular important for me as up to now I have been successfully implementing interactive lectures in small enrolment classes (<20 students) and now faced with the challenge to teach by myself a medium enrolment class (50 students) of the 2nd year students.

To test my hypothesis I applied a series of actions on the course Nanobio 1 of the Nanoscience education some of which are shortly mentioned here: A) Interview with group of students after the end of the course. B) compare their understanding (using online tools) between subject taught using classical
lecturing/preaching and subjects taught by interactive discussions C) compare students performance (grades) on subjects that are "preached" in the form of classical lectures, subject interactively discussed in the class and

subjects that are both interactively discussed and applied during practical exercises.

My results showed a remarkable increase in correctly answering the exam question, from 45% for subjects only lectured to 70% for subjects interactively discussed and 87% for subjects interactive discussed and applied in practical exercises. Similarly online quizzes using Student Response Systems (SRS) like *Socrative* showed an increase from <30% to often more than 90% in students ability to apprehend and interactively discussed subject and correctly answer a multiple choice question when knowledge is attained in the form of interactive processing of information.

Results and Discussion

Introduction

Interactive learning is increasingly recognized as an invaluable tool in promoting critical evaluation of information and attaining increased levels of conceptual understanding, intellectual development, and success. Most modern textbooks claim that students learn by actively processing the information (Popovic 2013, Cowan 2012). They also show that involvement in active discussions are more likely to stay "on task" and spend more time synthesizing and integrating concepts, relative to students who passively spectate lectures (Cuseo 2007), and importantly develop more positive attitudes toward the course's subject matter (Cuseo 2007). Interactive teaching strategies however are challenging to implement within the constraints of classical training which in turn increase faculty reliance on classical "lecture" methods. In fact the classical lectures, despite their limited effectiveness, is widely used by many academics to fulfill the mandate for regular didactic sessions on large number of students.

One of the main reasons behind this is often the sheer size and anonymity of large classes that seems to militate against the very elements that promote students' involvement. In fact as McKeachie (1980) notes, "[Class] size and method are almost inextricably intertwined, large classes are most likely to use lecture methods and less likely to use discussion than small classes". This consequently causes reduced frequency of instruction interaction and iteratively resulting in less active student and reduced *depth of student thinking* inside the classroom. Importantly it may initiate maladaptive mental habits or predispositions to learning generating passive seekers and transcribers of information rather than critical thinking and inquiring students (Blatchford et al. 2011). But how possible is it to attain all the beneficial results of interactive learning in classrooms with medium to high enrolment? I was recently faced with this challenge as I was assigned to teach full time a 2nd year of the Nanoscience education, Nanobio 1 with ~50 participants. The course was often discussed as needing both to improve its interactive nature and to achieve better student satisfaction. Importantly while I have been 2 implementing interactive discussion in smaller classes (<20 students) I have never had to apply this methodology to medium enrolment classes.

To deal with these objectives I performed 3 actions.

1. Designed and extensively used quizzes that evaluated in real time students conceptual understanding in subjects that were "lectured" or "interactively discussed". Quizzes were performed using online Student Response Systems (*Socrative*)
2. Designed exam question that targeted subjects that were a) "lectured", b) "interactively discussed", or c) "interactively discussed" and directly applied in the practical exercises
3. Formed a focus group of 6 students that were interviewed to provide an elaborate qualitative assessment of their opinion on the methods.

Methods and some details for the course

Online quizzes were valued using *Socrative*. Students were always given multiple choices (usually 5) to choose from within ~3 min. When team discussion was involved time was extended to ~6min. ~2-3 Socrative question were presented to the students per hour of a teaching occasion.

"*Lecturing*" a subject used for the evaluation corresponds to ~15 min of me preaching while showing slides or/and writing on the blackboard.

"*Interactive discussion*" on a subject used here for the evaluation corresponds to ~5 min of providing the basic information (in the form of slides and/or writing on the blackboard) and ~10 min where the student were discussing. Students' discussion in the first teaching occasions was gently guided by me being part of the discussion and appointing the next person to talk). At later stages (when students got acquainted with the discussion concept) my role was minimized to an observer.

Exam question were designed to target a subject similar to what "lectured" or "interactively discussed" in the class but it was never identical. The exam question always had a sub question for students to explain their choice. Students answering correct and scoring >50% of the total points of the exam question were considered as correct for the purpose of this study while students scoring <50% of the total points were considered as wrong.

In order to supplement the results obtained with the above methods with qualitative feedback, I conducted a 90-min focus group interview with 5 students from the course. They were given o questionnaire of 16 question were they had to provide a short 1-2 sentence answer. Subsequently we started a more in depth discussion of the answer ~5 min for each question. The interview was recorded on an iPhone 6 with the Voice Memos application. After the interview, all comments from the focus group were typed in to an excel spreadsheet. I did not attempt to fully quantify the responses, but have quoted some of the representative comments in the text.

Some more info for the course

6 hours of *teaching occasions* per week for 6 weeks, 2 weeks of *practical exercises* and 2-3 hours of *tutorial* per week for 3 weeks where students were taught to what they needed to write their graded report: a) use online tools to search literature (such as e.g isis web of knowledge) and Endnote to import references in the word files, b) use software to draw protein structures find and highlight positions of amino acids c) how to critically read articles, evaluate and write by themselves abstracts. During teaching occasions Each week students had to deliver a non graded (but compulsory to take the exam) set of problems. Subjects similar to the weekly problems, practical exercises and the *Socrative* quizzes formed the basis of the final exam questions.

Effect of interactive teaching in conceptual understanding and overall satisfaction

Introduction and use of interactive tools and Student Response System in medium sized classes.

The first steps in introducing the interactive discussion into the class were facilitated by the use of *Socrative*. Initially students were called to answer by themselves the quizzes, later on, to discuss in teams of two before answering. Towards the end of the course most student (~50%) overcame the barrier of talking in the class and were contributing actively to the discussion. *Socrative* was used to evaluate (rather than introduce) the 3 results of the discussion. Discussion at this point was either taking place in teams of 3-4 students or in the whole classroom with minimal contribution from my part.

During the focus group meeting students enthusiastically commented on *Socrative* as a tool to both facilitative real interactive discussion and to promote intellectual development. In detail they found it to be "an excellent way to make sure that you have understood the concepts", as "...it anonymously allows the real evaluation" while a third one commented "...it maintains you alerted throughout the lectures but also helps weak students not to fall asleep". A third student noted that "...it eliminates the fear of embarrassment" of not having understood something but feeling too embarrassed to say it.

The fact that ~22% of students (6/26) evaluating the course on Absalon noted that they would like even more (currently 2-3 per hour) *Socrative* quizzes to be implemented in the course shows *Socrativ*e to be well appreciated. These results strongly support SRS tools to be instrumental in triggering students' attention, maintain them alerted and "on task" throughout the teaching occasion time, and last but not least to promote active student involvement and consequently learning.

Role of Interactive discussion in conceptual understanding

Interactive learning environments are widely considered as ideal suited to give students personal validation and frequent feedback on their work, set high expectations and consequently to promote critical thinking conceptual understanding, and intellectual development. Their implementation however in medium to large enrolment classes is challenging and most institutions rely on classical lecturing methods were students are passive spectating knowledge preaching. Importantly the beneficial effects of interactive learning are often questioned in medium/large (>50 students) classes. My hypothesis is that interactive lectures can be introduced to large classrooms and that students' engagement and conceptual understanding can be greatly improved.

To evaluate this hypothesis we performed a direct comparison of student understanding of a concept using *Socrative*. A concept (why the charge of amino acids depend on the pH of a solution) was introduced in to the classroom in the form of a classical lecture. The introduction lasted for ~15min where I presented multiple slides with various ways to evaluate and interpret the concept. Subsequently the students were asked to select the correct answer out of a multiple-choice question quiz using *Socrative*. The data presented in fig 28.1 show that ~46% of the students answered correctly within the first 3 min. As a comparison another – more challenging – concept was introduced for 5 min and then interactively discussed in the class for ~10min (assigning the diastereomers of amino acids with multiple chiral centers). The students were then asked to select for the correct answer out of a multiple-choice question quiz using *Socrative*. The immense improvement in students understanding is highlighted in fig. 28.1 where ~95% of the students correctly answered the question.

Fig. 28.1. Comparison of level of understanding attained by a) lecturing (~15min) on a subject and b) providing the basis (~5min) and allowing interactive discussion (~10min) for students to understand a different subject.

To further examine the role of discussion between peers in students critical evaluating and understanding concepts we performed another test using *Socrative*. A multiple choice question was posted (fig 28.2ab) were two questions (option A and C in fig 28.2ab were correct and the students were given the option to select each of the correct answers, both (option D), another one (B) or none (E). After selecting their answers the student in teams of 2-3 discussed the answer without any contribution from my part and voted again. Before the discussion only 20% of the students had provided the correct answer (D in fig 28.2a) while 76% of the students had selected the first or the second of the correct answers (A or C) respectively. Remarkably after 3 minutes of discussion with peers 87% of the students answered correctly (fig 28.2b). The same experiment was performed twice (fig 28.2cd) using the same principles on a more challenging concept. In this case none (0%) of the students had found the correct answer (D in fig 28.2c) while 32% and 16% had selected each of the two correct answers.

After the discussion 68% of the students selected the correct answer (D in fig 28.2d).

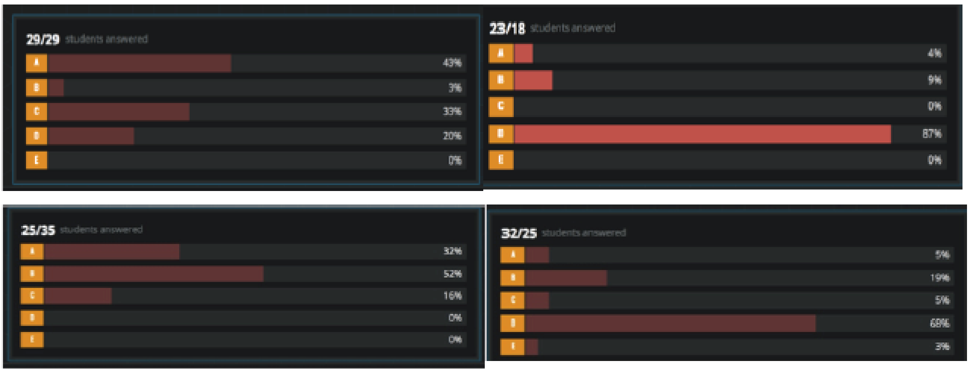

Fig. 28.2. Comparison of the level of understanding after on a subject before (a and c) and after (b and d) discussion with peers. In the first case ~20% of the students responded correct (D option) before discussion, shown in a), while 87% of them responded correct after discussion, shown in b). In the second case ~0% of the students responded correct (D option) before discussion, shown in a), while 87% of them responded correct after discussion, shown in b.

The opinion of students on the interactive lectures was explicitly discussed in the focus group. All participant students agreed on the success of the interactive discussion in attaining critical and conceptual understanding of the principles. They portrayed the advantage of the “non-judgmental” discussing with peers – as compared to the “intimidating” discussion with the professor – in critically evaluating and even doubting the information. As students highlighted “you had to listen to people at your own level and use your own knowledge to doubt and evaluate the information”. A second student found it as being a “non judgmental form of pertaining knowledge” or as another noted “if you said something wrong you were not looked down on you” while a third student found it “... as a good training for the exam as you put your own words in a argument” as compared to just listening and trying to memorize to an argument.

Importantly students highlighted the beneficial effect of direct and active processing of knowledge in mastering conceptual knowledge by saying “in depth knowledge comes when you apply immediately what you just heard/learned rather than have to wait until the exam”.

Students also highlighted that interactive discussions are “inspiring” and “motivating” as one student noted “... I know I can do it, hypothesize a solution/mechanism. This motivates me to fight harder challenges and find my way through this course". Another student also said "(being able to understand and hypothesize solutions)... boosted my self confidence and motivation" something that the whole study group agreed. An another student highlighted its beneficial effect in owning science, "a perfect way to learn new stuff. I think all courses could learn form this. *It felt you were part of the world of science*".

Similar comments and feedback was provided by the students using the absalon online evaluation. "...letting the students participate actively in the lecture is spot on! And the way you are alive and interact with the students is the way to go and make the lecture much more personal". The overall satisfaction of the students is also reflected by their comments on absalon where they used phrases such as "eye opening course" "very interesting and engaging course".

The results of these tests support our hypothesis that *interactive discussions can be implemented in the medium enrolment classes and furthermore so advantageous effect in strengthening student ability to critically evaluate knowledge consequently facilitating deeper, conceptual, understanding and intellectual growth*. In addition it appears to promote students inspiration, motivation and importantly satisfaction of their performance, all of which would propagate to their overall satisfaction of the course and the education system.

Interactive discussions/tools in preparation time and performance in exam

We then examined the role of interactive environment in the reading/preparation hours of the student as well as their level of understanding and performance in the exam. To do this we initially designed exam questions on subjects that were either simply "*lectured*" or "*interactively discussed*" in the classroom (see Methods section for disambiguation). Due to the limited amount of question in the exam only one question for each of the two methods was prepared.

Students severely underperformed in subjects simply "lectured" in the class (phase states of phospholipids dependence on their structure). As shown in fig 3a only 45% of the students (21 out of 46 student that attended the exam) answered correctly in a subject that was "lectured" for 30 min in the class. In comparison ~70% of the students (32 out of 46) responded correctly in an exam question that was interactively discussed for ~30min in the class, fig 28.3b (titration curve of amino acids). These data signify the importance of interactive environment for conceptual understanding though improved statistics would be required to solidify this further.

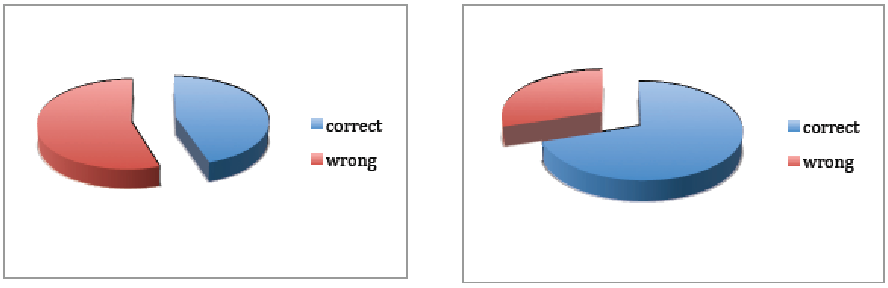

Fig. 28.3. Comparison of students' performance on the exam on subjects a) only lectured in the class b) interactively discussed in the class. The fraction of students that understood the concept and responded correctly in the exam was increased from 45% for a subject taught using classical lecture (phase states of phospholipids dependence on their structure) to ~70% for a subject taught using interactive discussions (amino acid titration curve).

To evaluate the time students spend in preparation for the lectures we interviewed the study group. The study group students had attended more than 90% of the teaching occasions. The results of the interview show relatively high preparation time for the teaching occasion. All (6/6) of student wrote they were prepared for most of the lectures (*almost every time*) while their preparation time was 1-1.5 h and as they noted, "I had to be prepared for the teaching occasions otherwise I was lost".

Importantly the study group highlighted that the *interactive lectures helped them read less for the exam*! The argument of one of the student 4, that all participants of the study group agreed on, was that ".. because we had to be prepared for every lecture, applied and understood the concepts we almost did not have to read any further for the exam."

Our results convincingly support students in interactive courses are forced to invest more time in preparation, directly evaluated and apply attained knowledge committing to deeper understanding of the principles and consequently requiring often less time to prepare and excel in the exam. In total the findings here support interactive teaching to be associated with a host of positive student outcomes on ranging from student attention retention, to critical thinking, and educational aspiration, in agreement with earlier studies(Astin et al. 1997, Lewis 1992).

Constructive alignment on exam performance and general student satisfaction

The role of constructive alignment between theoretical teaching and practical exercises was subsequently evaluated. I particular I was interested in identifying a) the effect alignment of theory and practical exercises as well as team work on students conceptual understanding, intellectual growth and performance in the exam and b) a possible correlation between students enhanced learning and intellectual growth to their overall satisfaction for the course.

To test for these I performed the following actions. A) The protocol for the practical exercises was lacking most calculations of amounts of chemical needed and some details of how to perform the experiments. The way to design and perform the calculations as well as how to logically think, design and execute the missing experimental part had been discussed during the teaching occasions. Students therefore had to simply critical think (in teams) and apply the conceptual knowledge they attained so as to perform the practical exercises. B) Exam questions were designed to target subjects similar to the ones applied in the practical exercises (and interactively discussed in the class). The students scoring on these exam questions was then compared to their scoring in subjects that were only interactively discussed during teaching occasions.

Students of the study group commented very positively both on the alignment of practicals with theory but importantly on their enhanced understanding by having to think in groups. One student found that "everything we needed was built in from the lectures and practical, we learned (by interactive discussions) to deduce/build concepts from first principles". A second student commented that "we actually had to think for ourselves and directly apply the principles we had learned in the course", or another "I actually had to think and was forced to work with every detail of the experiment" while another added, "yes *this was not just a cake recipe but real science*". Importantly students highlighted the beneficial effect of such methodology, as one says "I can remember every details of what we did in contrary to XX course's practical exercises that I cannot remember anything at all", something that all agreed. All students agreed to this comment.

The quantification of the beneficial effect of the critical thinking of the practicals and their alignment with theory was done by the exam results shown in fig 28.4. These show a remarkable increase on the students' scoring on subjects interactively discussed from 70% correct (fig 28.4a) (amino acid titration curve) to >87% correct for subjects both interactively discussed and applied in the practical exercises (fig 28.4b) (michaelis menten kinetics). It should be mention here that the exam question were targeting the conceptual understanding that students should have developed, and they were not a direct repetition of exactly what they did during the practical exercise. Notably, additional similar experiments would eliminate putative variations in the difficulties of questions and strengthen the results here. The overall satisfaction of the student is highlighted by their very positive comments outlined here and the fact that all students wrote that they liked the course (3/5 gave 5out of 5 stars and 2/5 gave 4)).

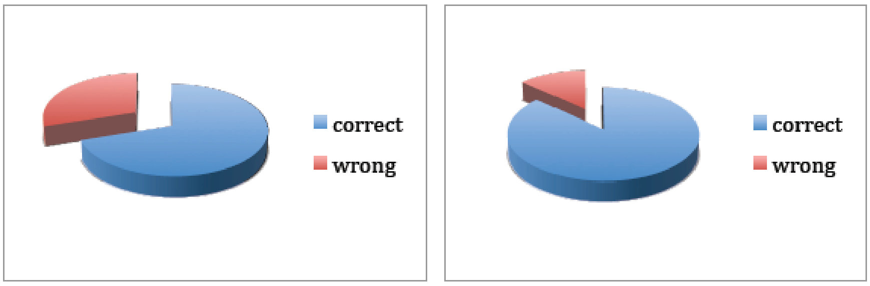

Fig. 28.4. Comparison of students performance on the exam on a concept a) interactively discussed in the class, b) as in (a) but also applied in the practical exercises. The fraction of students that understood the concept and responded correctly in the exam was raised from 70% for a subject taught using interactive discussions (amino acid titration curve) to ~87% for a subject taught using interactive discussions and applied in the practical exercises (michaelis menten kinetics).

These data support that active processing of information significantly augments conceptual understanding. Reading and interactive discussions may provide the strong foundation for deep, conceptual, understanding, but it can – and should be – significantly enhanced when a concept discussed in the class is applied in the in practical exercises. Constructively aligned therefore practical exercises with theory appear as instrumental in promoting intellectual growth and academic achievement.

Discussion with the department Supervisor

The department supervisor, Per Hedegård statistician from Niels Bohr institute, acknowledged the quality of the research the concepts the interpretation and the intriguing results that emerged. The main critical comment of the discussion that we had during the design of the actions, was that the statistical soundness of the exam results (figs 28.3,28.4) would be significantly enhanced by performing the same actions for multiple questions in additional classes, for different levels of the educational system and varying academic fields. This way the potential variation in difficulties between the exam questions used to evaluate classical Vs interactive teaching effect would be eliminated. This valuable comment, though practically impossible to implement within the time and scope of the project, prompted me to design and execute the socrative tests that are discussed in figs 28.1-28.2 here (note that data are presented in reverse order in the project description). The two tests of fig 28.2 evaluate in the same question students understanding before and after interactive discussion. Though enhanced statistic would further solidify these data they augment our confidence that interactive teaching increases student understanding in medium enrolment classes.

Conclusions and Perspectives

Active involvement in teaching occasions seems to make the course engaging and motivating triggering students' inspiration and excitement. Interactive discussions were found pivotal tools in *combining* students' own knowledge to *criticize* and *compare* the information provided by their peers allowing them to *hypothesize* and *formulate* their own arguments. This is highlighted both by the *Socrative* quizzes and the exam results illustrating dramatic enhancement of students' performance in conceptual understanding on subjects interactively discussed into the classroom. Though more robust statistics would be required to further solify the observed trends our results do show subjects taught by interactive lectures to be unequivocally better understood by the students since 70% of them answered correctly in the exam as compared to 45% on subjects taught by lecturing/preaching. Students recognized the advantageous effect of formulating their own arguments as a good practice for the exam. Importantly alignment of the practical exercises with theory further enhanced students understanding scoring ~87% correct answers in the exam, highlighting that further – critical – processing of information in the form of group aligned practical exercises is an elemental tool in attaining fundamental understanding.

Our result in summary support student faculty interaction to be strongly associated with a host of positive student outcomes ranging from a) student retention, (b) academic achievement, (c) critical thinking, and (d) educational aspiration (Astin et al. 1997, Lewis 1992). It may now be time to apply the principle of interactive learning to the redesign of teaching methodologies, creating more opportunities for students to indulge in critical discussions evaluating and perpetuating knowledge provide a learning environment that is conducive to both student engagement and student success.

It may now be time to apply the principle of interactive learning to the redesign of teaching methodologies, creating more opportunities for students to indulge in critical discussions evaluating and perpetuating knowledge provide a learning environment that is conducive to both student engagement and student success. We may thus replace mediocre student performance and passive knowledge seekers to critically thinking inquiring engaging minds predetermined to achieve academic and professional success.

A (Interview questions of the study group)

1. How many lectures of Nanobio 1 did you attend ?
2. I liked the Nanobio1 1 course (1-5)
3. I think that Nanobio 1 was interactive (1-5)
   Why (2 sentences)
4. I liked the socrative quizzes
   (why)
5. I liked the discussions taking place into the Nanobio 1 (1-5)
   why
6. The "interactive teaching" influenced how I studied (1-5)
   How
7. How often did you prepare for the nanobio 1 lectures
   a. Every time
   b. Almost every time
   c. About halph of the times
   d. Few times
   e. never
8. How long was the preparation time for each lecture (if/when you did so)
   a. 0 h
   b. 0.5-1h
   c. 1-1.5h
   d. 1.5-2h
   e. .2h
9. The "interactive teaching" helped me to better understand new concepts (deep understanding)
   Why
10. I think that the course teaching occasions, discussions practical exercises and exam were well aligned. (1-5)
11. The overall design of the course (interactive and alignment) inspired me to actively engage in discussions (1-5)
    Explain
12. The "interactive teaching" helped me to be better prepared for the exam
    why
13. In lab exercises the protocols required some work form our part in contrast to other course that they are very well defined. I liked that (1-5)
14. The design of the lab protocols helped me to understand better the lab exercises and the concepts behind them (1-5)
15. In comparison with other lab practical exercises (other courses) with very precise protocols I have learned more (1-5)
16. I wish this type of interactive teaching would be applied in other courses

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/kapitler/2015_vol8_nr1-2_bibliography.pdf/