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How to enhance student learning by improving the lecture format

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Introduction

During Blok 2 2010-11 I taught the graduate physics class "Condensed Matter Theory I" at the Niels Bohr Institute, University of Copenhagen. The course has been running for a number of years and the intended learning outcomes (ILOs) and the teaching and learning activities (TLAs) are, to my mind, well aligned with the exam (Biggs & Tang; 2007). The ILOs clearly state what the students are expected to be able to do after completing the class and the exam tests this. During the course the students (in groups or individually) have to complete and hand in four written assignments. They receive formative feedback (Biggs & Tang; 2007). The exam is constructed as a fifth written assignment, which they have 24 hours to complete.

Inspired by the KNUD programme, our pre-project ("*How does the lecture format influence student learning?*"), and Mazur's (1997) ideas about the didactic game of peer instruction, I became motivated to try new methods to make the lecture format more interactive with the purpose of activating the students and thereby enhance their learning outcome during the lectures. Some previous inspirational KNUD projects on changes in the lecture format have also served as inspiration for this project (Schneider; 2007; Xella; 2009). I was solely responsible for the planning of the class as well as the teaching, which gave some advantages with flexibility to intertwine lectures and exercise classes. I attempted to "measure" the learning outcome by anonymous questionnaires about the content of the lecture immediately after the sessions and also by observation of the student activity level. Ad-

ditionally, I gave the students a questionnaire at the end of the course about their views on the different activation activities used throughout the course.

The potential problem with lectures

What *is* the problem? Depending on the particular course, the particular lecturer, and the students there may not be a problem. But the aim is clear; to increase the learning outcome during the time the teacher and the students spend together. Traditional lectures are often hampered by an important problem, namely the misconception that student learning equals attentive listening. According to Mazur, we want to avoid the situation where a lecture becomes "a process whereby the lecture notes of the instructor get transferred to the notebooks of the students without passing through the brain of either" (Mazur; 2009). Even with highly motivated students as in the present specialized course with just 20-25 students, the level of concentration drops significantly after approximately 15-20 minutes (see, e.g., the excellent Chapter 2 of Forsvarskommandoen (1989)). A 45 minute lecture with a monologue by the instructor introducing highly technical concepts comes with a large risk of 1) loosing a large fraction of the students, 2) de-motivating a large fraction of the students, and 3) simply wasting everyone's time because the students are not susceptible to learn any more.

After having given some of these tour-de-force lectures myself in the past, the blank glare in the eyes of the students remaining awake clearly signifies that the learning outcome could be improved by changing the lecture format into a more interactive style. The philosophy is simple: you learn by doing, by making mistakes, and by learning how to undo these mistakes. According to a worldwide study we know that the learning outcome nearly triples by using an interactive teaching style centred on student involvement (Fagan et al.; 2002; *Peer Instruction: From Harvard to Community College*; n.d.). It is exactly this fact that motivated the present study. Is it still true that more activation of students during the lectures increases the learning outcome in a small and rather technical course of physics graduate students?

Improving the format of lectures

Personally, I very much prefer a problem-based learning (PBL) style (Biggs & Tang; 2007). However, the present course is very tool-oriented and the

students are constantly introduced to new rather abstract concepts. For this reason, I had trouble using PBL more than sporadically to illustrate some problem (which was unsolvable for the students) and thereby motivate the introduction of new methods. In addition, most of the students were actually very motivated already since they had specifically chosen this class because of their interest in the subject. Instead, I chose to introduce the following items into the lectures in order to enhance student activity (and thereby, hopefully, their learning):

1. Lectures and problem sessions were merged in order to shorten the lectures in the 20 minute sessions followed by individual or group work on a problem related to the past 20 minutes of lecturing.
2. Students were grouped together to discuss their solutions and help each other to reach consensus on the problem.
3. Depending on the specific problem, some groups presented their results followed by group discussions.
4. Students took turns to prepare a 10-15 minute part of the lecture (peer-learning).
5. During lectures I was very conscious of the need to ask the students questions regularly. Depending on the question or "active thinking activity" (ATA), they were supposed to answer right away, or briefly consider and discuss the question before proceeding.
6. Whenever suitable I introduced research papers and presented visual computer simulations to put another perspective on the material at hand.

Other ideas of student-activating TLAs can be found in Biggs and Tang (2007).

Results

In the beginning of the course, the students were handed a short questionnaire about their exposure to various lecture formats and their general preferences in this matter (Appendix A). The first noteworthy result was that on average 94% of the lectures that the students had attended were of the "traditional" monologue lecture format without student participation. This shows that this style is still by far the dominant teaching format at most universities. Half of the students claim to accept this format (although they have not been exposed to other lecturing formats) whereas the other half

find it problematic due to minimal personal participation. The students estimate that they lose concentration after approximately 15 minutes. The majority (90%) of the students prefer group work to solve problems and enhance their learning by peer instruction. They have concerns, however, about wasting time if the group is too large, and also many of them stress the importance of the participants in each group being on an equal level.

In order to measure the effects of introducing some of the above six items into the teaching, I decided to use two lectures in the old-fashioned style consisting of teacher-monologue interrupted by just a few questions (by the teacher or the students) as a reference point. After these 2×45 minute sessions, we had 2×45 minutes of problem sessions where the students worked individually on solving a number of problems related partly to the material covered in the lectures on the same day, and partly to a previous lecture. The solutions were discussed by the class afterwards. At the end of the 4×45 minutes, I gave the students a questionnaire about the main items covered on that particular day. The questionnaire consists of eight questions, four testing their ability to repeat an important result, and another four testing their deeper understanding of the newly introduced concepts (see Appendix B for an example). The former (latter) is referred to as a "superficial" ("fundamental") question. Of course, I realize that these questions do not properly test the declarative knowledge of the student, but it does give an idea about their initial learning outcome. In the case of the old-fashioned instructor-monologue lecture format, the results of the questionnaire are seen in the histogram plot (Fig. 4.1).

The y-axis shows the percentage of correct answers to the superficial (blue bar) and fundamental (red bar) questions. I performed this kind of test after two lectures, referred to as lecture 1 and lecture 2, which had eleven and fourteen participating students, respectively. Evidently the scores are disappointingly low. Personally, I was rather surprised to see these low scores. It does agree with the students' own feedback, however, that they lose their concentration after 15 minutes. This means a rough estimate of one-third (half an hour) essential "learning time" and two-thirds (one hour) wasted time during lectures. Although it is not completely clear, it seems that the exercise classes following the 2×45 minute lectures did not play a key role in changing the learning outcome of the session on these two days. This makes sense since the majority of the students did not learn the material during the proceeding 2×45 minute of lecturing. How then were they supposed to solve the related problems?

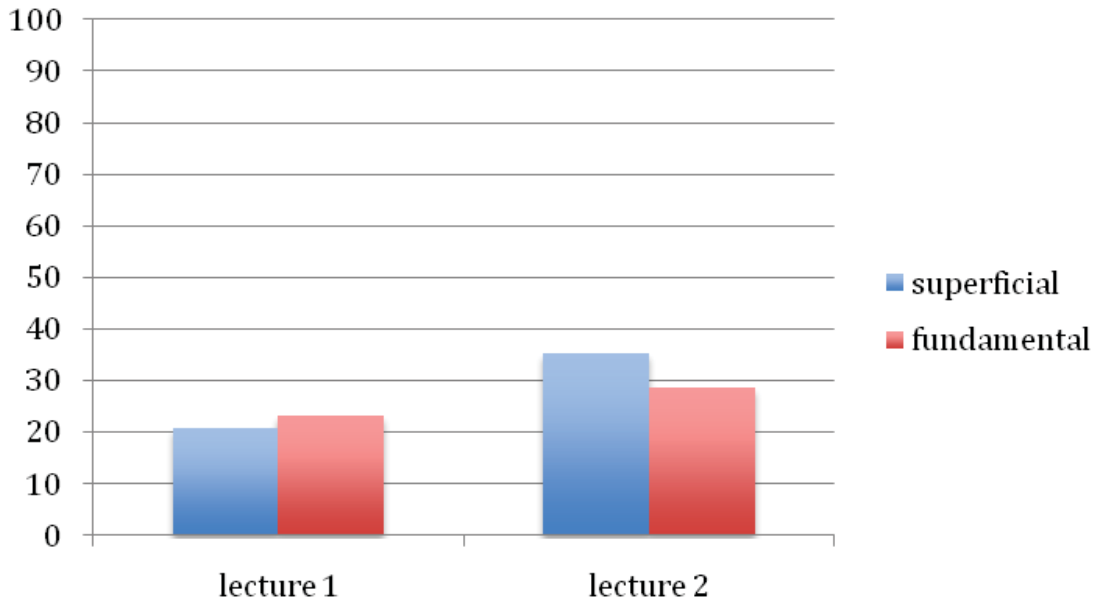

Fig. 4.1. Histogram showing percentage of correct answers to superficial (blue bar) and fundamental (red bar) questions for two different lectures of the traditional monologue lecture format.

Two questionnaires similar to the ones given after the non-student-centred lecture format discussed above, were presented to the students after 4×45 minutes with intertwined lectures and exercise classes (see e.g. Appendix C). In addition, several of the six items outlined above were introduced into these sessions. The lecture parts never exceeded more than 15-20 minutes and I took care to ask several questions during these lecture stretches. The results of the questionnaire are seen in the histogram plot (Fig. 4.2).

For these results lecture 1 and lecture 2 consisted of thirteen and eighteen students, respectively. Evidently the percentage of correct answers has dramatically increased and the learning outcome seems to have significantly improved, by a factor of three! Similar to the results from the old-fashioned monologue lecture format, there is no noticeable difference between the superficial and fundamental questions; they have both been enhanced by roughly the same amount. It is peculiar that this study finds the same enhancement in the learning outcome by a factor of three similar to the comprehensive survey reported in Fagan et al. (2002) and *Peer Instruction: From Harvard to Community College* (n.d.).

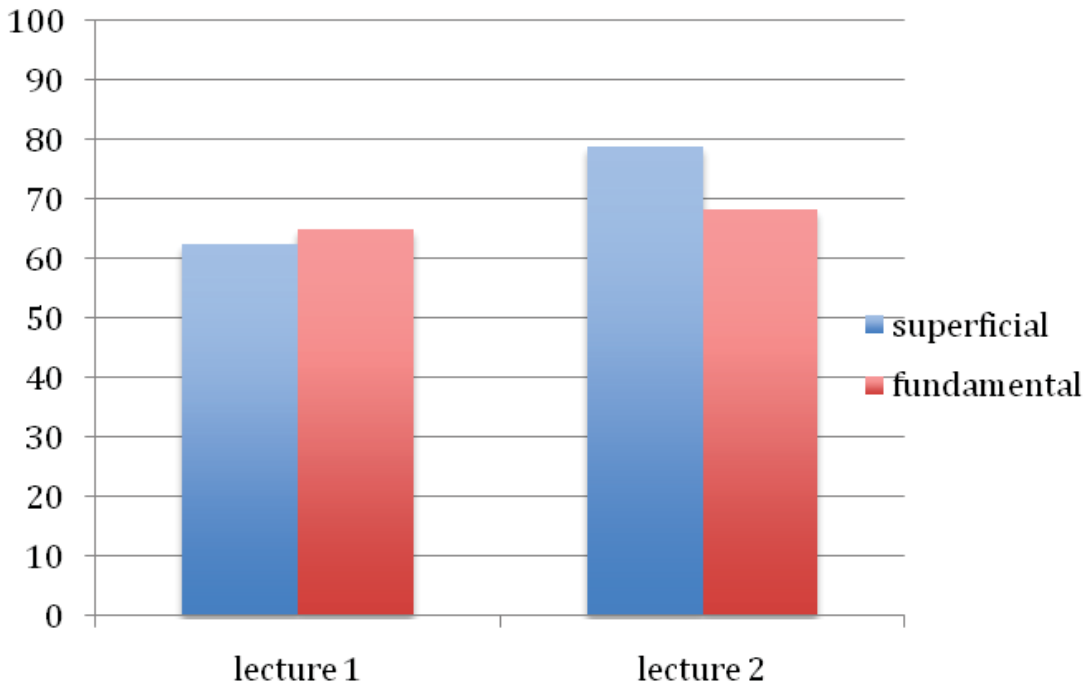

Fig. 4.2. Histogram showing percentage of correct answers to superficial (blue bar) and fundamental (red bar) questions for two different lectures containing the six items outlined in the above section "Improving the format of lectures".

Discussion

It is remarkable how the simple tests performed during this course have confirmed the superiority of the student-centred teaching format. Of course, one can question the (large) statistical uncertainties in this survey, and one might discuss the particular questions asked in the questionnaires. Nevertheless, I think the trend is very clear; the learning outcome *is* enhanced significantly by continuously activating the students, and keeping the "traditional" lecture stretches below 20 minutes.

Another less measurable difference between the two lecture formats investigated in this project is the overall atmosphere in the classroom. I find that student-centred activities naturally give rise to a positive learning environment. This is largely because such activities "break the ice" and the students quickly become used to doing something or discussing something with their peers during the lectures. Once this kind of environment is established, new questions are naturally generated and the barrier that would often exist to asking the instructor or peers has already been broken down.

As an additional spin-off, the sessions tend to be a lot more interesting for the teacher as well.

Halfway through the course, the students were given a short questionnaire about the lecture format and their estimated workload for this course. This questionnaire was intended mainly to correct the pace of the lectures or the exercises. For the present study, it is interesting that *all* (except one) found the pace of the lectures satisfactory. This was irrespective of whether I used the old-fashioned lecture style with minimal student involvement or the activated-student lecture format. The reason that students did not complain about the pace being too fast during the long 2x45 minutes monologue lecture is probably that the pace was appropriate, but that they simply got tired, lost their concentration, and the material presented just did not register. At this point, halfway through the course, a small (but sizable) fraction of 15-20% of the students "complained" that they missed the standard format of 2x45 minute lectures followed by 2×45 minute exercise classes.

The opinion of the students was followed up at the end of the course by a questionnaire with explicit questions about their preference for the lecture format (Appendix D): 80% of the students preferred the "new" lecture format for the following main reasons:

- Easier to stay focussed in shorter lecture stretches.
- Exercises came at opportune time.
- Activation by questions and peer discussions helped pinpoint which issues are not properly understood.

On the other hand, 20% of the students preferred the "old" lecture format but half of these still prefer lectures with questions and good discussions whereas the other half prefer a 2×45 minute monologue lecture. They question what they can learn from peers and point out a problem with intertwined lecture and problem sessions: wasted time for the good students. Regarding the former, I simply disagree. Even if they cannot learn much from their peers, they can still learn a lot from discussion with them and explaining the physics to them. Regarding the latter, I agree that there can be a potential problem in the sense that very good students end up waiting for the rest to catch up before the next part of the lecture can proceed. There need to be additional problems or follow-up questions to challenge these students.

Conclusions

The learning outcome can be significantly enhanced by planning student-centred and student-activated lectures. This is true even in small graduate classes where the students are supposed to learn how to work with new theoretical tools, i.e., in rather technical courses. The present study showed that the learning outcome is enhanced by a factor of (approximately) three by this method. This increase is valid both for the deeper understanding as well as the ability to use and remember newly acquired tools and results. While most of the students prefer the "new" lecture format this opinion is not unanimous. A minority of the students preferred the old-fashioned style with much less student-instructor interactions during the traditional 2x45 minute lectures. I speculate that this may be related to the fact that it is easier to remain inactive/passive, whereas continuing student challenges during lectures is more demanding for students. When lectures and problem sessions are intertwined special care must be paid to the stronger students to that they are challenged throughout the whole session.

A Student questionnaire on "How to enhance student learning by improvement of the lecture format"

Below, the phrase "traditional lecture format" refers to non-interactive lecturing where the teacher alone presents the material on the board/computer and asks only very few questions from the audience.

1. During your previous courses what percentage (roughly) have been by the traditional lecture format?
2. Do you like that way of learning? Why/why not?
3. How much of a 45 minute class would your brain tend to go on standby? What would it take to avoid this "zoom-out" state?
4. What other format have you been exposed to in lectures? Did any of them enhance your learning?
5. Do you find that group work makes you learn better? Why/why not?
6. Other comments/remarks:

B Small set of questions for today's lecture: 4 December, 2010

1. What is the meaning of A(τ) in the imaginary time formalism?
2. What is the definition of U(β,0) (words or equation)? What expression for U did we derive today?
3. We used U(β,0) to derive an explicit expression for $-\langle T\tau\,(A(\tau)B(\tau'))\rangle$. What was this expression?
4. What are iωn for fermions?
5. What is the free Green's function in terms of Matsubara frequencies?
6. What reasons are there for introducing the imaginary time formalism.
7. Why did we have to learn how to perform sums of Matsubara frequencies?
8. How is the imaginary time formalism related to what we have studied earlier?

C Small set of questions for today's lecture: 7 December, 2010

1. Why is Wick's theorem important for arriving at the Feynman diagrams?
2. What is the Master Equation for the full Green's function G(b,a) that we derived today?
3. How would you draw an expression containing W11'W22'G0(b,1')G0(1,a)G0(1',1)G0(2,2')G0(2',2)?
4. Is it possible to write the full Green's function G(b,a) in terms of only connected diagrams? Why/why not?
5. How would you draw $\langle U(\beta,0)\rangle$0 to 1. order?
6. What is a Feynman loop and what is the importance of the number of these beasts for a given diagram?
7. Our formalism is for imaginary time. But where exactly does temperature T enter a given Feynman diagram?
8. How many of the 6 Feynman Rules do you remember?

D Small set of questions to lecture format: 4 January, 2011

During this course we have had different formats for the lectures. This questionnaire asks your opinion about these.

1. Which do you prefer: (A) Standard 2×45 minute lectures followed by 2×45 minute problem session, or (B) mixed lectures and problem sessions with shorter stretches of lecturing by the teacher?
2. What are your reasons for choosing (A) or (B)?
3. Do you think you learn more/better with format (A) or (B), or does it not matter.
4. What is your preferred lecture format?
5. Often during the lectures we have had a student present a small section from the book. Did you like this? Why/why not?
6. During some lectures the teacher has asked many question to the audience. Do these help you? Why/why not?
7. Do you have any suggestions on how our 2×4 weekly hours together could have increased your learning outcome?

All contributions to this volume can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/2010-3-1/

The bibliography can be found at:

http://www.ind.ku.dk/publikationer/up_projekter/kapitler/2010_vol3_bibliography.pdf/