Lectures with Worksheets

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Abstract

We report on a teaching intervention in which mathematics lectures were modified to include the use of worksheets with tasks that students were asked to work on with peers periodically during the lectures. Do the students find this format beneficial, and does it help them with the challenges during lectures? The data consists of students´ perceptions about the intervention, collected as free-text answers to questionnaires, and was collected in two calculus courses, one in the USA (n=246) and one in Europe (n=106). The data is coded and categorised, and some basic descriptive statistics are compiled. As a framework for the analysis, we use three didactical challenges for lectures: (1) activating prior knowledge for all students, (2) retaining student focus, and (3) a lack of opportunities for students to get back on track during mathematics lectures. We find that the respondents mostly find the worksheets beneficial but time-consuming. There are indications that the respondents perceive that using worksheets diminishes problems related to the didactical challenges above. However, the challenge regarding activating prior knowledge for all students is not satisfactorily met. Practical implications of these results are discussed, including challenges with the time use and the need to understand which properties of the worksheets influence the students' experiences the most.

Introduction

Lectures are a standard mode of teaching at universities worldwide despite evidence in the educational literature that traditional lectures are less effective than active learning (Freeman et al. 2014). Lectures are often seen as opposed to student-active forms of teaching (ibid.), such as peer instruction or teaching that emphasises feedback (Hattie 2008). That seems to imply that the student learning environment will improve if lectures are removed and replaced by student activities, preferably with feedback.

However, Hattie and Timperley (2007) write, "If students lack necessary information, further instruction is more powerful than feedback". Research also exposes problems with methods activating students through minimal guidance and constructivist methods. The argument is that these methods are incompatible with our understanding of how the human brain works and causes high cognitive load (Kirschner, Sweller, Clark 2006). There is also evidence for the effectiveness of worked examples in learning and teaching, i.e., the learner is shown through direct instruction how something is done, which traditionally is an essential part of lectures (Schwont et al. 2009).

Merrill (2002) identifies the first principles of instructional design and states that demonstration/instruction and learners' application/activity are two. From that perspective, direct instruction and student activity are two essential and complementary parts of effective teaching. Instead of abandoning lectures, one should improve the format and study how lectures can contribute effectively to the learning environment (Harrington, Zakrajsek 2017).

Three challenges for lectures

In search of ways to improve lectures, we focus on three didactic challenges relevant to lectures. First, lectures deliver the same content to a large group of students, even though students individually have different prior knowledge and understanding. It is well known that learning is supported by connecting new knowledge with prior knowledge (Christen & Murphy 1991, Merrill 2002). Hence, the lack of differentiation between students in the lecture can impede the learning for students whose relevant prior knowledge is not activated, maybe due to lack of it.

Second, the students' focus decreases significantly after about 10 minutes of lecturing, and the student's thoughts may wander off to unrelated things (Risko et al. 2012). It is common for universities to have lecture sessions that are 40-50 minutes. In the age of smartphones, the focus span may be even shorter as students tend to multitask during lessons (Joshi, Woodward, Woltering 2022). This loss of focus may hinder students' cognitive participation and activity in the lecture. If a student is unfortunate to lose focus at a critical point of the lecture, it can be difficult to learn from the remaining part.

Third, students have limited opportunities to overcome individual knowledge gaps and untangle misunderstandings during a lecture. Few students ask the lecturer, and if so, other students may see it as disturbing the lecture flow. Resolving cognitive conflicts through peer discussion is inhibited by not wanting to disturb other students listening to the lecturer. The lecture keeps moving forward, leaving the student behind. In cumulative subjects, such as mathematics, this can make the rest of the lecture incomprehensible. A lecture is like a train – if you are not aboard, you get left behind. Hence, during mathematics lectures, students may lack opportunities to get back on track (Harris & Pampaka 2016).

The teaching intervention

We construct a one-page worksheet for each lecture with a handful of mathematical tasks and room for students to write their solutions (see appendix for an example). The worksheet is printed on paper, handed out at the beginning of the lecture, and is not supposed to be handed in. At certain times during the lecture, about every 10 minutes, the students are asked to work on a task with peers sitting close.

The lecture started with the students doing the first task, the refresher, in which prior knowledge essential for the lecture is recaptured. About five minutes is used for this. Then the lecturer quickly illustrates the correct answer to the task before continuing with regular lecturing for about 10 minutes. The students are then given about three minutes to do the second task on the worksheet. The task is designed to fit into the content discussed at that specific moment in the lecture, asking the students to do something related to what the lecturer just has done, work through an example or a part of a faded example (Retnowati 2017). Meanwhile, the lecturer walks around, listening to the student to see what is problematic and what is understood. All students are not expected to complete the task in the approximately three minutes allotted for this activity. The lecturer then briefly lined out a solution to the task on the board before continuing with the next part of the lecture. This toggling between worksheet tasks and regular lecturing continued cyclically till the end of the lecture.

Research question

1. How are lectures with worksheets experienced by students, as beneficial or disadvantageous for their mathematics studies?

2. Do the respondents find that lectures with worksheets strengthen the lecture format regarding the following three challenges: (1) activating prior knowledge for all students, (2) retaining student focus, and (3) small opportunities for students to sort out misunderstandings that they get into?

Method

The respondents are calculus students. We have collected data during two courses, one of which was a continuation course in calculus with approximately five hundred students at a major university in California, USA. There was a mix of students majoring in many different fields. The number of respondents was 246, giving a response rate of approximately 50 %. The other course was an introductory calculus course with engineering students at a technical university in Sweden. These students studied a three-year engineering program. This was their first course. Of the 275 students enrolled in the course, 106 answered the questionnaire, giving a response of 39 %.

We collected student responses on paper during a lecture in the middle of the course, with the benefit that the students are more likely to complete the questionnaire. However, it also means that the students that are not present are not given the opportunity, leading to a sample that may be positively biased towards the teaching. We chose not to pose questions pertaining directly to the intervention. Instead, the anonymous questionnaire contained three broad, open-ended free-text questions: What do you like about the course? What do you dislike about the course? How can we help you learn better? Broad, open-ended questions are helpful in eliciting people's first-order, intrinsic concerns (Ferrario & Stantcheva 2022). A weakness of this approach is that not all respondents may choose to comment on the questions in the focus of this study, the worksheets. However, we used open-ended questions to minimise our influence on the students' opinions, letting them focus on what they found most essential to bring up.

The data is analysed using thematic analysis (Clarke & Braun 2013). A typical answer given was either one short sentence or a list of points, each point consisting of a few words. We started by dividing each response into units of analysis pertaining to one identifiable aspect of the course. This typically resulted in 2-5 units per respondent. When the same thing came up several times from a respondent, that was considered as one unit. The units were gathered into labelled code groups. These code groups were then collected into themes or categories of related codes. The categories were then collated and checked for alignment with code groups and units. In this process, we chose to disregard categories with fewer than five units, categories that referred to aspects relevant to one of the courses only, and categories regarding things outside of the courses. We used responses to all three questions in this process, using the question to identify whether the respondent was positive or negative towards the phenomenon mentioned. The analysis resulted in the following eight categories: Worksheets, Pace, Theory, Textbook, Use of IT, Examination, Enthusiasm, and Pedagogical Ability. For examples of units and their categorisation, see the Results chapter below.

Result and discussion

We will only use two categories to answer the research questions: Worksheets and Pace. The remaining six categories only contain units that do not pertain to the use of worksheets and will therefore be excluded from this report.

Quantitatively, the category Worksheet was the biggest of all eight, with more than one-third of the respondents commenting on them. A great majority of them consider worksheets beneficial (RQ1); see Figure 1. Examples of units are as follows (in parenthesis: if it was liked or disliked and the respondent ID).

> *I like the worksheets given out in lectures. It helps me understand basic concepts and learn more in-depth when the lecture goes on* (like, S1234a). *The process: 1. Review related topics 2. Teach 3. Try problems ourselves. 4. Go over the problem. Being able to try the problem on my own helps me learn* (like, S1209b). *Students get to do practice problems and apply concepts immediately* (like, S1206b). *The tasks we get during lectures. Only through them, one understands* (like, S2089).

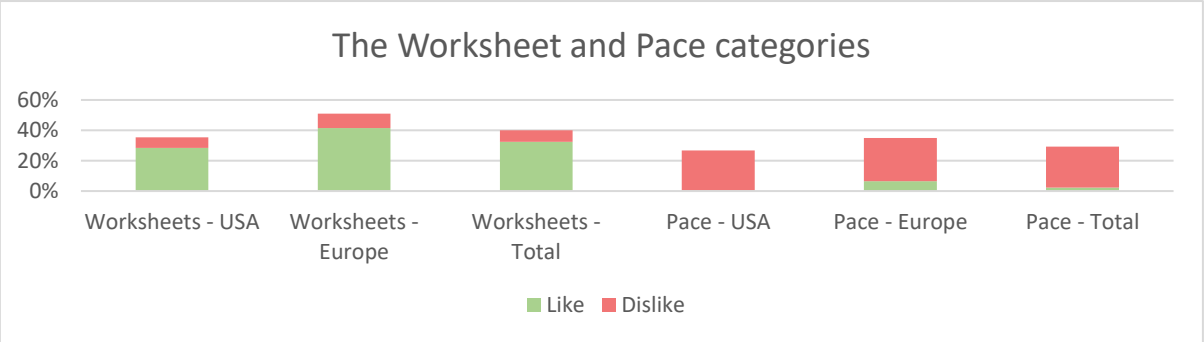

Figure 1. The percentage of students who commented on worksheets or pace, positively and negatively, at each of the two universities.

As can be seen in Figure 1, there are significant similarities between the responses obtained in the USA and Europe. Moving forward to research question 2, we consider the three challenges separately, not separating the two cohorts.

It is of value for learning that prior knowledge is activated (Christen & Murphy 1991, Merrill 2002). The respondents address prior knowledge, pointing to the first task on each worksheet, the refresher.

> *I like that we have warmups to see what we know and don't know. It shows us what we have to study* (like, S1122a). *Telling us what we should know for the lecture in part 1 of the worksheets* (like, S1216b).

The purpose of the refresher, to highlight knowledge that the students need, and to activate necessary prior knowledge to understand the lecture, seems to be fulfilled for some students. The idea is to bridge any gaps in prior knowledge and equalise the difference in prior knowledge between the students. However, some students find the remaining set of questions hard.

I feel like I don't know enough before attempting the questions (dislike, S1217c). *Worksheets, but have almost never been able to answer the questions. Think they are too difficult* (like, S2063).

Hence, we conclude that the refresher is helpful for some students to activate their prior knowledge and may help other students to identify what they need to study. However, for the students lacking knowledge, the refresher is not enough to help them cope with the lecture's content, and they are still left behind.

During lectures, declining student focus is a problem (Risko et al. 2012). The respondents addressed focus.

- *The exercises during the lecture make it easier to stay focused* (like, S2033). *Worksheets, if they are quick, make me not lose focus* (S2085). *Good with worksheets variation in the teaching* (like, S2079).

Hence, alternating between lecturing and worksheets seems to help students with their focus. While not mentioned by the respondents, a lack of self-regulation can be a problem (Joshi et al., 2022). It is worth noticing that there is more significant social pressure to stop using the smartphone when discussing with peers than when listening to the lecturer. Hence, we believe that the habit of multi-tasking during lectures can be partly remediated by peer collaboration on worksheet problems.

In mathematics lectures, students have limited opportunities to get back on track when lost (Harris & Pampaka 2016). The respondents highlighted the aspect of staying on track.

The worksheet provided every lecture. They really help in following the path of the lecture (like, S1117b). *That you have the possibility to think by yourself already during the lecture* (like, S2072). *Going over an example and then working on a very similar problem on our own* (like, S1243c).

It appears that the students appreciate having the opportunity to apply something that has been introduced, do an example, or investigate one of the concepts.

The respondents also point to the benefits of talking to a peer.

Working on problems with peers (like, S1237b). *It is good to be able to discuss during lectures* (like, S2076). *Interaction with peers* (like, S2095).

The worksheets allow the students to ask each other questions, fill in gaps, and sort out misunderstandings with a peer. There is also evidence that communication with fellow students has a strong positive impact on learning. Studies show that peer communication helps students to understand concepts even without any influence from authorities about what is right or wrong (Smith et al. 2009).

As time is a limiting resource when lecturing, the benefits of worksheets must be weighed against the time used. Some students think other things should be prioritised, for example, doing more worked examples on the board.

The system with worksheets. Better to do more examples on the board (dislike, S2011).

The time used for the worksheet means less time for lecturing. In the courses reported here, this was dealt with by increasing the pace of the lectures, limiting the notes on the board, and leaving more material for the students' self-study.

I hate how sometimes lectures can go too quick and some problems are not clearly explained (dislike, S1105). *I hate how we sometimes run out of time* (S1116). *Sometimes lecture is too fast and I could not fully catch up* (dislike, S1210).

Most comments about pace are negative, but not all.

The pace is good (like, S1213b). *I like the flow of the lectures* (like, S1249b). *I like the pace of the class and the worksheet problems complemented by the teaching* (like, S1219c).

There is little time given for each worksheet problem. This is also affecting the students.

I wish we could have more time to work on the problems in lecture (dislike, S1132b). *Not enough time to go over all problems on worksheet* (S1214). *How we don't go over all the questions in the first part of the worksheet* (dislike, S1221a).

Conclusions

Some respondents expressed that the worksheets affected them negatively, preferred traditional lectures, or pointed to weaknesses in the content of the worksheets.

That the worksheets and homework don't prepare me for midterm, since the problems are very different (dislike, S1124). *How the worksheets are generally a lot simpler than the homework problems* (dislike, S1207). *Wording of worksheets sometimes confusing* (dislike, S1132a). *Not covering everything in worksheets* (dislike, S1113).

However, the respondents generally are positive towards the worksheets and indicate that they help them focus and stay on track. The data shows that the respondents appreciated the refresher in the worksheet, aimed at activating their prior knowledge. It is, however, less clear that the worksheets helped students with weak prior knowledge. It helped them identify gaps in prior knowledge but was not enough to help them during the lecture.

An effect of using worksheets was the increased pace of lecturing in this intervention. Did this increase in pace outweigh the benefits of the worksheets? This is still an open question, but the strong support for the worksheets from the students from both universities suggests that worksheets are worth their cost. Further research is needed. The overall positive response about the worksheets call for further experiments, including calibrations of the implementation regarding the use of time, the difficulty of worksheet tasks, and the design and use of worksheet refresher.

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