The ongoing Digitalization of an Introductory Programming Course

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Abstract: *This paper is about the ongoing digitalization of a C programming course. The paper describes our considerations about the use of video resources, as well as other digital learning resources. In particular, we discuss the ongoing transition from using a number of supplementary videos (in a traditional course setup) to a flipped course based on video lecturing and active learning. The results in this paper are, in part, based on the student's reflections about the course held in the fall of 2015. It is concluded that the time is now ripe to flip the classroom, with an implied strengthening of active learning.*

Key words: *Short video lectures; Quizzes; Flipped classroom; Imperative programming course; Student opinions.*

INTRODUCTION

This paper is about the ongoing transition of an introductory programming course from traditional lecturing to video lecturing. The course is about imperative programming in C. In the paper we also discuss other uses of digital learning resources than video.

The current paper is number three in a series of papers. As in the two first papers [3,4] we reflect on the experiences from the latest iteration of the course (via results from a questionnaire sent to the students), and we describe the plans for the upcoming iteration of the course. Taken together, the three papers describe the transition from a "traditional course" to a "modern course" supported by substantial video resources. We discuss the role of these videos, and similar digital assets. During the first few years of this course the videos were supplementary resources. We have now reached a point where it must be decided if the videos should play a more central role - replacing some of the auditorium lectures with videos.

A number of important issues and questions pop up in the slipstream our considerations:

- To which degree do we wish to keep having plenum sessions in an auditorium?
- Are we heading towards a flipped course [1], or do we aim at another course model?
- How do we support active learning in the programming course as a key ingredient of a possible course flip?
- What are the economic implications of adjusting the course, both in terms of resources allocated to teaching and relative to the use of big rooms?
- How does the transition from traditional lecturing to video lecturing affect student satisfaction, and student results (grades)?
- How do digital learning resources relate to the use of the traditional text books?

In the remaining parts of the paper we will first discuss different course models, to which the use of digital learning resources must be adapted. Next, we will describe the digital learning resources attached to the course. In the fourth section we discuss the experience from the fall of 2015. This is followed by discussion and conclusion. The full version of this paper [5] includes the results from the 2015 questionnaire.

COURSE MODELS

The course model interferes in several respects with the transition to a more digital variant of the course. Therefore we will in this section outline different course models (past, present, and future).

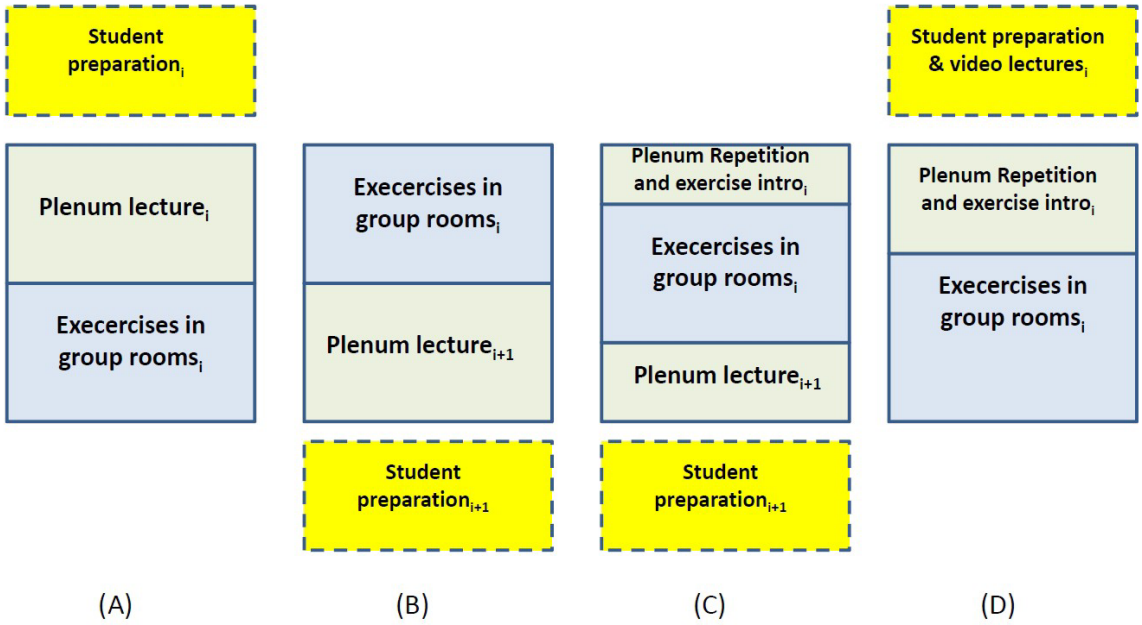

Figure 1. Four different course models that illustrate the mutual order of lectures, exercises, and student preparation

The course is currently joined by more than 200 students (from three different study directions). As of 2015, the course consists of 14 sessions, and each session lasts approximately 4 hours15. Each session involves plenum activities in an auditorium (the lecture) and exercises carried out in smaller group rooms. The plenum lecture is passive for most students, whereas the exercise part calls for much more student activity. Figure 1 outlines four different course models.

In course model A the exercise part is carried out just after the plenum lecture. Thus, in this model, the exercises depend on the material just lectured. This calls for some student preparation before the session.

In course mode B the order among the lecture and the exercises is switched. We start with exercises (covering the material lectured in the previous sessions) and after that new material is introduced in a plenum lecture. Using this this model, the students main preparation will be between two course sessions, after the lecture and before the corresponding exercises. Course model B is, however, irregular in the first session and in the last session, because of initial and pending exercises respectively.

Course model C is a variant of model B, where we meet in the auditorium for repetition purposes and in order to introduce the upcoming exercises. Thus, in this model the exercise session is placed in between two plenum gatherings.16 After the exercises - in the last hour (or so) - new material is introduced in a plenum lecture. This model requires availability of the auditorium in four hours (on a flexible basis). In the case where auditorium space is a scarce recourse, this model is therefore problematic.

In course model D a session starts with a relatively short plenum gathering (with some lecturing, repetition and introduction of the exercises, and practical matters). This part assumes, as a prerequisite, that the students have watched a number of video lectures as part of their preparation. This model typically leaves slightly more room for the exercise part, and it is not greedy relative to auditorium space.

In model C the traditional plenum lectures are short, and in model D the traditional plenum lectures have disappeared. In these models plenum lectures are partially or fully

[15] In the Computer Science Department at Aalborg University most teaching is organized in half day slots. A single slot contains a lecture and an exercise session (in this order, or reversed). The use of half day slots allows the student to concentrate on only two different activities per day. In addition, scheduling of the course activities in half day slots is relatively simple (contrasted with more fragmented schedules).

[16] Additional activities can be carried out in this part of the session, such as feedback to homework assignments [2].

replaced by video lectures. As a consequence, more time can be allocated to active learning elements (exercises). In addition, in both model C and model D, the exercise sessions are prepared for in plenum. This creates much better conditions for the exercises, because the students understand the context of the exercises and have been introduced to the problems behind the exercises - "just in time".

In our previous paper [4] course model A and B were collectively called the traditional classroom approach. Model C was labelled the *mixed classroom approach*. Model D is a variant of a *flipped classroom approach*, in particular if the plenum repetition is based on student activity.

DIGITAL LEARNING RESOURCES

The course discussed in this paper is supported by a number of different digital learning resources.

At the most basic level, there exists a set of (HTML) course slides. The hand in of weekly programming assignment is supported by a custom made web-based system [2]. This system organizes the feedback that the students receive from the course instructors.

The course videos are the most substantial digital learning resource in the course. Currently we support 79 videos with an average playing time of approximately 10 minutes. The videos are deliberately kept small, and focused on a single topic. Some videos explain practical topics (such as software installation and guides to the use of tools). A number of the videos show how to program in C. None of the videos are "talking slides". The videos are all in Danish. Figure 2 of the predecessor paper [4] gives a categorized overview of the course videos (as of the fall of 2014).

In the course period (from September 1, 2015 to January 31 2016) the videos have been played 8.923 times for a total of 33.100 minutes. In the previous run, the videos were played approximately 6000 times for a total of 25.000 minutes. The higher numbers are, in part, explained by a larger student population in 2015 than in 2014.

In the 2015 run of the course we introduced multiple choice quizzes (in a custom made web system). Each quiz addresses details in one of the course videos. The quizzes were introduced as an additional motivation for students to watch the associated videos. Each correct answer to a question gives a number of points, and the students can accumulate points by answering a number of quizzes. It is allowed to answer a given quiz more than once, but a few points are deducted for each retry. Students can see their own accumulated points relative to the points obtained by fellow students (either named or anonymously). As such, we have added a slightly competitive element to the quiz facility.

FOURTH RUN EXPERIENCE

The role of the traditional CS1 text programming books should be reconsidered. Only 6% of the students in this course find that the text book was important for their learning. 29% of the students did not use the book. Programming text book are often between 800 and 1000 pages because they cover both conceptual issues and programming language reference material. For most programming languages there exist excellent internet resources - both programming tutorials and reference manuals - supplied by the organizations or companies behind the programming systems. Students prefer to consult these resources because they can be more easily searched, and because they are free. In addition, programming text book may be difficult to follow in relation to understanding the programming process. A narrated video lecture, which shows and explains the programming steps involved, seems to an attractive alternative. 72% of the students in our programming course prefer to learn programming from a video; Only 12% prefer a text book (the remaining 10% are either in doubt or indifferent).

The quizzes, which were introduced in the fourth run of the course (in the fall of 2015), were not successful. Less than half of the students (48%) worked on the quizzes, and in average each student only answered 4 quizzes during the course. However, among

those who did, almost all students reported about a good or a reasonable outcome from their efforts. Many students tell that they used the quizzes as part of their preparation for the exam. Seen in retrospect, there needs to be stronger student incentives to take the quizzes.

Student motivation is a driving force for successful learning, and a certain amount of discipline is needed for having success in the course. Almost 45% of the students are more motivated by attending a traditional lecture than by following the lecture on video. (12% are more motivated by video, and as many as 31% are indifferent). Almost 39% of the students find that it takes more discipline to watch a video lecture than to attend a traditional lecture. (28% are in favor of the opposite, and 22% find no difference with respect to discipline). Being together in plenum sessions - and learning together - is apparently a strong motivational factor among the students. If the students are bored by watching video lectures we may end in a situation where the students are not able to get a sufficient outcome from the exercises, because they do not understand the concepts and theories.

DISCUSSION

It is interesting to reflect on the resources used for producing digital learning resources. It took a considerable amount time to prepare and produce the various kinds of videos that cover the programming course. If the course is flipped, the preparation and execution time of the plenum lectures will be saved. Based on the experiences from this course, it is apparent that it takes more time to produce videos than it takes to prepare and give traditional lectures.

The video material can - of course - be used over a number of years, but it is not safe to assume that the video material is static over a number of years (say five years). It will typically be necessary to renew selected videos every year - due to renewal of course topics or software tools, and due to errors and weaknesses identified in older videos.

The amount of time it took to produce the course quizzes for the fall of 2015 came as surprise. Furthermore, producing good quizzes with essential questions (relative to the learning goals) is not easy. In the programming course, some questions ended up being specialized about non-essential technicalities. Unfortunately, we did not complete the set of quizzes for the course in 2015.

The transitioning to video lectures may decrease the need for auditorium space. In our setup, auditorium space is a limited and expensive resource, so therefore this part of the resource accounting plays a role in the overall picture. With respect our forthcoming use of course model D (from Figure 1) we will still make use of plenum sessions, so therefore we do not expect to be able to release much auditorium time.

In the next iteration of the course we expect to make a transition from course model B to model D, see Figure 1. Effectively, this can be seen as a transition to a flipped classroom approach. We wish to keep the plenum gathering for non-lecturing purposes, such as questions, discussion, feedback on assignments, and introduction to upcoming exercises. Thus, the plenum sessions in auditoriums will hopefully be experienced as "active learning", and as a motivational factor to join the session (cf. the experiences about motivation and discipline in the previous section).

The upcoming transition to course model D is opposed by 28% of the students in the 2015 class. (However, 32% of the students are positive, and 29% are positive to some degree). It seems to be the case that many students both wish to attend "the traditional teaching activities" (which includes a two hour lecture in an auditorium) and to have access to a lot of video material. We foresee some degree of student resistance to the flipped classroom approach of course model D. In part because of conservatism, and in part because it actually motivates the student to join the auditorium lectures. Nevertheless, we plan a transition to a flipped approach in the programming course, in order to harvest the benefit of more and to better prepared active learning elements in the course.

In the new approach, almost all lecturing will take place via videos. In addition to the existing small videos, we will add one *lecture video* per lecture, which provides an overview of the material in each session of the course (lasting 20-25 minutes). As preparation for a course session, the students are required to see the lecture video and 3-4 essential videos with selected details on central topics. We plan to introduce a feedback system which allows students to comment on specific parts of a video (in terms of questions or different types of reflections). We intend to ask each student to provide at least one piece of feedback for each video watched during the preparation period. We have developed a *course video management system* for this purpose. Hopefully, the feedback provided via this system can be used to address problems and issues in the "plenum repetition sessions".

CONCLUSIONS

During the last two years, the 60-70 short video lectures have played an important role as supplementary resources in the programming course - relative to the traditional course lectures. For almost half of the students the videos played an important role in learning to program in C.

The video lectures seem to be a serious contender to programming text books. Some students get a better outcome from watching a video about programming than from reading a corresponding section in a text book. It is, in particular, attractive to use video to describe and illustrate dynamic processes - such as programming processes or how to use programming tools.

The upcoming transition from a "traditional course" (with supplementary video resources) to a "flipped course" (without traditional auditorium lecturing) will be taken, because it is not any longer necessary to use precious time at university for passive listening to a teacher. Video technology is ripe for taking over that role. Videos can be prepared more carefully than a lecture in an auditorium, and video can be played *just in time*, and multiple times (if desired). With this transition, we expect to strengthen to elements of active learning (programming exercises). We do not, however, expect the transition to be immediately popular among the students. It takes time to adapt to a new mode of learning.

From our experience - from a teacher's perspective - it seems to take more resources to prepare a flipped course (based on video lectures) than to run a traditional course. Even though video lectures will last for a number of years, the investment in producing the material is substantial. The total price for a complete video material seems higher than sum of conducting the annual auditorium lectures. We also found it time expensive to prepare for extensive quizzes (in the slipstream of the video lectures). In the longer run it will be attractive to rely on existing digital learning objects, from traditional publishers, from selected universities, or from third part providers.

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The paper has been reviewed.