

LEARNING THEORY THROUGH VIDEOS

A Teaching Experience in a Theoretical Course based on Self-learning Videos and Problem-solving Sessions

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Abstract: In this paper we describe a teaching experience applied to a theoretical course thought in a computer science degree. The main feature of our experiment is the introduction of videos specifically designed for self-learning as part of the learning process. Master classes are replaced by working sessions in which the involvement of students gains prominence. The teacher explains almost nothing in class. Instead, most of the time is devoted to the presentation of solutions to exercises assigned to students in advance. All presentations are done by students, and the teacher only intervenes in order to complete explanations and correct mistakes. The result of our experiment is promising from several perspectives. The exam results are better with the new approach. The students learn to learn on their own and take better advantage of the time in class. The work load is uniformly distributed along the course. The new approach also benefits the teacher since he/she spends considerably less time preparing theory lectures, and gets continuous feedback to better follow the students development. The videos are valuable in themselves and have been made publicly available. In fact, our students prefer them to a master class. They can pause, rewind and replay the video, take a rest, and postpone the lecture if necessary. Moreover, the interest for these videos goes beyond our university boundaries: according to the visits' place of origin and posted comments, they are being used by students from other countries.

1 INTRODUCTION

Typically, lectures in mathematically founded sciences include two different types of sessions: theory and problems. The first type often consists of a set of lectures in which the professor presents all the basics on the subject, such as definitions and proofs of relevant and useful results. This kind of content is well established and does not lend itself to discussion.

The second part is devoted to the presentation, either by the teacher or students, of solutions to problems previously given as homework. This second part is often understood as a practice for the exam.

In our experience, theory lectures impose a rhythm which is often difficult to follow by students. Usually, theoretical concepts require an assimilation time which exceeds the time allocated in master classes, and it is different for every student. Moreover, students tend to lose part of the teacher's explanation while taking notes. Their interaction with the professor is limited to asking questions in case the material is not well understood. In our opinion, the

teacher's capabilities are not optimally exploited with this kind of teaching approach, since active learning approaches, and in particular problem-based learning, are especially well suited for scientific disciplines (Handelsman et al., 2004). For this reason we believe that active interaction in problem solving sessions should be a central activity of the teaching process. Educational theory suggests that there are better ways to promote learning than the traditional master class approach. The learning pyramid (see Figure 1), introduced by the National Training Laboratories based on Dale's work (Dale, 1969), illustrates the average retention of contents that corresponds to different teaching methodologies, which is higher for audio-visual material than for traditional lectures. In this vein, Tutored Video Instruction (TVI, (Gibbons et al., 1977)) is a teaching method pioneered by Stanford University. It consists in combining video-taped material with teacher active tutoring. Our work falls into this trend. The goal of this work is to combine video-based material with problem-solving sessions where the students actively present and discuss their solu-

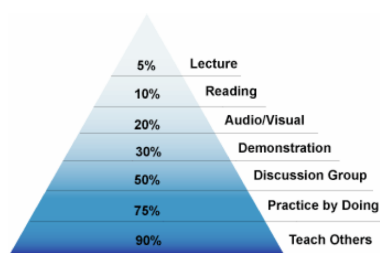


Figure 1: The Learning Pyramid.

tions.

In recent years, there has been a great increase in the amount of audiovisual teaching resources freely available on the Internet (VideoLectures, 2010; AcademicEarth, 2010; KhanAcademy, 2010). On the one side, one can find commented slides and informal explanations of a specific part of a subject (KhanAcademy, 2010). While this material is well suited for solving particular questions when the topic is already known, it is not enough for guiding the learning process of a whole subject. On the other side, one can find recorded lectures given by specialists on a certain topic (VideoLectures, 2010; AcademicEarth, 2010). They are usually very interesting since they allow us to attend a master class taught by an important professor regardless of time and place. The main disadvantage of these videos is that their content has no added value with respect to the original class, and has all of its defects. For instance, they may be disordered or redundant at times, and contain mistakes derived from the difficulty of the subject and improvisation. These mistakes cannot be easily fixed in the video.

For certain topics, teaching videos that are specifically prepared for this purpose have several advantages over regular master classes (Anderson et al., 2001; Bauman and Jurgens, 2002; Day et al., 2005). By careful preparation of content, image and audio, one can produce a very succinct, well-ordered, adequate and coherent material almost free of mistakes. We have prepared videos of this kind for “Theory of computation”, a course with a strong mathematical background of the computer science degree in our University. These videos are intended as a self-learning alternative to traditional master classes on theory. Hence, they are self-contained, provide general ideas, intuitions, precise definitions, proofs and proposed exercises. The idea is to combine the precision and completeness of a textbook with the intuitions and dynamism of a good lecture.

Taking advantage of the videos, we have experimented with the following teaching approach. Master classes disappear and the teacher does not introduce any material in class. Students learn theory on their

own by watching the videos, and are expected to solve exercises assigned in advance. During class, students explain their solutions on the blackboard as part of the evaluation method. The teacher only intervenes in order to complete explanations and correct mistakes. One weekly session is devoted to study time, during which students work on their own and the teacher is present to help them, solving questions and giving insights into the previously digested material. After this continuous interaction with students, the teacher gets a lot of feedback from each of them, making his/her interventions more accurate and helping in the detection of common difficulties on the subject.

We applied our teaching approach to only one of the groups of students of the course. The remaining groups followed the traditional teaching method. This allowed us to evaluate the impact of our method versus the old one. The results are very promising: students using the new approach were satisfied both with the method and their performance on the subject. The professor that followed our method also expressed satisfaction with his new role in the course. On the one hand, the method allowed him to influence the students’ learning process more positively. On the other hand, the teacher felt free from the tedious part of the lectures thus improving his general attitude towards teaching the subject.

2 THE TEACHING EXPERIMENT

2.1 The Course

We have applied our teaching method to “Theory of computation”, a mandatory course taught during the second semester of the third year of our computer science degree. This course is of theoretical nature, and is heavily based on mathematic principles. The objectives of this course are mainly twofold: first, to formally introduce the mathematical principles on which computation is founded and, secondly, to teach the students to follow and produce formal proofs and solve problems in a rigorous manner. The contents are hard, and students generally have difficulty with the course. Moreover, it is mandatory, which altogether results in a rather negative attitude towards the subject. Despite the difficulty, the subject is interesting, and the problems it presents can be very challenging and intriguing. This course has to compete with other courses for the attention and dedication of the students. These other courses tend assign more applied work such as programming projects, which are typically done in groups. Students spend a lot of their time doing these projects, and concentrate on

this course just a week before the exam.

Students are divided into three groups, each taught by a different professor. The lectures of two of the groups are scheduled in the morning. The ones of the third group are in the afternoon. We have applied our new teaching methodology to the afternoon group but allowing students to choose between the traditional and the new evaluation method. The course has a teaching load of three sessions of two hours each per week (per group), the students are expected to devote another 6 hours to self-study for an adequate assimilation of the contents.

2.2 Comparison of Teaching Approaches

The main difference between the traditional and new methodologies is the use of especially designed videos to teach the theoretical basis of the course contents. Another difference is in the evaluation method. In the new methodology, participation in the classroom is explicitly considered in the grading method. In our system, grades are between 0 and 10 (10 being outstanding). A nominal qualification is associated to each mark range: 0 – 4.9 is *failure*, 5 – 6.9 is *pass*, 7 – 8.9 is *good*, 9 – 9.9 is *excellent* and 10 is *with honors*. Students who fail (with a grade of less than 5) must take the course again. The results are usually not good. The percentage of students passing the subject varies between 20% and 40%, resulting in a high number of students taking this course 2 or even 3 times.

2.2.1 The Traditional Teaching Approach

In our university, “Theory of computation” is traditionally taught in a series of master classes. Two of the three weekly sessions are devoted to the presentation of theoretical contents by the professor. These contents include definitions, fundamental results, and formal proofs of the results. The third session consists in solving problems where the concepts introduced in the theory sessions have to be applied.

Lecturers usually encourage their students to participate in class, with very little success. Partly, because participation is not explicitly considered in the grading method. As a result, solutions are presented by the teacher on the blackboard. For this reason, problem solving lectures become in practice a master class in which the students only copy the solutions presented by the professor, with the hope of understanding this material while preparing for the final exam.

Evaluation Method. The students take five tests of 30 minutes each throughout the course. These tests are fairly easy, since in order to pass them it is sufficient to carefully study some proofs given during the theory lectures. Let C be the overall mark from all of these tests, which is between 0 and 2.5. There is also a final exam, whose mark, F , lies between 0 and 10. The mark of a student in this subject is obtained by the formula $F + (1 - \frac{F}{10}) \cdot C$. The formula may seem strange at first. It is similar to a weighted average, but note that the less F is, the more weight is given to C . For example, if one gets a 10 in F (the best grade possible), then the weight of C is 0. Thus, in this case the value of C does not affect the final mark. If one gets a 0 in F (the worst grade possible), then the weight of C is 1. Thus, in this case the final mark is just C . The formula benefits students who work during the course, even if they perform badly on the final exam. The following example illustrates this situation. If one gets a 4 in the final exam (F), the weight of C is 0.6. In this case, the final grade is given by the formula $4 + 0.6 \cdot C$, which is between 4 and 5.5. So, in this case, the student only passes if he/she obtains a good grade on the tests (C).

2.2.2 The New Teaching Approach

We pretend to radically change the dynamics of lectures, giving more emphasis to students’ involvement, and making the professor’s role much more interactive and fruitful.

Our new approach introduces both a different kind of lecture and a new evaluation method. As mentioned above, students learn theory on their own by watching the videos¹, and the teacher does not introduce any material in class. Instead, this time is used by students to explain their solutions on the blackboard. Note that 4 hours of master classes are substituted in the new method by 4 hours of interactive problem solving sessions. The third weekly session is devoted to study time, during which the professor’s only task is to solve and clarify questions. In other words, the teacher is not grading or teaching, but is in the class to help with the content. They can come with their laptops, look at the videos again, ask questions about them, and try to solve the assigned exercises with possible hints given by the teacher. These sessions create a positive atmosphere where the students can more easily overcome their shyness and become active members of the class.

¹Videos are posted on youtube and linked at the end of the main subject’s page (www.lsi.upc.edu/~ggodoy/tc.html).

Evaluation Method. Given the nature of our institution and our students, participation does not come easily. Therefore, we try to stimulate participation by including it explicitly as part of the evaluation method. To this end, the teacher scores presentations of solutions by the students.

The new method has three parts: the results of five tests taken during the course (C , the same ones as in the traditional evaluation method), the result of a final exam (F , also present in the traditional method) and a new part, P , corresponding to students presentations of solutions to problems on the blackboard. The formula used to compute the final grade is $\min(10, 0.8 \cdot F + 0.6 \cdot C + P)$, where C ranges between 0 and 2.5, F ranges between 0 and 10, and P ranges between 0 and 1.5. Note that with this methodology, students can score a maximum of 11 points. This is to encourage students to choose the new approach.

2.3 The Experiment

We have applied our new teaching methodology to the afternoon group. The other two morning groups follow the traditional approach. Our experiment consists of comparing the performance of the students under each of the methods applied. Note that the fact that the new teaching approach is applied to the afternoon group only, may be a drawback for the success of the experiment: experience shows that the best students are usually registered in the morning groups.

We believe that students should always have the right to be evaluated with just a final exam, therefore we allowed students in the experimental group (i.e., the afternoon group), to choose between the traditional and the new evaluation method. That is, they can attend the lectures with the new method, but they will be scored with the traditional approach. Notice also that all students have access to the videos, including the ones in the morning groups. Moreover, any student can benefit from the problem solving sessions and presentations by other students, even if he/she is not required to do the presentations. Both these facts may bias the result of the experiment against the new method, since the newly created materials benefit all the students. It is also true that students of the afternoon group could attend the master classes in the morning. However, an opinion poll conducted among students (see Section 3.2 below) indicates that students prefer the videos to the master classes.

3 RESULTS

3.1 Video Accesses

The videos are posted on youtube² and are public. This site monitors the number and origin of video sightings. We give a brief summary of this data. We restrict ourselves to the videos in catalan and spanish, since the ones translated to english have not been available long enough to give meaningful numbers.

The number of accesses varies widely depending on the video. As of October 21st, 2010, the most viewed video has 5419 accesses. The least viewed one has 126 accesses. In the following table, we count the number of videos for several ranges of accesses.

Table 1: Video accesses.

# accesses	# videos
125-249	20
250-499	6
500-999	7
≥ 1000	4

Only 27 students chose the new approach. From their comments, we know that each of them watched each video twice on average. It is expected that some of the other students watched the videos too. However, most of the accesses come from other countries, mainly from Latin America. Since the topic is theoretical and very specific, we believe that the viewers are students from other computer science degrees. This fact suggests that the videos are useful to learn the subject in general and not only in the context of our teaching approach. Not surprisingly, the most accessed videos are the ones introducing classic material that is present in any course in theory of computation.

3.2 Students' Opinion

We collected anonymous opinions from students along the course. Some of the students were taking the subject for the second time, so that they were able to compare both methods. Here we summarize the most frequent ones:

- Being able to watch the video at one's convenient time is better than being forced to attend a lecture at a fixed time, thus avoiding situations when one is tired after several classes, has had a plentiful lunch recently, or has a bad day.

²The videos are posted on the channel <http://www.youtube.com/guillemgodoy>.

- With the videos, one can pause the lecture at any time, take a rest, rewind it, and see it again and again if necessary.
- With the old approach, once one gets lost in the class, the rest of the time is useless. This problem is solved with the new approach.
- Presenting solutions of problems each week is a good motivation to follow the course. The material is better understood in this way.
- The method forces one to work on the subject continuously during the course. The effort required is constant during the course and not excessive. It is deferential toward other subjects. The opposite is not true in general. Other subjects have strong peaks of work during the semester.
- A big amount of exercises are solved in class. This makes it more interesting, and seems a better preparation for the final exam, which essentially consists in solving exercises.
- The first created videos are too slow. Nevertheless some students were able to accelerate them making use of a computer application (the video speaker is concerned about the quality and tone of his/her voice as a consequence of such acceleration).

3.3 Teachers' Opinion

Here we summarize the impressions of the teacher who applied the new method:

- The fact that the students have to present their solutions on the blackboard motivates them much more than just delivering a paper with the solution. In fact, being exposed to their classmates criticisms forces them to prepare well their respective presentations.
- The solutions presented by each student are very interesting and rewarding for their classmates. Even if such solutions contain mistakes, the discussion generated from them is very fruitful.
- The professor is more accessible to the students with the new approach. They frequently ask questions about how to find solutions and how to present them.
- After an intensive interaction with the students during the course, the professor has more accurate information of each student, such as his/her knowledge on the subject, skills, strengths and weaknesses. Thus, it is possible to take more aspects into account in addition to the ones evaluated by a written exam in order to give a final mark to each student.

- 1.5 points for the blackboard presentations are not enough to motivate all students. Due to the high workload imposed by other subjects, half of the students did not solve the assigned exercises of the last part of the course.
- The preparation time and effort of the teacher is lower. It is not necessary to prepare master classes, which is hard and takes time. The continuous evaluation is done in the class, so it does not impose additional correction workload with respect to the old approach.

3.4 Students' Results

An unavoidable point for the comparison between the previous and the new teaching approach is the performance of students on the subject. We will avoid fine-grained comparisons since we consider that the population is not large enough for a rigorous analysis. Instead, we just present the result of our experience letting the reader extract his/her own conclusions.

Table 2: Comparison of results.

	Group 1		Group 2		Group 3	
	P	N	P	N	P	N
# students	46	0	50	0	19	27
# students passing	12	0	20	0	7	20
% students passing	26.1%	-	40.0%	-	36.8%	74.1%

Table 2 shows the number of students registered for the course, the number of students who passed the course, and the percentage of this two values, grouped by the followed teaching approach. In the table, *P* stands for previous teaching approach, and *N* stands for new teaching approach. Recall that only students of group 3 were allowed to choose between the two approaches while all the members of groups 1 and 2 were evaluated and taught using the previous approach.

Finally, we would like to remark that applying the previous evaluation method to the 20 students that passed the subject being evaluated with the new approach, 18 of them pass the subject anyway. In other words, 18 students pass the subject with the old evaluation method out of the 27 students to which the new teaching approach was applied. This represents a 66.7% of students passing the subject. This strongly suggests that the good performance of students that followed the new approach is not due to a more relaxed evaluation method.

4 THE VIDEO CREATION PROCESS

In this Section we describe the video creation process. Each video is at most 10 minutes long, since this was the limit given by youtube for freely submitted videos. This length actually works fine for us: a succinct and well prepared video of 10 minutes may give as many concepts as a class of 50 minutes, and it is more accessible. This is because lectures are partly improvised, the teacher can make mistakes, he/she can waste time in complicated details which are difficult to keep in mind, may explain related facts which are interesting but not central, etc.

We have created 37 videos in total, mostly in Spanish. They are being currently translated to English. In fact, most of them have been already translated to English.

Our video creation method has evolved until finding a procedure with a good balance between quality and effort. The first couple of videos took about a week each to make. While they have been a success in the sense that they have over 5000 visits and positive comments, they took too much time to make. After that, we thought of more efficient ways to create videos, and came up with the following process, which we applied to all of the remaining videos.

1. First, we write a pdf document that contains the image as well as the script of the video's audio.
2. Secondly, we capture the audio. Any mistake is immediately corrected by moving back the audio recorder a few seconds.
3. Third, we mark a screen capture area and record the image in this area while the audio is being played.
4. Finally, we combine audio and video with a video editor.

The second, third and fourth steps may require half an hour in total for a video of 8 minutes. Hence, one can invest most of the time in the first step, namely the creation of the contents.

In addition to a good balance between quality and effort, our video creation approach has other advantages: re-editing, correcting errors and translating into other languages is very fast. One just needs to translate image, script, and re-run the last steps (around 2 hours in total). Perhaps this method could be combined with a pen tablet, a tablet pc or a smartboard of enough quality to avoid the problems we mentioned above.

5 CONCLUSIONS

We have tried a new teaching approach using specially designed videos for self-learning instead of master classes. The results show that the method is a success from different perspectives, such as exam results, and students' and teacher's opinions. We believe that this method may also be useful for other scientific matters.

Given the success of our videos in the Spanish-speaking community, we recently translated them to English to make their contents available to a wider audience. English version of videos are posted on youtube and linked from www.lsi.upc.edu/agascon/videostc. We are curious to see what the impact of this translated material is. We are also interested in sharing our experience with other universities. In fact, we have made the videos publicly available in order to benefit the academic community in general.

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