STUDENTS’ BENEFIT FROM VIDEO WITH INTERACTIVE QUIZZES IN A FIRST-YEAR CALCULUS COURSE

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Abstract

The present study investigates learning benefits from non-interactive videos and from interactive videos (videos with quizzes) in an introductory calculus course. The videos were produced especially for this course as pen-casts. Also, interplay of videos in the course curriculum and other course activities is evaluated. The theoretical background is that multimodal learning resources helps students both in motivation and cognitive achievements. The videos are one of the learning resources for preparing the lessons (flipped classroom) and for simultaneous use during exercise classes.

Students evaluate how they benefit from the different video types and the use videos together with other course activities. Students experience a significantly larger learning outcome from the videos with interaction and that they reflect the awareness of their learning progress as they watch the videos. The videos correspond with the overall course curriculum and are superior to other learning resources available. The students interact with the videos as expected. The use of videos stimulates high level of reflection on both knowledge, study-process, and own use of learning resources (learning strategy).

Keywords: Interactive video, flipped learning, in-video quiz, student preparation, calculus course.

1 INTRODUCTION

Studying mathematics students often experience challenges in understanding the calculation methods, applying the proper theoretical solutions to specific equations etc. The purpose of this study was to examine if videos could help students overcome some of these challenges. Furthermore, we wanted to find a learning resource which was applicable for students’ individual learning processes and supplementary to individual needs.

Build on earlier experiences with non-interactive videos we wanted to stimulate processes that went beyond remembering and understanding to stimulate the student’s application of knowledge [1]. Interactive videos were considered relevant due to the general benefits of the principles of multimedia learning [2] and the use of interactive videos [3] containing a combination of corrective and explanatory feedback [4].

The learning theory we rely on to support interactive videos and how it is expected to affects learning is manifold. We recommend [5] for a review of diverse backgrounds for using interactive videos in teaching. Many studies try to cast a light on interactivity in video for learning purposes. Vural [6] explains how the quizzes in video can rely on the constructivist theories for learning and the Cognitive Information Processing Theory namely due to its invitation to self-regulation of learning and supporting the cognitive phases where students receive, group, connect to previous knowledge, transfer and finally “…recall (knowledge) from memory to apply ... across learning environments.” In this study, we consider the rotations with preparation with interactive videos and a face2face lecture followed by 1½ hours face2face exercises to feed in on this process. This process has similarities to the pedagogical method flipped learning where students in the preparation phase work with the lower level of cognitive skills and in-class work with the higher levels of cognitive skills facilitated by the teacher [7]. However, because two-thirds of the videos contains build in quizzes with subsequent feedback, the students seem to acquire a good basis of lover level of cognitive skills. Interactivity in the used videos can to a certain degree enhance the students learning in the preparation phase but it is the integration with face2face lecture and face2face exercise session that provides students with the reflective feedback during lessons.

All videos were based on the multimedia principle [8], which means that they combine spoken words and corresponding graphics to enhance the students understanding. Some were linear videos simply explaining a specific mathematical issue (video type 1). The rest were interactive [3] - the video pauses and the students meet questions. The students are encouraged to find the intermediate...
results, as part of solving a larger problem (video type 2a) or select between a set of solution methods (video type 2b). The students were immediately provided with corrective feedback [4] in terms of correct or incorrect, and the video continues demonstrating the proper solution method via explanatory feedback [4]. Explanatory feedback is also provided during face2face lessons.

We have aimed at leveling the difficulty of the videos regarding the prerequisites for students in this course. The intention is that videos are a tool for supporting learning within the zone of proximal development (ZPD) [9] not a tool for killing motivation. From a ZPD perspective the video must be understood as the more knowledgeable person who assist the students with hints and feedback so that new knowledge occurs at a level that is higher than what the student can achieve alone. Another argument for adding interactivity is to stimulate self-regulated learning processes supporting both cognition and motivation [10].

We assume that questions in video makes students aware of own needs and goals and reflective on content and the hypothesis is that videos with integrated quizzes and feedback enhance the student learning outcomes in the preparation phase which entail that they will arrive at face2face lecture and subsequently face2face exercise session with a higher level of knowledge (e.g. the applying level) which corresponds to some of the fundamental ideas in flipped learning [7].

This leads to the questions:

1. Are there any differences in how students estimate the learning benefit from three types of videos?
2. Are there differences in how students use the three types of videos?
3. Do interactive videos support deeper learning?
4. Do students value the idea of flipped classroom, the connection with the face2face elements (lectures and exercise sessions), and the integration of the different learning resources.

2 METHODS

2.1 Teaching interventions

We used a first semester calculus course for engineering students as a case study for using videos as part of the learning resources. 79 students were enrolled in the course and each of them was following one of the education programmes: BEng in Electronics and Computer Engineering, BEng in Electrical Energy Technology, and MSc in Engineering - Physics and Technology. The mathematical part of the course consisted of 14 three hour blocks, each composed of an interactive lecture and an exercise session. Lectures digs deeper in the theories and ends with a small formative calculation exercise. At exercise sessions students work with more examples like the ones from the videos. Thus, the rotations apply to ideas about flipped learning method tough lectures are still present. Prior to each block students were encouraged to watch one or two videos and read in the textbook. The course started in September 2016 and with exam in January 2017. An overview of the course structure is given in fig. 1.

Fig. 1. The continuum for the course and the points of data collection
2.2 Learning-resources

Learning resources used in the course were the textbook “Calculus a complete course, 8th edition”, by Robert A. Adams, a few videos from Khan Academy videos and several videos that was produced by the teacher. The homemade videos, which is of interest in this paper, were in Danish but will be referred to using their English title. The videos that are mentioned in this paper are listed in table 1 and can be accessed on this link. There are two main types of videos, video type one (VT1) are non-interactive videos without quiz elements and video type two consists of interactive videos with quiz elements. Videos of type two is subdivided into two sub categories which are differentiated by the quiz challenge. The challenge in VT2a is to calculate some intermediate results and the challenge in VT2b is to choose the proper solution strategy. The content areas which this paper focuses on integration and differential equations are both covered by all three types of videos to eliminate inter content differences.

<table>
<thead>
<tr>
<th>Video title</th>
<th>Type</th>
<th>Duration (m:s)</th>
<th># questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integration by substitution, example</td>
<td>VT1</td>
<td>5:44</td>
<td>0</td>
</tr>
<tr>
<td>Integration by parts, example</td>
<td>VT2a</td>
<td>7:48</td>
<td>4</td>
</tr>
<tr>
<td>Partial fractions</td>
<td>VT1</td>
<td>7:18</td>
<td>0</td>
</tr>
<tr>
<td>Choose integration technique</td>
<td>VT2b</td>
<td>6:36</td>
<td>4</td>
</tr>
<tr>
<td>Long division of polynomials</td>
<td>VT2a</td>
<td>6:16</td>
<td>1</td>
</tr>
<tr>
<td>Separable differential equation</td>
<td>VT1</td>
<td>10:33</td>
<td>0</td>
</tr>
<tr>
<td>First order linear differential equation</td>
<td>VT2a</td>
<td>11:39</td>
<td>4</td>
</tr>
<tr>
<td>Types of differential equations</td>
<td>VT2b</td>
<td>9:09</td>
<td>3</td>
</tr>
</tbody>
</table>

Table 1. Video type, duration, and number of questions for each video represented in the questionnaire.

2.3 The questionnaire

The questionnaire was produced for this purpose because we wanted specific information on students’ opinions on

- their learning benefit from videos including non-interactive vs. interactive videos
- the way they used the videos
- how they considered the interactions between the learning resources (videos and books) and the face2face lessons.

The questionnaire was presented in SurveyXact [11] and the students were met with an e-mail if they didn’t respond within the period. In addition, the web page serving the videos logged the video’s name, the visitor’s name (if logged in) and timestamp.

2.4 Evaluation of results

2.4.1 Quantitative results

The students were requested to evaluate different things in the questionnaire on Likert scales. Responses were analyzed using the R statistical software [12]. The Wilcoxon Rank Sum Test [13] is used for assessing whether differences in answers to the Likert based questions are significant.

2.4.2 Qualitative

The questionnaire contains free text questions assigned to each of the three types of video, the compliances to the book and face2face lessons. Answers from all students to each specific free text question were pooled and analyzed. A given free text answer were assigned to one or more subcategories defined by the analyzer. Two authors completed the analysis separately in order to
verify the subcategories for the answers and the amount of answers in each subcategory. Since the categorization were almost the same as well as the counting we concluded the reliability was sufficient and agreed on small differences.

3 RESULTS

Questionnaire was sent to the 79 enrolled students. We received answers from 48 students. Mails were sent twice to remind students to answer. Approximately 60 students are considered active during the course. 59 students attended the final exam.

3.1 Students evaluation of the videos’ support for learning

Students were asked “which type of video helps you the most in your studies”. We see a significant difference testing VT1 vs both VT2a and VT2b. This leads to the conclusion that interactive videos of either kind are significantly estimated as better learning objects by the students. The possibility of dialoguing interactivity is appreciated by the students in both the calculations (VT2a) and the reflections of proper methods of solutions (VT2b). We observe in the underlying software that the students actually use the dialogue questions in the videos.

![Image](image.png)

Fig. 2. Students’ responses to the question “which type of video helps you the most in your studies?” Percentages at the right accumulates the two categories “large effect” and the one before (the counts of 3 and 4 on the Likert scale). Percentages at the left accumulates “no effects” and the next category (counting 0 and 1 in the Likert scale). Students estimate Interactive videos to be a significantly better help during learning than non-interactive learning videos. (P=0.0013 for VT2a and p=0.0011 for VT2b). There is no significant difference between the two interactive types of videos P=0.68.

3.2 Students evaluation of the difficulty of the videos - are videos within the ZPD and are the most difficult the ones that are repeated most frequently?
Fig. 3. How hard do you remember the difficulty of the videos?

![Graph showing the difficulty of videos](image)

Fig. 3 shows that videos are not too hard for the students. In fig. 3 the ranking of the most difficult videos from top to bottom does not mirror the Video Types. The conclusion to this is that other factors than the video types is determining whether the students find the video difficult. The teacher explains the distribution to mirror the new parts of the curriculum in the top as well as the parts considered generally hard by students.

Combining fig. 3 with fig. 4 we see no correlation between number of views and difficulty. The number of active students is approximately 60 general students and in general a student watch the videos 1 or 2 times some students even 5 times. Fig. 5 confirm that reviews are taking place. Graphs raise more than the number of students. Data in fig. 4 was collected before examination and as shown in fig. 5 videos are displayed again toward the exam in January indicating that new counts in January could be a bit higher.

Fig. 4. Students’ report of number of views (in november). No student enter 0 views and therefore graph starts with 1.

Fig. 5. The distribution of views throughout the course. The graph representing long division seems to be on somebody’s opening page and therefore we do not use that one for any conclusions.

Graphs on specific videos raise in views the two days before the lecture in the relevant content. Student return to the videos even if the lecture covering the content was several weeks ago. Just before exam graphs generally raises again. In the videos, we see that students on average answer
about 40% of the posed quiz challenges and that 59% of the responses are correct. These numbers vary a lot from video to video.

3.3 Students estimated benefit from videos, course activities and other learning resources

Students’ estimation of the effect of different learning resources are shown in fig. 6. As also confirmed in fig. 2 we have significant difference in the learning effect between the videos of type 1 and the two video types 2a and 2b. Here this result compares the estimated benefit all course activities. The textbook is considered a significantly bad resource compared to our videos in students’ evaluation. Even measured against the lowest scoring video (VT1) textbook is significantly considered not beneficial (p=0.5\times10^{-7}).

![Fig. 6. Students’ estimation of all course activities including the learning resources books and videos.](image)

3.4 Students view on integration between videos, textbook, lectures and exercise sessions (the flipped learning perspective)

3.4.1 Video and textbook relations

As shown in fig. 6 the book is not appreciated by students. Comments on video book relations we received 30 answers. 21 answers refer to videos as a very good supplement to the book which opens up the content of the book:

“Videos are good for isolated topics but doesn’t give you the overview of all content for the week”, “Video works as a good intro before reading. It gives you an idea of the core-content and the expected skill”, “I often understand better what I see in the videos than what I read in the book”, “Videos have given me a clearer understanding of content we read in Calculus. Book seems somehow complicated at times and it is nice to have a media which quickly and precisely clarifies how things are connected. if I could choose I would like this kind of videos in all of my courses”. 7 answers directly critique the book “I have difficulty understanding the book and use it only for supplementing the video and for topics with no videos ...” Only 5 mentions that the videos to a degree replace the book “Videos gives you the same as the book but much more eatable. Often I don’t read the book as thorough if I have seen a video”.

3.4.2 Video and lecture relations

As seen in fig. 5 most students view the videos before lectures. Students describe videos as satisfactory for both preparation and supplement to the lectures “…They (lectures and videos) are leaning onto each other and function really good together”, “videos are good preparations. It makes it
much easier to understand the lecture”, “... I feel that in each video elements are used also in the
lecture which enhances my learning of the content”.

3.4.3 Video and exercise sessions relations

Comments are also very positive in this matter; some examples explain deeper: “videos enhances the
prerequisites to solve the exercises”; “Videos help a lot if you are stuck in an exercise. Then you can
return to the video in which you explain the content”.

3.5 Students interactive habits are reflective as well as behavioral

3.5.1 Reflective behaviour

In the text answers, very many students mention dimensions of reflection. VT2a&b (interactive videos)
are preferred by many “I feel that I learn more from videos with interaction. You don’t just get a
passive listener”; “Questions help me to keep focused and it makes fun to see if you understand”.
More than half of the 30 comments present perspective on videos supporting reflection. One third are
explaining how the videos improve their understanding like “It is much easier for me to understand
new content if somebody draws and explains it to me. I am not that motivated to sit and read so
therefore I think an oral explanation is fantastic”. The calculation process is important for better
understanding; “seeing the calculation process is important to me”, “it helps me to follow the
calculations instead of just reading them in a book”.

Another reflective behavior is note taking during watching and explaining integrating of knowledge
from videos into classes: “all types of video helps me a lot to understand the content... usually I take
notes and write down all calculations and use them as exemplars in the exercises in class”, “feel
better prepared for face2face lessons”.

3.5.2 Motivational aspects

Almost half of the answers mention motivational aspects of interactivity through a good learning
experience. An example: “questions help me to keep focused and it makes fun to see if you
understand”. Some of the reflective answers praise the multimodal input in general “using both eye
and ear helps me a lot”, “it’s easier for me to learn visually”. Others don’t pay attention to the
difference: “Frankly I didn’t notice the differences. I just saw them as different approaches to the same
(the best possible teaching). Sometimes one format fits and sometimes another.”

3.5.3 Behavioral interactivity

Regarding the behavioral interactivity (rewinding, acceleration, etc) students find their own strategies,
but remarkably, behavioral interactivity is mostly mentioned together with a reflective dimension of
metacognition: “being able to pause the video and run through hard calculations again is a big
advantage for me”. Some students compare the qualities of the three video types for reviewing: VT1
(non-interactive videos) are “often easier for repetition because you are not disturbed by the
interactive exercises” and another strategy VT2a&b (interactive): “easy to find what you are looking
for because of the “chapters” tied to the exercises” and “for a quick repetition I don’t use the interactive
parts”.

4 DISCUSSION

Signs for deeper learning that we look for to document deeper learning is: students describing that
video motivates them (appreciation), demonstrate a self-regulated meta reflection on their own
learning outcome [10] and that students have an appropriate use of learning resources in the learning
process [3]. The data shows that students significantly estimate that they learn better using the two
interactive video formats. This underpins the relevance of our four research questions.

A general trait in the results is students' self-driven motivation and metacognitive reflections on their
own progress (section 3.5). The students generally appreciate the multimodal learning opportunity
(Fig. 2). From the number of views (fig. 4 and 5) and the text responses we conclude that students
value the resource in general.

As expected the data confirm the work of Clark and Mayer [8] regarding the modality principle,
which underpins the importance of spoken words supported by graphics as the primary source in good
educational videos. Students appreciate that the videos are based on audio and drawing (graphics) (section 3.5).

Moreno and Mayer [3] differentiate between behavioral and reflective practice. Here the distinction between behavioral (winding and rewinding) and cognitive activity (calculations and reflections, quizzes) is of utmost importance for learning. In this study, there is a significant difference in the self-estimated benefit of learning from the videos with and without interaction. Solving the interactive exercises clearly are cognitive interactions. Especially the process of calculating difficult equations are often mentioned as returned to for reflection in later reviews of the videos. Generally, we observe only a very little tendency for students to unreflected behavior (conclusion from free text answers). Also, the fact, that students to a very high degree report that they take control over their own learning while using the videos we interpret as a statement for deeper learning processes. “if there is things that I do not understand I try to go through it again and maybe calculate along with the video” (VT1), “I pause it, think it over, and take notes” (VT1). Thus, we find support in our data that students are very conscious why they repeat a whole video or parts of a given video even also the non-interactive videos. The interactivity per se is regarded as a wakeup call for some students and for others the tasks are a clear help for self-evaluation. Therefore, we reason that at least part of the explanation to the significant higher score in learning benefit from our interactive videos is that this encourages students to work at a level above “just listening”. This monitoring of own learning progress is found to be of outmost importance for effective learning processes [14].

The reflective trait also continues throughout the results regarding interaction with other learning resources like the textbook. The way students describe that they use the videos together with the book clearly describes the higher order thinking (a large proportion of the students was able to both apply and transfer methods to new challenges at the final oral exam). It seems that the videos make students reflect on their own learning process and their learning success. Examples are: “After watching the video I read the book to see if I actually understood everything, which is normally the case since I get more out of the videos than the book”, “it (videos) can offer you a better understanding for what's in the textbook. I always watch the videos first”. Students take control over the learning process. The benefit of this trait is supported in Boekaerts ideas of learning. Boekaerts [10] and earlier studies suggests that in active constructive goal directed learning ... “the self-regulated learners rely on different types of prior knowledge, including: domain specific knowledge and skills, Cognitive strategies that can be applied to these domains, Metacognitive knowledge and skills, and metamotivational knowledge and skills” This apply nicely to our results where videos are closer to students' former experiences with mathematics than the book itself. To stimulate deeper learning students must be motivated to use the learning resource. Our student report multiple reasons why videos are good for them. We regard two perspectives to confirm that kind of motivation among students: Multimodality [8] and the manageable difficulty [9]. The videos seem to be inside the student's ZPD but still challenging, and take up the challenge of the quizzes (section 3.2). Videos that are reported most difficult is representing new content for the students and the difficulty mirrors the students' prerequisites. If textbook was the only learning resource, we interpret from our data that the students would be left with a non-motivational learning resource.

Looking at the results in a flipped learning perspective brings yet another light on our study. Often flipped learning approaches is met with queries whether the videos replace the book, if students prepare and if students take part of the face2face activities. We found that students in general were very satisfied with this “new channel” in the learning resources. A few of the students replace the book but then risk to miss the rest of the content. More students are aware that the videos are a supplement for training the application of the theory in the book and find their own strategy to study the materials. As far as preparation we see that the videos are watched before the lessons. Videos for supporting and scaffolding in relation to the book is an important aspect, that makes preparation more effective than if students were left with only the book. Therefore, students feel more safe during preparation. The students explain that video helps them prepare, helps them understand the book, and is a good resource in the group work as a good “just in time” resource for learning. Student activity during preparation is confirmed in more of our results for instance fig. 5. The documentation of view before the lectures and the explanations of how the students use the videos supports that we have reached our goals of providing students with a learning resources that stimulates reflective behavior and that students use it reflectively. This applies for all three types of video formats. They also to a very high degree pause the videos, solve the exercises, and receive feedback as a “dialoguing interactivity” according to [3].
The answers from the students supports that the course applies properly to the 5 principles of a learning design by [3]. For “guided activity”, principle 1, we aimed at providing a clear learning path for students through a weekly notice from the teacher and using the videos in combination with face2face teaching. The students explain that the videos supplement nicely to the lectures and the exercise sessions. As explained above Principle 2, “reflection”, is remarkably high during preparing. The face2face interactive lectures focus on a more scientific background for the video content, which can be considered skill related. Regarding feedback (principle 3) corrective feedback (CF) is provided in the interactive videos (box for results turn red or green and explanatory feedback). Explanatory feedback (EF) is given both in the video when things are explained and during exercise sessions when teachers help students with relevant exercises. Here content from all videos are being trained and tasks like the ones in the interactive videos are taken up. Hence the exercise sessions is a resource for feedback on problems the students might have. This connection is confirmed by several students in the free text answers.

Principle 4, pacing, is shown in this research to be a very relevant factor indicated in the answers from many students e.g., accelerating speed, jumping, reviewing parts or whole videos, and even choosing not to watch the videos and use other resources or see the videos again much later. We consider this a very interesting finding, in that this individualization of pace actually seems to help student a lot in taking control of the learning process, which is very important [14].

5 CONCLUSION

The results support that access to videos helps students feel more prepared for face2face session. The interactive videos are estimated significantly better than both non-interactive videos and the book. Interactivity in itself is an important factor for learning and furthermore the results provide us with important information about the effect on students' motivation and self-regulation of learning. This gives a meaningful contribution to learning at a higher level during preparation. Whether the learning resource directly leads to the “applying” level is not proven, but indications are present, that the videos are supportive in that process (research question no 1-3).

The high estimation of the videos' benefit for learning and the fact that students draw on knowledge from the videos both during the lectures and during the exercise sessions (and even use the videos actively in the exercise classes) supports that the ideas of flipped learning with interactive videos is meaningful for students in a calculus course of this kind (question no 4).

To fully utilize the potential of interactive videos in future courses at the University of Southern Denmark we plan to apply the following adjustments. 1) support in video navigation by adding chapters, 2) produce additional videos with interactive elements, 3) clearly state that the videos only give an overview of a topic and that the textbook have additional details and 4) research on students’ perception of feedback both during interactive videos and during face2face sessions.

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REFERENCES


