Learning Physics with Interactive Videos – Possibilities, Perception, and Challenges

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Abstract. Videos on YouTube are very popular among students and therefor the number of educational videos is growing. In general, such videos are a learning opportunity with unique features like visual highlighting or multiple representations and can be watched as often as you like. Moreover, videos can be used in many different ways: to repeat things, to learn something new, or for entertainment. Here the paper presents a study among n=260 German students to determine how often and why students are watching educational videos in Physics, Chemistry, and Biology. Furthermore, the study shows unfortunately that students often just watch learning videos passively; whereas, learning needs an active processing. So making already available online videos more interactive with tasks, questions, and quizzes can foster an active processing and students should perceive interactive videos as more helpful when learning online. To do so the paper presents the free and open source tool H5P, which can be easily used by every teacher to enrich learning videos with tasks, feedback, summaries, or additional information.

1. Options for Learning with Online Videos

YouTube is the most popular web service among children and adolescents in Germany between the age of 12 to 19 and more than 60% are watching videos on YouTube more than once a week [1]. Also more than 60% use videos on YouTube to get news and information. In general videos on YouTube cover all conceivable topics, and are available for free. Therefore, even learning videos in STEM subjects can reach thousands of students [2]. Such videos can be paused and replayed. Also videos can contain visual highlighting, animations, multiple representations [3], and visualizations of invisible things like electrons or concepts like electric or magnetic fields. Moreover, online videos are available 24/7, can be watched on Smartphones, and can be used nearly without copyright concerns. So the large number of available educational videos on YouTube seems to be an ideal learning opportunity for students.

Unfortunately, students watching videos on YouTube are mostly passive recipients even if the videos are educational videos. On the other hand, most theories of learning with multimedia, for example Mayer’s “Cognitive Theory of Multimedia Learning” [4], are based on an active processing assumption. Thus, learning needs active processing of the given information. Such theories are supported by a wide range of studies, which show that active learning increases student performance (a meta-analysis see [5]). So it seems to be necessary to make these already available videos more interactive to foster learning [6].

1.1. How often and why are students watching educational videos

However, it is largely unknown how often and why students watch online learning videos in physics, chemistry, and biology. Do students watch educational YouTube videos for entertainment, do they want to learn something new, or do they want to repeat a topic they did not understand in class? These
aspects influence the students’ selection of videos, the amount of time they spend watching a video, and their whole learning process when watching an educational video. For example, it is more likely that a student watching an educational video on YouTube as preparation for a test in school is interested in explanations and summaries than a student watching a video for entertainment. Probably this student is more interested in new insights, and spectacular effects and interactive elements could scare him off.

1.2. Watching videos related to school
In general, educational videos do not have to be related to class but definitely some students are searching for such videos. Also teachers consider the use of videos in their classes nowadays more often and the technical equipment in most schools is improving so teachers can easily use online videos hosted on YouTube in their classes. They also can recommend videos to their students or use videos as part of their homework. Here the students’ attitude towards the videos and their learning process are again different. For teaching in a flipped classroom concept or for MOOCs videos are essential and students attending such a course have to watch the provided videos. Usually such videos are embedded in the course and tasks related to the videos are provided. As mentioned before this should foster learning with the videos.

However, here again it is largely unknown how often videos are used in class, are recommended by teachers, or are part of the homework. Also the students’ attitude against educational videos in class is unknown. All these aspects affect, what a good educational video for a certain user group has to contain. So we developed a questionnaire with 27 questions about the students’ use and perception of educational videos on YouTube in physics, chemistry, and biology.

2. Questionnaire Study about Using Educational Videos
To gain knowledge about the students’ use of educational videos on YouTube, their attitudes towards interactive videos and the use of educational videos in schools we performed a questionnaire study with students.

2.1. Structure and content of the questionnaire
The questionnaire consists of different sections, each with a different focus. In the first part we tried to determine how often students are watching educational videos related to their classes in physics, chemistry, and biology and how much time they spend watching such videos. Also, we asked for subscribed channels and their additional activities when watching an educational video (reading or writing comments, doing related exercises, writing a summary). Moreover, we asked how much time they spend watching online videos on YouTube in general without a relation to their classes.

A second part was about the students’ attitude towards educational videos, their experiences (for example with errors in videos), and their interest in the integration of interactive task in videos. Moreover, we asked about the perfect length of an educational video and helpful elements like tasks with solutions, explanations, or applications in everyday life.

The third part was a comparison online videos and other typical References used in school and when learning online (books, websites, Wikipedia).

The last part contained personal questions about age, sex, type of school, grades in physics, chemistry, and biology and total time doing homework and preparations for classes.

Most questions were single choice questions and in questions about personal attitudes Likert scales with four or five options were used.

2.2. Conduction of the survey
The study was carried out with support of the school labs: the PhotonLab – the laser laboratory for school students, and the DLR_School_Lab Oberpfaffenhofen. The PhotonLab is a cooperation between the Munich-Centre for Advanced Photonics, the Faculty of Physics at the Ludwig Maximilian University (LMU) and the Max Planck Institute of Quantum Optics (MPQ). It is located in Garching near Munich designed for students in the 9th grade and above. The DLR_School_Lab
Oberpfaffenhofen is also located near Munich, but visited by schools from all over southern Germany. So students from different schools participated in the study. Data collection took place in a short period of time in June 2018 where students could fill out the paper-and-pencil questionnaire voluntarily after visiting one of the two school labs.

2.3. Data processing and basic characteristics of the participants

Subsequently, the data was digitized and transferred into a SPSS-database and all evaluations and analyses were performed with SPSS 25. In total the collected data of n=260 students were usable. 184 students (more than 70%) were at the age of 16-17, 61 students were at the age of 14-15, and only 9 students were 18 or older (see table 1). 6 students choose the “no answer” option. 148 female students (57%) and 106 male students (41%) participated (again 6 students choose the “no answer” option). All students visited a Gymnasium (advanced secondary education).

| Table 1. Basic characteristics of the participants. |
|-----------------------------------------------|
| Age 14-15 | Age 16-17 | Age 18+ | no answer | Total |
| Male | 25 | 71 | 8 | 1 | 106 |
| Female | 36 | 110 | 0 | 2 | 148 |
| no answer | 0 | 3 | 0 | 3 | 6 |

3. First Results

Initial analyses show that there are no major differences between male and female students in our data. Even if male students watch slightly more online videos in general, the use of educational YouTube videos related to class is almost identical. Therefore, in all subsequent analyses, the entire sample was always considered and not distinguished between the sexes.

3.1. Frequency of using educational videos in physics, chemistry, and biology

About 40% of the students watch YouTube videos without relation to class more than 4 hours per week. Additional 20% watch between 2 and 4 hours. Only 18 watch online videos less than 30 minutes per week. In contrast, about 60% of the participants watch educational videos related to physics, chemistry, or biology less than one a week. 28% watch such videos only 1-2 times. So 76% of the students spent less than 15 minutes per week watching online videos related to class. Nevertheless, 65% of the students subscribed a YouTube channel related to physics, chemistry, or biology and about 60% is able to name the channel. Among the students in Germany “The SimpleClub” and “100SekundenPhysik” are most popular.

3.2. Use of educational videos by teachers

Moreover, students report that many teachers regularly use YouTube videos in class. 15% of the teachers use videos once a week or more often. In total about 60% of the teachers use videos more than once a month and only 6% of the students state that their teachers never use videos in class. In contrast, teachers rarely use videos as part of their homework, and they rarely recommend educational videos to their students. 36% never use or recommend videos and 18% less than once a semester.

3.3. Attitude towards educational videos on YouTube

Students show a positive attitude towards educational videos on YouTube. On a 5-point Likert scale from always (4) to very rare (0) students answered the question “At the end of an educational video, did you feel that you understood the content?” with an average of 2.82 (SD=.62). Also 76% of the students rated the quality of the educational videos as good or very good. 52% of the students never noticed a mistake in an explanatory video in physics, chemistry, or biology and 24% very rarely noticed a mistake.
Asked if educational should be shown more frequently in physics, chemistry, and biology classes, 50% of the students fully agreed with this statement. Another 33% rather agreed and only 5% disagreed with the statement. Basically, the students want the use of YouTube videos especially when introducing new content and for repetitions.

3.4. Tasks related to the video
Finally, we asked if tasks related to an educational video should be presented at the end of the video and if such task should be integrated in the video. Here 46% totally agreed to present task at the end of the video and another 40% rather agreed. Regarding the integration of tasks in videos, the results were somewhat less positive, but still 24% totally agreed and 30% rather agreed. Only 9% disagreed.

4. Discussion and Conclusions
As mentioned in chapter 1 videos provide unique learning possibilities and can be easily accessed. So educational videos can be used by teachers in their classes and students can use videos to foster their learning in physics, chemistry, and biology.

4.1. Frequency of use by students and teachers
Our results show that most students use educational videos related to class on YouTube but much less common than they watch YouTube videos without a connection to their classes or homework. An aspect that can explain that difference is, that teachers rarely recommend videos and very rarely use videos as part of the given homework. On the other hand, most teachers use educational YouTube videos in their classes. Here further research is necessary to answer why teachers rarely use videos as part of exercises and why they do not recommend videos to their students for example as preparation for a test. Maybe teachers do not know many different YouTube channels where educational videos can be found or teachers judge differently about the quality of available educational videos. But as videos become more and more the students’ central information medium, it seems necessary for teachers to deal with them more and to use videos more often.

In comparison to the rare use of school-related videos, it is surprising that nevertheless 65% of the students have subscribed to an educational YouTube channel. A possible explanation is that students just “bookmark” channels that may be helpful in the future by subscribing. Another possible explanation is that students like educational videos from specific channels like “The SimpleClub” and just watch their videos even if they have no relation to the class.

4.2. Attitude towards educational videos and quality of educational videos
Our results show a positive attitude of students towards educational videos. At the end of the most videos students feel that they understand the contents of the video. However, it is critical to note that this may be a misperception. After watching a 5-minute video on quantum physics, you can hardly reproduce the central concepts correctly, even if you feel you have understood the video. This also applies to less complex content. Again, problems are to be expected when solving tasks following the video. Nevertheless, the videos give students the feeling that they understand the content. This can be used in particular for the motivation of the students and for a positive self-concept in physics, chemistry, and biology.

Somewhat surprisingly were the results regarding errors in the videos. Here, most students stated that they had never or rarely discovered errors in videos. In contrast, discussions and comments on the videos suggest that at least some of the videos contain bugs. This suggests that students cannot reliably detect errors in videos when they are unfamiliar with a topic. Here further research is necessary to determine the actual quality of educational videos in physics, chemistry, and biology.

4.3. Videos and tasks
The results of the study make it clear that students want exercises related to educational videos. The students prefer it when the tasks are present at the end of an educational video. Integrated tasks are not considered as positive as tasks at the end. A possible explanation for this is that students have very
limited experience with interactive videos where tasks are integrated. Another reason could be that videos with integrated tasks are more challenging. When watching an interactive video, a student cannot be some passive recipient. This could seem daunting at first. Nevertheless, taking into account different learning theories the integration of task into video appears more promising.

5. Conclusion: Creating Interactive Videos with H5P

According to multimedia learning theories and the active processing assumption learning videos should be more interactive to foster an active processing of the presented information. According to our results videos should include tasks related to the presented content (at the end of the video or integrated).

Therefore, it seems advantageous to make learning videos more interactive by including tasks directly in the video. Unfortunately, new videos must be recorded to realize such a scenario. A more promising way is to adapt videos with H5P that are already available by just adding interactive tasks.

5.1. Adapting already published videos with H5P

H5P (www.h5p.org) is a free and open technology, licensed with the MIT license and developed to create, share, and reuse HTML5 content and applications. H5P can be used for creating quizzes, memory games, fill in the blanks task, and in particular for creating interactive videos. For this purpose, only the URL of a YouTube video is copied to H5P and any interaction can then be added via a web interface. No programming knowledge is necessary for this and every teacher can easily create, share, and adept interactive videos. Furthermore, H5P provides plugins for Learning Management Systems (LMS) like Moodle and can be used for learning analytics. Another tool which can be used to create interactive videos is Adobe Spark Video.

With H5P various ways can be used to improve learning with videos. For example, a specific question can be placed at the beginning or a quiz can be placed at the end of the video. Moreover, H5P enables real adjustments on YouTube videos. Additional text can be displayed, the playback rate can be modified, and most important different tasks and questions (single-choice, multiple-choice, fill the blankets, drag-and-drop tasks) can be displayed as overlay over the video. For example, figure 1 shows a single choice question in the video frame. Thus, after the presentation of the experimental setup in the video, students have to predict the result of the experiment. A short interactive video with many different interactions is available under https://h5p.org/node/274069.

5.2. Feedback for students and teachers
Computer-based feedback is another advantage of interactive videos. For most types of tasks students receive an individual feedback after they submitted their answers. The positive effect of feedback for learning has been proven for example by Hattie in his meta-study [7]. Figure 2 shows the feedback a student receives after solving a “Fill in the Blanks”-task. In addition, it is possible to jump to a specific scene in the Video based on the student’s answers. For example, if a student did not properly name the parts of an experimental setup, the video may jump back the setup. In addition, the teacher also receives feedback about the student’s success in answering the questions in a video. This allows the teacher to control whether a student has watched the video and how successful he has learned with the video. Hattie and Timperley describe such feedback as particularly effective for teachers [8]. So on one hand, interactive videos can activate students and thus promote learning with videos. On the other hand, the feedback and control options can lead teachers to more intensively use videos and their unique learning potential.

![Feedback for a “Fill in the Blanks”-task with H5P.](Image)

**Figure 2:** Feedback for a “Fill in the Blanks”-task with H5P.

**Acknowledgments**

This study was supported by the Joachim Herz Stiftung, Hamburg ([https://www.joachim-herz-stiftung.de/en/](https://www.joachim-herz-stiftung.de/en/)).

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