# STUDENTS PERSPECTIVES ON VIDEO-BASED LEARNING IN CDIO-BASED PROJECT COURSES

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## ABSTRACT

This paper aims at demonstrating the applicability of video learning in CDIO-based project courses and at evaluating to what extent it benefits students. The courses are Machine Elements (PPU210), Product Planning - Needs and Opportunities (PPU085) and Engineering Design and Optimization (PPU190) in the Mechanical Engineering programme at Chalmers University of Technology. The research was carried out by first creating a set of videos for selected topics in three courses. In total, 22 videos were created including topics such as “Benchmarking”, “SWOT”, and “Prototype lab equipment instructions”. The learning outcomes of the video lectures were mapped to the CDIO syllabus. A blended learning environment was developed, i.e. the videos were utilized as additional support alongside existing learning activities. The videos were then used in the courses and the students’ feedbacks collected through a dedicated questionnaire, the regular course evaluation survey, and in student-teacher group meetings during and after the courses. The collected data was analysed to produce inferences about the applicability and utility of the video lectures.

The resulting analysis shows the students’ preferences regarding the evaluated video lectures and instructions. The students find videos more appealing compared to traditional lectures. One of the main benefits highlighted is the possibility of watching the videos in parallel to the design-build-test project execution rather having the classroom lecture only. This helps in reinforcing concepts, and results in less dependency on supervisors during the project execution. Videos proved to be suitable for creating a blended learning environment and improved the perceived learning experience for the students. In order to maximize student satisfaction and interaction with the videos, the videos should be short and closely aligned to the other learning activities. The paper also suggests future improvements to be carried out for video-based learning in the courses, and proposes an easy adaptable way for teachers to develop video material.

## KEYWORDS

CDIO Standards 2, 5, 7, 8; Video-based learning, Design-build-test project, Blended Learning, STEM education, Problem-based learning

## INTRODUCTION

It has been observed recently that the advancements in information technology and digitalization, along with the increased affordability of educational technology, has led to a broader adoption of those technologies in higher education. At the same time, student behaviour towards learning is changing and many students prefer student-driven personalized learning, which is typically enabled by an availability of online resources (Chen, 2008; Cronhjort & Weurlander, 2016). This gives students more flexibility and control over their learning process.

There are many examples of successful applications of video-based learning (VBL) in engineering and science education, e.g., in software and control theory (Cabezuelo *et al.*, 2015) or physics (Stöhr *et al.*, 2016). However, there are comparably fewer examples of video-based learning in design-build-test project courses. Reasons for this may include that design education often relies on personal tutoring and feedback in small-group settings as well as the wish and need to build things as learning experiences.

The Mechanical Engineering programme at Chalmers University of Technology has a strong emphasis on problem-based learning (PBL) which is fundamentally based on the CDIO syllabus. The courses included in this study are *Machine Elements* ("*Maskinelement*", PPU210, 2016), *Product Planning - Needs and Opportunities* (PPU085, 2016) and *Engineering Design & Optimization* (PPU190, 2016). In order to effectively execute the CDIO-based project assignments within the timeframe of the course schedule, students need the knowledge and experience of design tools and methods beforehand or alongside the project execution. In the current scenario, the design tools and methods are given to the students through lectures by the professors and project supervision session by the teaching assistants (TAs).

The three CDIO-based project courses faces a number of challenges. The project execution in the considered courses usually requires close supervision and tutoring for the students. There has been a trend observed that the students demand more supervision time during the project execution which puts constraint on the amount of resources to be allocated. Further, the regular supervision time assigned in the course is often used to troubleshooting and to answer trivial questions from the students which does not contribute to develop a deeper understanding of advanced concepts. Other practical constraints experienced during the courses are delays in the start of project by the students, for example due to a lack of motivation or that some students miss assignment or lecture sessions if they are not mandatory. Video-based lectures or instructions might be a way to address those challenges and are tested in this study.

This paper aims at demonstrating the applicability of video-based learning in CDIO-based project courses and at evaluating to what extent it benefit students. The paper will also demonstrate the pilot process used in video development and provides recommendation for future usage of VBL. The questions raised here are:

- Is the video-based learning (VBL) format suitable for supporting CDIO-based project courses?
- What are the key features (video length, difficulty level, scope for video content, etc.) to take into account for video development from students' perception?
- What are the perceived advantages and drawbacks with VBL for supporting CDIO-based project courses?

The paper is divided into the following sections; literature review, method, course description, results, and discussion followed by conclusion. The literature review investigates the prior work in the areas of blended learning, PBL and VBL. The method section highlights both the methodological approach that was applied for this study along with the methods used to generate the videos for the courses. The next section briefly introduces the studied courses and characterizes the project assignments according to the CDIO syllabus. The results section presents the outcomes of the quantitative and qualitative evaluation of the VBL in the different courses from the student's perspective. The results are then discussed in the section including recommendations for using VBL in project courses. Finally, the conclusion presents the overall reflection of VBL for a CDIO-based project course.

## LITERATURE REVIEW

In this section, a brief review of the work in the area of blended learning, video-based learning and problem-based learning is presented. The aim is to identify the trends, opportunities and constraints within each area and highlight the gap which can be fulfilled by combining the three areas stated above.

The term blended learning encircles any combination of learning delivery methods such as traditional lectures, and computer technologies (So & Brush, 2008). One method to create a blended learning environment is through the utilization of videos in project-based courses. Garrison & Kanuka, (2004) describe blended learning as an effective and low-risk strategy for universities to position themselves alongside the ongoing development in technology which fundamentally alter the way we learn. There are many considerations to be made in order to effectively utilize blended learning such as; planning, resource allocation, scheduling, and support for both students and teaching staff (Garrison & Kanuka, 2004).

The use of video lectures in higher education has gained popularity in recent years. This trend is supported by popularity of Massive Open Online Courses (MOOCs) and pedagogies such as the Flipped Classroom model (e.g. Yousef *et al.*, 2014; Svensson *et al.*, 2015). Alongside these, there have been many successful use cases of VBL reported from different universities across the world in the CDIO community. One common denominator from CDIO papers is the generally positive feedback that students gave to VBL. Benefits observed through the use of VBL are an increased flexibility in learning, the complementation of course material, an increased students control over their pace of learning and the creation of extra time that can be used for discussions and active learning activities (Viksilä, 2013; Sellens, 2014; Cronhjort & Weurlander, 2016; Demaziere *et al*., 2016). Unlike for student satisfaction with VBL, there is only limited empirical evidence regarding positive effects of VBL on the students' performance and learning (Cheah *et al*., 2016;; Gommer *et al.,* 2016; Hugo & Brennan, 2016; Schminder *et al.,* 2016; Stöhr *et al.,* 2016).

Problem-based learning (PBL) has been in use for the past 25 years. There are varied advantages highlighted in the literature such as higher motivation, increased understanding and experience-based learning with respect to the course topics (Prince & Felder, 2007). At the same time, the implementation of PBL requires a spectrum of instructional features such as: provoking the students' interest; experience in teaching to handle logistical and interpersonal problems; confidence in subject knowledge; and excessive time (Prince & Felder, 2007). Blumenfeld *et al.* (1991) describe PBL as a tool to engage students in the investigation of real world problems. They emphasize that the teacher's responsibility for providing activities, instructions and managerial roles plays a crucial role for the successful implementation of PBL, which can, but does not necessarily have to, be supported by technology. Macías-Guarasa *et al.* (2006) showed the complexity and management requirements for project-based design for electronic systems curricula, which resulted in increased motivation and improved students' performance. On similar grounds, the CDIO initiative has a strong focus on supporting design-implement projects (CDIO Standard 5) which is one form of PBL (Crawley *et al.*, 2014). Edström & Kolmos (2014) showed the similarity and compatibility between CDIO and PBL, and further highlighted the need to take inspiration and learning from both approaches. A recent study examining VBL in a flipped classroom setup for project-based design course observed that on the one hand, students were offered extra opportunities to practice the engineering design process under supervision as the major course contents were covered in video lectures, but that on the other hand there was no significant increase in the students' learning performance (Saterbak *et al.*, 2016). Prince & Felder (2006) argue that inductive methods of teaching such as PBL can be successful depending on how much care is put forward in the course design and implementation. They conclude that PBL can result in inferior learning outcomes and unsatisfied students, if the appropriate amount of guidance is not provided.

Based on the literature review, it can be concluded that VBL can be successfully used to manage the excessive demands on teachers expected by students, and thereby increase the motivation of students in the CDIO-based project courses. However, there is still a need for in-class supervision sessions in order to provide guidance for problem-based learning. Thus, blended learning environments appear best suited to achieve this balance, but the design process requires an investigation as carried out in this study. The inclusion of videos into a CDIO-based project course will add an extra dimension into the course and students' feedback will serve as an important input to develop this.

## METHOD

An action research method was applied to perform a case study on the applicability of the video-based learning in the CDIO-based project courses. Avison *et al.* (1999) described action research as the combination of theory and practice; and is an iterative process for a particular cycle of activities. Action research is conducted by setting four premises: establishing purpose of research; setting practical actions; practical action relation with theory; and reasoning by the collaborative team involved (Baskerville & Myers, 2004).

The research was divided into three phases consisting of development-use-evaluation. Firstly a set of videos was created on selected topics for each specific course. Secondly, the videos were then used in the courses and the students' feedback was collected by conducting a dedicated survey, the regular course evaluation questionnaire, and in student-teacher meetings during and after the courses. Lastly, the collected data was analysed to produce inferences about the applicability and utility of the video lectures/instructions. The results from the survey were used to identify indicative trends in the different courses.

The survey consisted of open and closed questions for capturing the students' perspective on using videos in the three courses. The closed questions addressed the students' behaviour and video usage, the preferred length and difficulty level, and their opinion about the future use of videos. The open questions gathered qualitative feedback about the perceived benefits and drawbacks of using video in the CDIO-based project courses. In order to receive the most constructive feedback, dedicated survey was carried out at the end of the course so that the students had finished the projects and could provide a holistic perspective of the course and videos.

### *Video Development Process*

The video development for the each course followed a peer-review process as defined by Figure 1. The aim with this process was to create quality content. In total, 22 videos were developed for three courses under consideration. The relevant topics for the project execution were identified based on the content of the project, and past experience. The learning objectives for the videos were mapped based on the learning objectives from the project or the course (CDIO Standard 2) using constructive alignment (Biggs, 1996). This also served as an index for the viewer on what set of learning was expected from video. The content of the video followed the learning objectives and consisted of interactive experience covering the method(s) or tool(s) followed by example(s) or demonstration(s) (CDIO Standard 7).

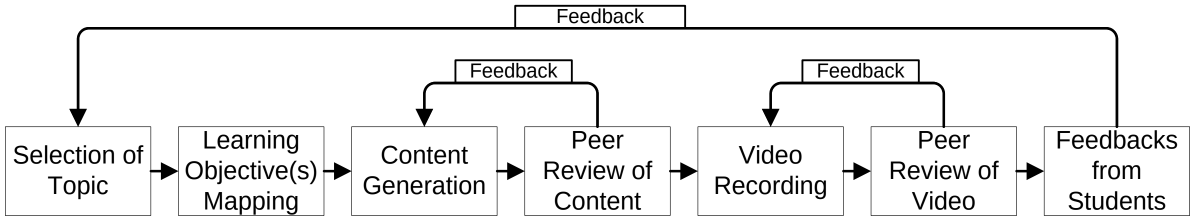


Figure 1: Peer Review Process for Video Development

The developed content was peer-reviewed by the internal development team for the course with immediate feedback. The purpose of the review before the recording was to attain the desired quality and minimize the amount of necessary changes after the video has been recorded. The video recording was carried out in different formats depending on the content and choice of the instructor. The typical format included: PowerPoint presentations, computer-screen recordings for tool demonstrations, mathematical problem solving, etc. The generated videos were again reviewed by the development team to give feedback. If major changes were required, the video was re-recorded. The videos were then used during the course in different format such as advance instructions, flipped classroom, etc., (CDIO Standard 8).

## COURSE DESCRIPTION

Within the considered courses in this paper, the CDIO-based project assignments can be categorized as close-end, open-end, and semi-open-end project assignments. A close-end project is characterized by a well-defined problem with a fixed input data set and students are expected to utilize the knowledge of design methodologies and tools to generate a specific solution for the problem. An open-end project assignment is characterized by the limited input data/information provided to the students and opportunity to produce variable solution output for the project. An open-end project typically originates from industry which is classified as; technology push and market pull projects. A semi-open-end project is on the middle of the continuum of the above two where the students are given a defined problem and are expected to utilize the design methodologies to produce alternative solutions for the project. For all the projects, the supervisors were expected to guide the students with the design methodologies, and the concepts associated with the problem. The short project assignments approximately ran for 2-3 weeks of time whereas the long project ran between 7-8 weeks of time. Both type of project assignment were resource-intensive. The short project assignments required more frequent meetings with supervisors compared to the long project assignments. Table 1 represents the three courses considered in this research and their respective project assignments characteristics. Table 1 represents the three courses considered in this research and their respective project assignments characteristics.

The purpose of video lectures differs somewhat in each course, though in general they are used to support CDIO-based project assignments. The PPU210 course is a large course (up to 180 students). Supervision demands are high accordingly and can only be handled through several tutors. However, the course has been criticized for providing disparate information. One objective of videos is therefore to provide uniform information about the project, systematic design methods and motivate students to move forward in projects. For the PPU085 course, the CDIO-based project assignment are performed in collaboration with different industrial partners. The idea with the videos in this course is to provide students with descriptions of design methods ahead of time. This should enable them to manage the project properly and give them a head-start with the project execution. In the PPU190 course, students

Table 1: Represents the characterization of CDIO-based project for each course.

| | | | | |
|---|---|---|---|---|
| **Course: PPU210 - Machine Element - Year 2**<br>The student should attain deep, basic understanding about selection of machine elements which is of central importance in mechanical engineering. The machine elements covered in the course are: rolling bearings, hydrodynamic plain bearings, bolted joints, linear springs, brakes, toothed spur gears and belt transmissions. | | | | |
| No. of students ~ 180 | No. of supervisors ~ 6 | Group size: 2 | Number of videos | 7 |
| **Project Assignments** | | **Type** | **Duration** | **Characteristic** |
| PA1- Shaft and Roller Bearing Design | | Semi-open-end | Short - 2 W | C**DI**O |
| PA2- Hydraulic Cylinder | | Close-end | Short - 2 W | C**D**IO |
| PA3- Gearbox for metal lathe | | Close-end | Short - 2 W | C**D**IO |
| **Course: PPU085 - Product Planning - Needs and Opportunities - Year 4, 5**<br>The student should develop an understanding of how product development coincides with business development and the fundamentals of product planning and analysis of different stakeholders' needs and requirements. | | | | |
| No. of students ~ 50 | No. of supervisors ~ 10 | Group size: 4-6 | Number of videos | 6 |
| **Project Assignments** | | **Type** | **Duration** | **Characteristic** |
| PA1- Market, Technology and Competitor Analysis<br>PA2- Customer Needs Mapping<br>PA3- Product Development Project Plan | | Open-end | Long - 7 W | **C**DIO |
| **Course: PPU190 - Engineering Design and Optimization - Year 4, 5**<br>The student should integrate traditional design methodologies with concepts and techniques of modern optimization theory and practice. With the approach and instilled knowledge the student is expected to be able to create design solutions that are creative and have better performance compared to traditional conservative methods. | | | | |
| No. of students ~45 | No. of supervisors ~ 2 | Group size: 2 | Number of videos | 9 |
| **Project Assignments** | | **Type** | **Duration** | **Characteristic** |
| PA1- The Cantilever Challenge | | Semi-open-end | Short - 2 W | C**DIO** |
| PA2- Redesign, material selection and optimization of a failed product | | Semi-open-end | Short - 2.5 W | **CDI**O |
| PA3- Multi-objective optimization of an engine encapsulation component (MDO) | | Semi-open-end | Short - 2.5 W | C**DI**O |

Table 2: Represents the classification of videos according to CDIO syllabus.

| Conceive | Design | Implement | Operate |
|---|---|---|---|
| PEST analysis | Function Structure | Design of Experiments | |
| SWOT analysis | Morphological Matrix | Prototyping lab machine tutorials (multiple) | |
| Benchmarking | Pugh Matrix | | |
| Questionnaire design | Kesselring Matrix | Software Tutorial (MATLAB, COMSOL, CATIA, JMP Suite, etc.) | |
| Customer need elicitation | MATLAB Optimization | | |
| Market identification and selection | FMEA | | |
| | Material Selection | | |
| | SFD and BMD construction | | |
| | Bearing Dimensioning | | |
| | Screw Design | | |
| | Gear ratio for lathe | | |

have different specializations from the Mechanical Engineering programme such as Product Development, Applied Mechanics or Automotive Engineering. This results in a high variance and diversity in the students' knowledge before the course. Thus, the primary objective of the videos is to fill those knowledge gaps that are required for the successful execution of the project, mainly covering the usage of diverse software tools and the concepts associated with it. The videos developed in the considered course can be mapped to the CDIO syllabus, see Table 2. The vision here is to develop video library for design methods which can be used by multiple product development courses.

## RESULTS

The results section is divided into two parts, the quantitative survey data indicating the students' preferences and usages of the videos and the open answers regarding the perceived advantages and drawbacks of videos. In total, 143 responses was received out of which 85 (59.4%) were from PPU210 course, 17 (11.9%) from PPU85 and 41 (28.7%) from PPU190 course. Figure 2 shows six bar plots with the student answer distributions to different questions about their watching preferences and behaviour in the three courses.

With regard to student interaction with the course videos, figure 2 (a) shows that for PPU210 and PPU190 course, around 60 to 70% of students watched the videos, and at least in parts even more than one time. On the other hand, in the PPU085 course only one third of the students used the videos in this way. 20% even did not watch the video at all (the "other" category) because they were not aware or reminded of the videos. This observed difference in interaction patterns between the courses might be related to the different contents of the videos. The videos presented in PPU210 and PPU190 were tutorial/instructional videos that could be used for working on the project assignments, whereas PPU085 contained lecture-based content.

Figure 2 (b) shows the students' preferred video length from the three courses. The majority of students in all the three courses indicated that a video of up to 10 minutes is suitable. But the data also indicate that for almost 40% of the respondents in PPU210, the video length did not matter and this number correspondingly decreased for the PPU190 (25%) course and PPU085 (12.5%). The probable reason for is that the PPU210 course has close-ended projects for which the video content became more relevant to the project execution.

Figure 2 (c) presents perceived level of difficulty level of the videos. The vast majority of students found the content to be at the right level or somewhat too easy. The videos were usually aimed to be short (5-15 minutes) which sets limits to the level of detail in the topic descriptions. It can be noted that more than 50% in PPU085 course found the content be at low level which is consistent with the scope of the course which is not technical.

Figure 2 (d) shows the level of agreement with the statement "the videos helped me to prepare for the project assignment" which was the initial motive for the using video in the CDIO-based project courses. The videos were highly appreciated by the students in all three courses as in average about 80% of the students agreed or strongly agreed that the videos were helpful.

Figure 2 (e) depicts the students' general attitude towards using VBL before the start of the courses. Although between a third and half of the student in the courses stated that videos made the course more appealing, most students were indifferent.

Figure 2 (f) shows students' attitude towards using videos after the course and there are few notable observations in comparison with figure 2 (e). For PPU190 and the PPU210 course, the students' opinion shifted positively towards VBL. In both courses, about 50% of the students preferred videos and one tenth even strongly preferred VBL. The probable reason is the close alignment of the video content with the project assignments. On the other hand, after the PPU085 course, only 28% preferred videos. About the same amount preferred traditional classroom teaching and almost half of the students had no preference. This result is consistent with the interaction patterns from Figure 2(a), indicating that the students were not able to utilize the videos to the same extent as in the other two courses and that the open-end projects in PPU085 require more face-to-face interaction and discussions with teacher.

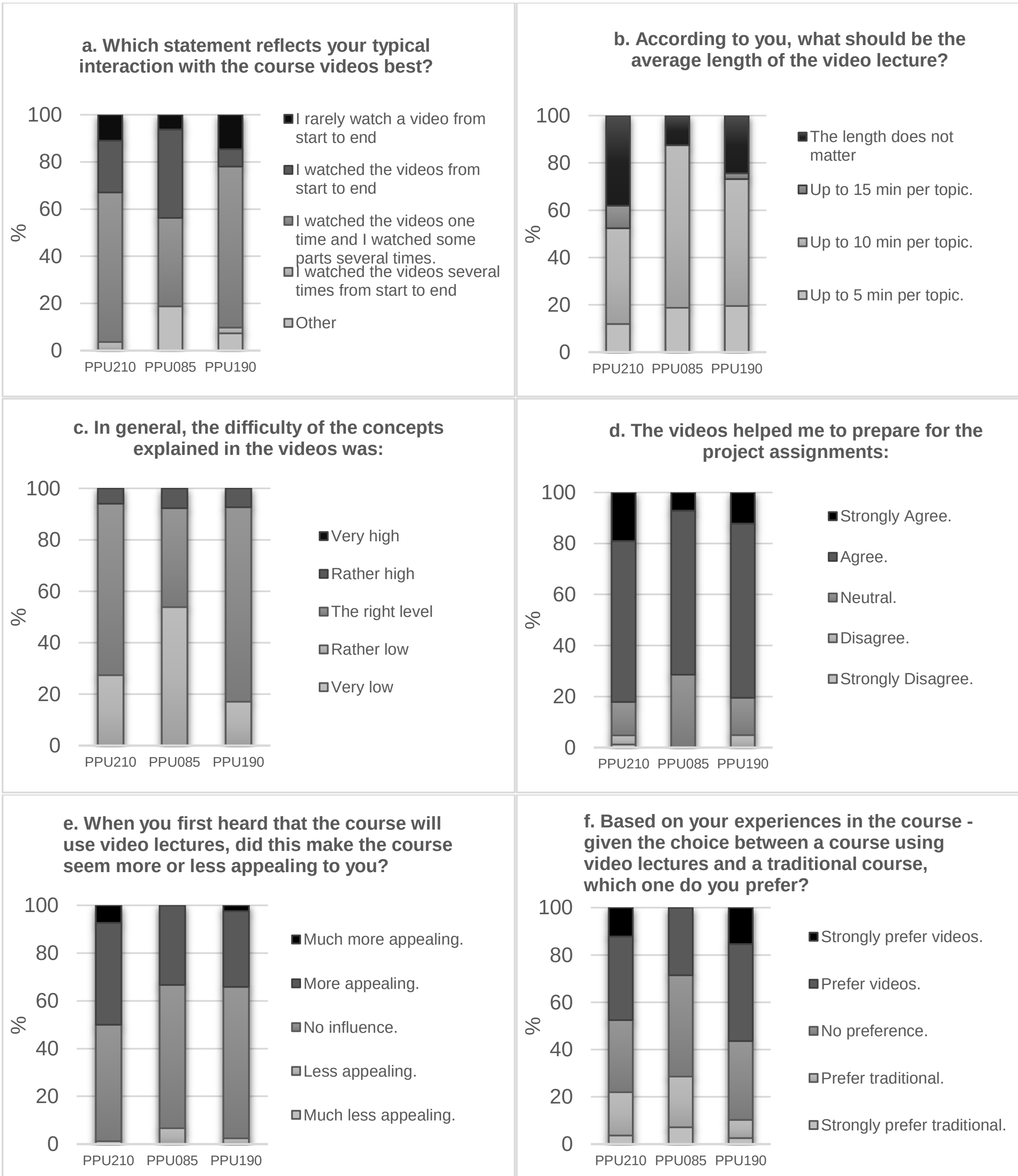


Figure 2 Graph showing student's perception for video in the courses.

### *Student perceptions of benefits and drawbacks of using videos in PBL*

In two further open questions, we asked students where they see the main benefits and drawbacks of using video lectures. We collected the answers for all three courses and categorized them in main categories. The ten most frequently named categories can be found in table 3.

Table 3. Student's top ten benefits and drawbacks of using videos in PBL

| | Benefits of videos (N*=129) | % of N | Drawbacks (N*=89) | % of N |
|---|---|---|---|---|
| 1 | Can be watched repeatedly | 63 | Cannot ask questions immediately | 38 |
| 2 | Easy access anytime and anywhere | 22 | Lack of deeper information and topics | 8 |
| 3 | Can be watched at own pace (pause, rewind, jump) | 14 | Poor video quality | 6 |
| 4 | Better compared to other formats (e.g. ppt, pdf, mp3) | 8 | Project assignments become too easy | 4 |
| 5 | Can be used while working on the project assignment | 8 | Less motivating, easy to skip | 4 |
| 6 | Allows to catch up if one misses a lecture | 6 | Videos are misleading | 4 |
| 7 | Possibility to select and skip known parts | 5 | Hard to find relevant content | 3 |
| 8 | Additional explanations | 5 | No face-to-face contact to the teacher | 2 |
| 9 | The assignments become simpler | 3 | Bad pedagogic quality | 2 |
| 10 | No need to ask teacher for clarification | 3 | No drawbacks | 28 |

*N = number of students that answered the question.

The by far most frequently mentioned benefit of videos was the possibility to watch them several times be it as preparation for the exam or if a concept was not understood during the in-class lecture. Further, students frequently saw the increased flexibility in terms of where and when and at what pace to watch the lecture as a benefit. For example, several students wrote that they feel more comfortable at home, or are more productive in the evening hours. Some students also argued that it is easier to learn from videos compared to slides, text documents, or audio recordings, partly due to the opportunity to better visualize critical aspects. A number of students particularly from the Engineering Design and Optimization (PPU190) course and the Machine Element (PPU210) course underlined the usefulness of videos for conducting the assignments. The videos did not only have further explanations that could accessed in relation to the specific knowledge gaps of the student, they also can be used in parallel while working on the assignment. In sum, those benefits reflect the increased flexibility and possibility to adapt the learning process to the individual needs of the student.

The most significant drawback of using video lectures was seen in the missing opportunity to ask immediate questions. Even if the possibility to ask questions via email or the next in-class session was given, over one-third saw this as a main drawback. Student's further expressed concerns regarding the lack of deeper information and the limited amount of relevant content that, in addition, can be difficult to find and misleading. Others thought that the assignments became easy compared to attempts to solve those without the additional explanations, which can be perceived as unfair. Finally, a few students criticised the poor video quality (e.g. resolution, audio), the lack of face-to-face contact with the teacher, the lack of motivation to watch videos or the general poor pedagogic quality of videos as learning material. However, interestingly, more than one-fourth did not see any drawbacks at all. In sum, those drawbacks point at the lack of social interactivity of video lectures as well as the challenging pedagogic and technical design.

## DISCUSSION

The overall positive student feedback about the use of videos in the three courses supports the conclusion that VBL is suitable for CDIO-based project assignments. Nevertheless, there is a need to further develop the pedagogics of using videos for such courses in order to make VBL more attractive and useful for students. The perceived benefits and drawback of VBL that the students expressed are similar to the findings from other studies (e.g. Viksilä, 2013; Sellens, 2014; Cronhjort & Weurlander, 2016; Saterbak *et al.*, 2016), although this study particularly highlights the benefits of VBL for PBL and the importance of aligning the videos to the other learning activities.

The next research question was to examine key features for the video development from the students' view. From the survey results students preferred a shorter video length of 10 min, which is consistent with other research (e.g., Oishi, 2007; Maniar *et al.,* 2008, Guo *et al*. 2014). Nevertheless, it can be argued that the optimal video length depends on a multitude of factors such as the meta-cognitive abilities of the learners, the course's scope and the video type. Students from the 2nd year are likely to possess only limited pre-knowledge and control over their learning which increases the possibility that they need more information and direct student-teacher interaction to successfully execute the projects. On the other hand, students from 4th and 5th year have broader knowledge from a wider set disciplines and are better equipped to develop individual learning and problem solving strategies and therefore can utilize shorter bits of video information more effectively to get an understanding of the topics.
The scope of the course can also influence the preference for video length. For example, PPU210 contains detailed design theories for which well-elaborated explanation are required, whereas PPU085 and PPU190 contain topics that are more on an applied level and cover wide areas of application. Finally, the group sizes for the project assignments also varied between the courses and may influence the interaction with the course videos. However, the data gained in this study do not allow for any causal conclusions and has to remain somewhat speculative, but one can once again stress the importance of a constructively aligned approach to video development which appears somewhat easier to achieve for tutorials that connect well with the actual project assignments.

In terms of the level of difficulty, the study showed that the students majorly found the videos to be at the right or lower levels for all the courses. This finding connects to the discussion of video length since, short videos do not leave room detailed topic descriptions and the information was presented in summarized form. In addition, in PPU085 and PPU190 the incoming students had different master programs, partly from other universities, as background and one purpose of the videos was to bridge the gaps in the pre-existing knowledge of the students that was relevant for the assignments. Thus, even though it appears that the videos served this purpose well, they had to be kept on an introductory level. In order to include contents on a higher difficulty level, more video time would be required, which could be handled by splitting the video content into smaller chunks. However, this will pose a challenge in managing and presenting such information which will require further development in pedagogics. Eventually, learning analytics could help in this process by identifying topics and video parts of higher and lower relevance to the students (e.g. Demaziere *et al.* 2016)

The type of the video, appeared to have a strong effect on student perceptions and usage of the videos. As outlined earlier, the videos presented in PPU210 and PPU190 were tutorial/instructional videos whereas PPU085 contained lecture-based content. The tutorial/instructional videos were actively used by the students and very positively evaluated. The tutorials enabled the students from different backgrounds to reach the learning level necessary to do the assignments, which required an intensive use of software, such as MATLAB. On the other hand, the PPU085 course is more qualitative in terms of methodologies and students showed less interaction with the videos and an inclination towards traditional classroom teaching, where it is possible to have face-to-face discussions. Videos were seen as a backup option.

From a teacher's point of view, the success factors for the VBL can be seen in a long term perspective. Videos for the course can be generated in stages, with incremental improvements and formative feedback over years. Students can watch videos in a flexible way, selective and at their own pace depending on their need and prior (gaps in) knowledge. In a long-term perspective, using videos can be seen as an effective way of improving the course. Advantages observed here included an increased uniformity in instructions, less dependency on supervisors and online support resulting in more flexibility for student learning. In order to maintain the quality of the videos, guidelines for generating videos need to be developed in the future.

As the final part of this discussion, there are also a few concerns and limitations. First of all, since this study was limited to student perceptions, there was no investigation whether VBL had an actual effect on the students' performance and learning. Thus, while the results of this study are in line with research on student satisfaction in blended learning, no conclusion can be made to the discussion around VBL effects on student learning. Using videos also poses drawbacks in that there is a risk that instruction becomes too transparent and only one-way as evidenced by the student answers in this analysis. Just as in-class lecturing should be combined with active learning exercises to induce deeper learning, VBL needs to be combined with other forms of student engagement. In PBL, this appears the case which requires careful planning of video content so that it is aligned with the course project assignments, as the content cannot be spontaneously adapted as in regular classroom teaching. Further, VBL might fail if it is not introduced properly and students fail to see the benefit and how the videos contribute to achieve the intended learning outcomes. During the feedback in course evaluation meeting, it was suggested by the students to use more structured way of presenting videos in course introduction and to highlight the differences between what will be presented in traditional classroom teaching and what will be presented in video lectures/instructions. Lastly, a from the students' perspective serious limitation of using videos is the lack of immediate feedback to questions that students have while and after watching the videos. This is an interesting aspect for future research. On the one hand, further studies can attempt to address this issue by for example testing clearer instructions to the students about how they can communicate with the instructor, one could also develop and test tools and techniques that provide feedback without the exclusive reliance on the teacher. That might for example involve forums, FAQs, Wiki's and social media platforms or even computer-generated automated feedback. However, another way of looking at this issue of "not able to ask immediate questions" is that it encourages students to think more intensively for themselves and encourages them to look for additional learning resources or discuss the question with their peers. Future iterations of the courses will try to address these concerns.

## CONCLUSION

This paper examined the applicability of videos in three CDIO-based project courses. Based on student feedback via a survey, the course evaluation and group meetings, the analysis showed a positive response of students to the videos. They found them particularly suitable to work with design-build-test assignments. As a main benefit, the videos provided flexibility to the students as they get an extra online support that they can access at any time and study at their own pace during the project assignments. This helped reinforcing concepts, and enabled less dependency on supervisors during project execution. In order to maximize student satisfaction and interaction with the videos, the videos should be short and closely aligned to the other learning activities. Videos proved to be suitable for creating a blended learning environment and improved the perceived learning experience for the students. Further pedagogical development is nevertheless needed to improve the utility and attractiveness of videos into the course.

## REFERENCES


Avison, D. E., Lau, F., Myers, M. D., & Nielsen, P. A. (1999). Action research. *Communications of the ACM*, 42(1), 94-97.

Baskerville, R., & Myers, M. (2004). Special Issue on Action Research in Information Systems: Making IS Research Relevant to Practice: Foreword. *MIS Quarterly*, 28(3), 329-335.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher education*, *32*(3), 347-364.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. *Educational psychologist*, 26(3-4), 369-398.

Cabezuelo, A. S., Conde, M. Á., & Rodríguez, J. L. S. (2015). 6th International Workshop on Software Engineering for E-Learning (ISELEAR15). *Proceedings of the 3rd International Conference on Technological Ecosystems for Enhancing Multiculturality*, *ACM*, 661-665.

Cheah, S., Lee, H., & Sale, D. (2016). Flipping a Chemical Engineering Module Using an Evidence-Based Teaching Approach. *Proceedings of the 12th International CDIO Conference*. Turku, Finland: Turku University of Applied Sciences.

Chen, C. (2008). Intelligent web-based learning system with personalized learning path guidance. *Computers & Education*, 51(2), 787-814.

Crawley E. F., Malmqvist J., Östlund S., Brodeur D. R., & Edström K. (2014). *Rethinking Engineering Education: The CDIO Approach* (2nd ed.) New York: Springer.

Cronhjort, M. & Weurlander, M. (2016). Student Perspectives on Flipped Classrooms in Engineering Education. *Proceedings of the 12th International CDIO Conference*. Turku, Finland: Turku University of Applied Sciences.

Demazière, C., Stöhr, C. & Adawi, T. (2015). Using learning analytics in virtual learning environments. In Palsson, Victor (Eds.). *Proceedings from 5:e Utvecklingskonferensen för Sveriges ingenjörsutbildningar* (pp. 121-126), Uppsala: Uppsala Universitet.

Demazière, C., Stöhr, C. & Adawi, T. (2016). Students' "resonance broadening" to teaching or how to improve students' learning using flipped classrooms. *Proceedings of International Topical Meeting on Advances in Reactor Physics (PHYSOR)*. 1471-1482.

Edström, K. & Kolmos, A. (2014). PBL and CDIO: complementary models for engineering education development. *European Journal of Engineering Education, 39*(5), 539-555.

Garrison, D. & Kanuka, H. (2004). Blended learning: Uncovering its transformative potential in higher education. *The Internet and Higher Education*, 7(2), 95-105.

Gommer, L., Hermsen, E., & Zwier, G. (2016). Flipped Math, Lessons Learned from a Pilot at Mechanical Engineering. *Proceedings of the 12th International CDIO Conference.* Turku, Finland: Turku University of Applied Sciences.

Guo, P. J., Kim, J., & Rubin, R. (2014). How video production affects student engagement: An empirical study of mooc videos. *Proceedings of the first ACM conference on Learning@ scale conference, ACM*, 41-50.

Hugo, R. & Brennan, R. (2016). Student Study Habits as Inferred from On-Line Watch Data. *Proceedings of the 12th International CDIO Conference.* Turku, Finland: Turku University of Applied Sciences.
Macías-Guarasa, J., Montero, J. M., San-Segundo, R., Araujo, Á., & Nieto-Taladriz, O. (2006). A project-based learning approach to design electronic systems curricula. *IEEE Transactions on Education*, 49(3), 389-397.

Maniar, N., Bennett, E., Hand, S., & Allan, G. (2008). The effect of mobile phone screen size on video based learning. *Journal of Software*, 3(4), 51–61.

Oishi, L. (2007). Did You Just See that? Online Video Sites Can Jumpstart Lessons. *Technology & Learning*, 27(6), 32.

PPU085 - Product Planning - Needs and Opportunities. (2016). Chalmers University of Technology website. Retrieved 5 April 2017, from https://student.portal.chalmers.se/en/chalmersstudies/courseinformation/Pages/SearchCourse.aspx?course_id=25443&parsergrp=3

PPU190 - Engineering Design and Optimization. (2016). Chalmers University of Technology website. Retrieved 5 April 2017, from https://student.portal.chalmers.se/en/chalmersstudies/courseinformation/Pages/SearchCourse.aspx?course_id=25034&parsergrp=3

PPU210 - Maskinelement. (2016). Chalmers University of Technology website. Retrieved 5 April 2017, from https://student.portal.chalmers.se/sv/chalmersstudier/minkursinformation/Sidor/SokKurs.aspx?course_id=25096&parsergrp=3

Prince, M. J., & Felder, R. M. (2006). Inductive teaching and learning methods: Definitions, comparisons, and research bases. *Journal of engineering education*, 95(2), 123-138.

Prince, M. J., & Felder, R. M. (2007). The many faces of inductive teaching and learning. *Journal of college science teaching*, 36(5), 14.

Saterbak, A., Volz, T., & Wettergreen, M. (2016). Implementing and Assessing a Flipped Classroom Model for First-Year Engineering Design. *Advances in Engineering Education*, 5(3).

Schminder, J., Najafabadi, H., & Gårdhagen, R. (2016). Learning by Teaching: Student Developed Material for Self-Directed Studies. *Proceedings of the 12th International CDIO Conference.* Turku, Finland: Turku University of Applied Sciences.

Sellens, R. (2014). Video Microlectures: Simple to Make; Valued by Students. *Proceedings of the 10th International CDIO Conference*. Barcelona, Spain: Universitat Politècnica de Catalunya.

So, H. J., & Brush, T. A. (2008). Student perceptions of collaborative learning, social presence and satisfaction in a blended learning environment: Relationships and critical factors. *Computers & Education*, 51(1), 318-336.

Stöhr, C., Demaziere, C. & Adawi, T. (2016). Comparing student activity and performance in the classroom and a virtual learning environment. In Novotná, Jancarík (Eds.). *Proceedings of the 15th European Conference on e-Learning ECEL*. 664-671.

Svensson, L., Hammarstrand, L. & Stöhr, C. (2015). Flipping a PhD course using movies from a MOOC. In. Palsson, Victor (Eds.). *Proceedings from 5:e Utvecklingskonferensen för Sveriges ingenjörsutbildningar* (pp. 168-171). Uppsala, Sweden: Uppsala Universitet.

Viksilä, R. (2013). Effectiveness of Video Lecturing in ICT Learning. *Proceedings of the 9th International CDIO Conference*, Cambridge, Massachusetts: Massachusetts Institute of Technology and Harvard University School of Engineering and Applied Sciences.

Yousef, A. M. F., Chatti, M. A., & Schroeder, U. (2014). The State of Video-Based Learning: A Review and Future Perspectives. *International Journal on Advances in Life Sciences*, 6(3/4), 122-135.

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