

LEARNING BY TEACHING: STUDENT DEVELOPED MATERIAL FOR SELF-DIRECTED STUDIES

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ABSTRACT

The objective of the presented paper is to demonstrate how e-learning course material developed by the students can enhance active learning for self-directed studies outside the classroom in a flipped classroom concept. A method which merges different learning activities such as learning by teaching, video based teaching etc. was developed to improve the students' personal and interpersonal engineering skills in relation to CDIO standards. In an effort to assess the students' satisfaction and practical use of the students' created material, a survey was conducted. Statistics, the students' feedback, and observations show an increase in learning motivation, deepened understanding, and expanded communication skills.

KEYWORDS

Flipping Classroom, Active Learning, CDIO Standard 2 and 8

INTRODUCTION

Motivating students for active learning is a challenge, and theory-loaded engineering courses are no exception. To devise and explain technical problems or presenting complex results to an expert or non-expert so that the listeners can follow and understand the presented problem or solution is in turn also a challenging task to many engineers. The CDIO syllabus 2.0 (Crawley et al., 2011) gives clear guiding principles about what kind of communication skills are required for an engineer and where the focus in teaching should lay. The question is how can we train students to communicate so that they reach their audience? A prior condition for communication in a classroom is that students are actively participating during classes, and not only passive note-takers, which also is the essence of CDIO Standard 8.

Many didactic approaches e.g. learning by teaching, flipped classroom or multimedia teaching have been tested and evaluated in the last decade to facilitate active and hence deep learning. However, the application of these approaches to engineering classes can be challenging due to different boundary conditions and practical limitations, e.g. the available time budget, the number of students, or due to inadequate lab space and equipment.

This paper presents an attempt to adopt the above mentioned approaches and CDIO recommendations to a new introductory course for gas turbine engineering, given to students in their final year of different master's programs, at Linköping University, Sweden. The

foundation of our approach is based on the assumption that a student-centered focus, with students actively embedded in the teaching process, improves learning and communication.

LITERATURE STUDY

Teaching engineering students is till this day, with exception of some few courses, often characterized by lecture-based instructions including teacher-centered teaching giving the students little or no room for creativity, communication or self-contained learning. The negative impact on the students learning, when applying this type of teaching, is documented in many studies. Bligh (1998) showed that both psychological and physical performances decrease if not varying the students' stimulation during a lecture. Active student participation during a course reduces the risk that students take on a role of a passive knowledge recipient. The majority of the course participants will most likely favor in their learning when varying class activities. Knight & Wood (2005) showed in their study that *"even a partial shift towards a more interactive and collaborative course format can lead to significant increase in students learning gains"*. When Bonwell & Eison (1991) promoted active learning in their report to the Association for the Study of Higher Education (ASHE) in 1991, they claimed that students should actively do things and think about what they are doing by promoting analysis, synthesis and evaluations. Thereby they acted on suggestions postulated by Bloom's taxonomy of learning domains (Bloom, 1969) which ask teachers and instructors to work actively with their students' mental skills (cognitive), their attitudes (affective), and physical skills (psychomotor) in order to promote higher forms of thinking. Grabinger & Dunlap (1995) stated in their work that *"active learning is based on constructivist values and theories"*. The basic idea of constructivist teaching is that learning occurs as learners are actively participating in a process of constructing meaning and knowledge. An educational technique which includes both active learning and the constructivist philosophy is the idea of the "inverted" or more known as flipped classroom. The basic concept was firstly presented in a paper by Lage et al. (2000) which asserts that if subject matter is outsourced out of the classroom, into e.g. online resources and media, there will be more time available for problem based learning activities during a lecture. The flipping classroom method also combines and employs other learning theories like student centered learning (SCL), which is mainly based on the theoretical work by Piaget (1952) and Vygotsky (1978). Instead of a teacher-centered approach, where the lecturer decides what and how the learner should be taught, SCL aims to shift the focus to a student-centered teaching by enhancing students' self-directed learning and supporting group based activities where cooperative learning is encouraged.

Cooperative learning can be accomplished in many different ways like peer editing, Jigsaw, or by peer-led team learning. However, the heart of all these methods can be traced back to a long known finding that: "by teaching, we learn" Lucius (ca 4 BC - 65 AD). Fiorella and Mayer (2013) studied the hypothesis that learning is enhanced through the act of teaching others. In their experiment they tested if preparing to teach or the entire teaching process including explaining content to others show any benefits in learning or if this could influence the students' attitude to learn. The results of their research showed the fact that to let students prepare content without teaching and explaining it actively is not very useful. However, if students are actively involved in the teaching and explaining process, a better understanding of the content and a deeper learning could be observed.

As mentioned before e-learning outside the classroom takes an important position in the flipped classroom concept. Teaching videos are created and provided online by the course instructor so that students can prepare, review and learn course specific content in their own

pace. However, Beach (2012) refers to the problem that students are under these conditions once again only passive consumers and not actively involved in the process of creating knowledge like it is demanded by the definition of active learning. For this reason Engin (2014) suggested to turn the student, by using student produced videos, both into producer and customer and thereby promote active learning.

COURSE STRUCTURE AND LEARNING OUTCOMES

The method presented in this paper was implemented and proved in an introductory course for gas turbine engineering (TMMV12) at Linköping University. The course includes 160 hours of total study time including lectures, labs, assignments and self-study, corresponding to 6 ECTS credits.

The aim of the course is to provide fundamental knowledge and understanding about the functionality of industrial gas turbines and jet engines. Furthermore, different components such as compressors, combustors and turbines, common in all types of turbine engines, are introduced, and fundamental thermodynamic, fluid mechanic and aerodynamic design problems are from an analytical and theoretical perspective discussed for all these parts. Another objective of this course is to promote the students interpersonal skills. These include skills in multidisciplinary teamwork, communication, knowledge discovery, engineering reasoning, and system thinking according to (Crawley et al. 2007) which also correlated to the CDIO Standard 2.

Students which attend the class are mostly mechanical, aeronautical or environmental engineering students in their final year. Approximately half of them are European and international (from all over the world) exchange students. The variety of so many different students and their diverse educational backgrounds are a challenge for every course designer when aiming to offer each student an equal chance to reach the same degree of learning outcome as compared to his class-mates. In addition, many students are often used to more traditional teaching styles, letting them struggle with self-determined and active learning teaching methods like regularly used at Linköping University. Furthermore it is well known and documented (Felder & Silverman, 1988, Biggs, 2001) that students in general receive and process information in many different ways. For this reason, the decision was made to aim for the flipped classroom concept because it offers the necessary flexibility for different student advancement, and involves the students actively in the course and content design.

METHOD

To achieve the above mentioned learning outcomes, groups of ten students were formed and given an assignment in which they prepared and taught an essential topic that typically is not covered extensively in the lectures. The assignment consisted of a written report, creating a problem, and giving a lecture. First the students studied relevant literature concerning the topic, and summarized their gained knowledge in a report. After that, they created problems in which the presented theory was applied. Fiorella and Mayer (2013) have shown that active teaching, by the students, is essential to ensure a high learning outcome. Therefore the idea emerged to let the students teach by producing short videos of max 15 min length. The material created by the students is subsequently collected and uploaded in a student platform called LISAM. This is a learning environment used at Linköping University in which students can collaborate, communicate, and exchange digital course material interactively between each other and with

the teacher. The content from the reports is copied to LISAM into a simple Wiki application creating a digital reference book for current and future students. The problems are also uploaded and serve currently as supplementary material for exam preparation or just to delve into a specific topic. LISAM also offers the possibility of having a video channel where the produced teaching videos are uploaded and presented. The equipment for the video production and the necessary video editing software are provided by the Information and Communication Technology studio (ICT) at Linköping University. ICT is a recourse supporting students, teachers and scientists in areas related to information and communication technologies.

For all three parts of the assignment the students got very few constrains in order to ensure a high level of creativity. However each group was moderated and supported by teachers and experts during the course to ensure relevant content and educational usefulness. By doing so, it was ensured that the material is understandable, technically correct, and that potential problems (technical or interpersonal), occurring during the assignment, could be caught and solved. For the video production extra support in form of small workshops was offered to ease and reduce the workload to burrows into the story telling, technical equipment, animation, and post-processing. To increase the visual and artistic variety of the videos, the students were encouraged to record their videos not only on-campus but also off-campus by visiting workshops or technical museums.

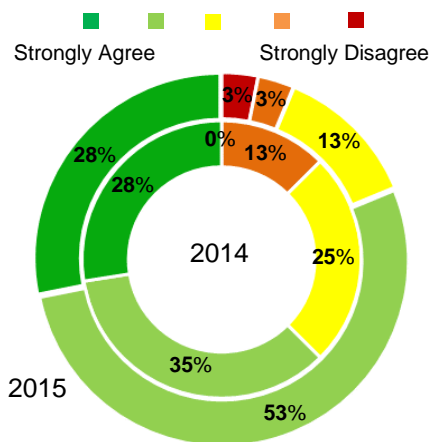
STUDENT PERCEPTIONS AND DISCUSSION

To see how the students reflected about the given assignment and how they worked with the study material produced by their former peers, a survey was given out to each student at the end of the course. In total 70 students completed the survey during the last two years, answering questions using a Likert five point scale or multiple choice answers. In addition, the students had the possibility to write some personal comments to each question.

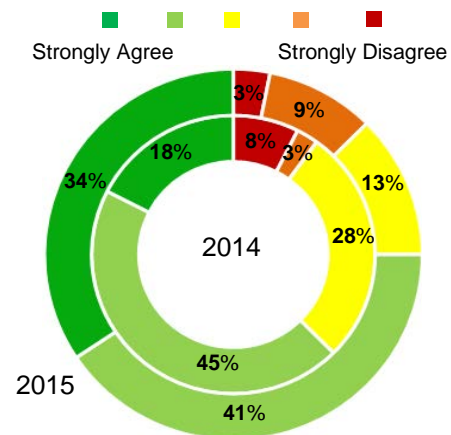
The students' reflections on question 1 indicate that the majority of the students believe that the overall concept of "learning by teaching" favors their learning and understanding of technical content. The diagram also shows that in 2015 the agreement increased, which can be attributed to some changes in the task and group work, based on experiences made in 2014. One of the actions we took in 2015 to improve the learning outcome of this assignment was to introduce the cross-reading of the student developed course material. Because the students only explained a certain component of a gas turbine, they complained that they got experts in only one specific topic. Letting them cross-read the other students' assignments helped them to deepen their knowledge in other gas turbine components, and at the same time reflect about the others' and their own work.

Since motivation is one of the basic requirement for learning (Ngaosuvan, 2004), it was interesting to see if this kind of activity could increase the students' motivation compared to traditional assignments. Most of the students think that learning is promoted by applying the presented method, question 2. The results also show more positive reflections among the students in the subsequent year. The cause for this improvement is most likely the fact that students who attended in 2015 could use and profit from the course material prepared by their former peers for the first time which is an observation from question 7. This probably helped to clarify the basic idea that this teaching method has increased their motivation. Their predecessors in 2014 didn't have access to this supplemental material because they were the first for which this concept was introduced and tested.

When asking the students more in detail what specific parts of the assignment they liked or disliked the results got more differentiated. In general, the students have a positive opinion about the overall setup of the assignment, question 3, however many students took a critical attitude in relation to the video production which they thought was too time demanding. But also writing a technical report, developing a theoretical and practical calculation problem, or to come up with a good pedagogic framework for their teaching seemed to be a challenge for them.



Question 1: The overall concept of teaching a small topic can lead to a better understanding of what you should learn in a technical course like TMMV12.



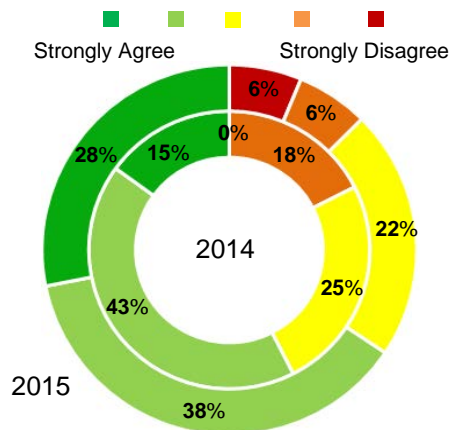
Question 2: This type of assignment motivates me more, compared to ordinary calculation assignments, to go deeper into the course subject.

Question 1	Positive	It was easier to understand and memorize the topic because that what you teach you probably don't forget that fast.
	Negative	I prefer traditional classes as I learn more in the lectures. It is possible that you will learn deeper and memorize the content better when doing such assignments, but it's hard to assess this.
Question 2	Positive	You get to know the content better by doing an assignment like this. With pure calculation assignments you often just use the equations without thinking about them.
	Positive	More fun = more motivation. In order to produce something that get public, you put more effort and drive on it.

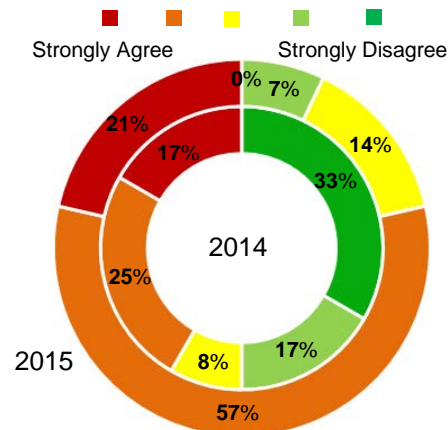
When comparing the student's assessments and comments from 2014, some of the mentioned problems could be segregated and solved in the following year. A major concern of the first students was that each group had clearly defined subgroups (video, problem, report) in which they solved their tasks. However, the problem raised that not all work, needed to solve the assignment, was sheared equally between the group members. The subgroups involved in the video production were not sufficiently embedded in the literature study and the arrangement of the content. For this reason, the students in 2015 were encouraged to share not only the literature survey better between the group members but also to show more flexibility when it comes to "inter-departmental" collaboration. The positive results were clearly noticeable when observing their work in 2015, i.e. less complaints concerning this problem. Furthermore, a

higher learning outcome was indicated by 50% more students who “passed with distinction” in the final exam.

Also if the majority in both years agreed that the overall setup of the assignment worked well it was important for us to understand how difficult it was for the students to solve the separate parts of the assignment.



Question 3: The setup of the assignment including creating a report, video, and problem is a good way to learn.



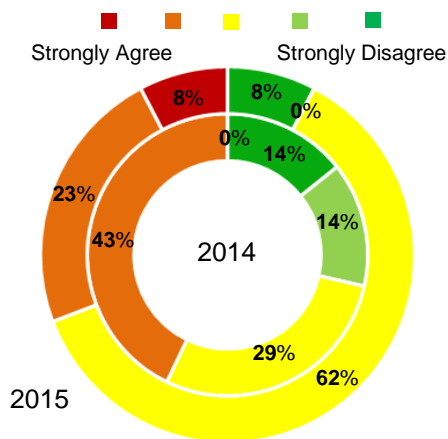
Question 4: It was difficult for your group to create a video.

	Positive	It is a good multidisciplinary approach, great!
Question 3	Negative	Creating a video is no help to understand the topic better. I would rather take a book and read it instead of doing this assignment.
	Positive	Yes, but it was also an interesting experience.
Question 4	Negative	The video production and editing took too much of the available time-budget.

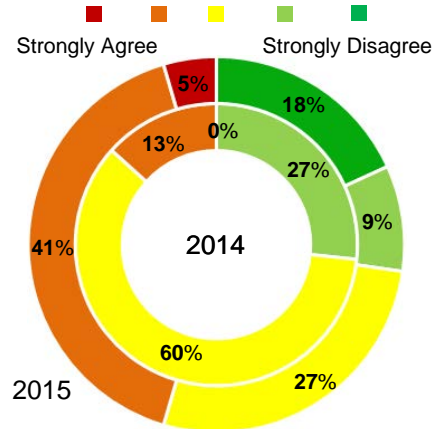
Comparing the students’ responses for questions 4-6 highlights that the video generation was the largest challenge for the students. Despite the fact that the students got help in form of small workshops how to prepare and produce a video, they still struggled with that task notably. Comments like: “time was a major issue”, “more equipment was needed”, “or difficult to create good illustrations and animations” exemplify the problems they faced. However, it seems that not every time this task is equally problematic. The class in 2014 had less problems compared with the following students in 2015. During the course it was observed that more students in the first year of this project had worked with video production earlier and were so probably better prepared.

Compared with the video team the students who worked primarily with the theoretical report and the problem had less difficulties, see questions 5 and 6. However, also here the majority thought that it was not easy to generate good and pedagogical valuable texts or problems. During the team meetings a problem for several groups went to the surface, showing that many of the students seemed to be well trained in solving problems by themselves but to change the perspective and see things from the “learner’s perspective” was quite hard for some of them. However, an important part of teaching is to understand how someone else thinks, approaches a problem, and understands things. Discussing this in small groups or individually helped them

to overcome these problems. It was also important to show them the need of the task because many couldn't see a real-world application of the method used in this assignment. Though making them aware of that explaining, introducing, and training people (customers / colleagues) on technical problems or equipment is today a common work task for many engineers too, increased their understanding and motivation. Another observation made during both years was that the students showed difficulties to find necessary literature and material by their own. Some of them googled or used the course book but the available literature in the library for example was hardly used.



Question 5: It was difficult for your group to create a good problem.



Question 6: It was difficult for your group to write a theoretical book chapter.

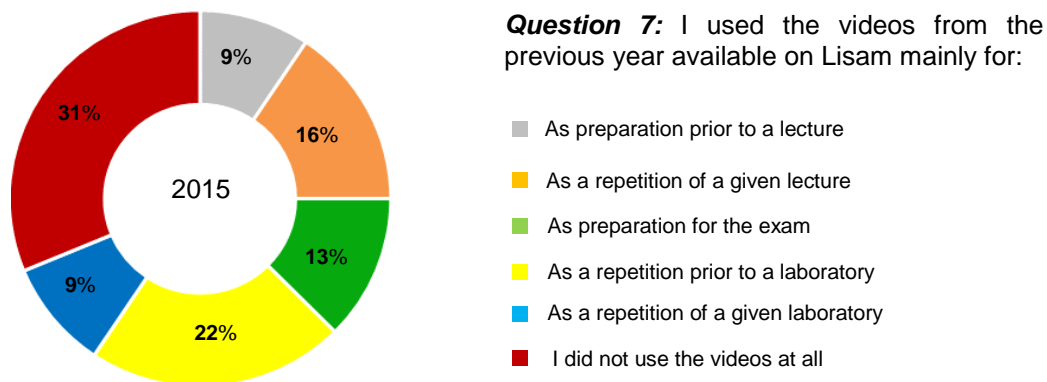
Question 5	Positive	It was difficult but feasible. It was an interesting experience to see how hard it is to create good problems.
	Negative	It is hard especial if you don't have some engine data to create such problems.
Question 6	Positive	I learned that you need a good methodology and focus on the important facts if you want to write a good report.
	Negative	Yes it was, because it was difficult to find good sources.

Another problem they often commented in the assessment was that they often had problems to figure out what information is important for the report. They expected to get clear instruction from the teacher instead of making own decisions what content could be significant for a good understanding, and what could be neglected. A combination of uncertainty to make own decisions and, as previously discussed, the lack of ability to adopt the learner's perspective could be reasons for the large agreement to the question if it was difficult to write the report, question 6.

The above explanations are an attempt to understand why the numbers look like they look. However not all of the student's disagreements can be explained by that. Some of the students mentioned that they would have preferred a more traditional teacher-centered course. Those comments are nothing new in this context, likewise critics and observations were made before when introducing equal or similar teaching methods at other universities and schools Chetcuti et al. (2015) and Triantafyllou et al. (2015). Many students, particularly if they are in final years, are so used to traditional teaching styles, that it is hard for them to adapt to new more active

teaching methods. This negative attitude can be faced with clarifications of why this method may be beneficial for their learning.

Another interesting aspect to consider was related to how the students would use their own course material. The students' reflections show that they use their videos mainly as introduction and preparation before upcoming lectures or as repetition of content that was taught earlier in the course, see question 7. About 32% of the students didn't use the videos as supplement material at all. Also the available problems were only used by 50% of the students to some minor extent for their learning. This probably has two reasons: first there wasn't after the first year sufficient content available to create enough interest and second, this



study material was so far only offered as supplementary material. From this year on, the students' generated teaching materials will be integrated more into the course including small examinations about the presented content.

Question 7	Positive	It is a nice way to get introduced to the topic and motivate to go further into it.
	Negative	The videos are interesting but not sufficiently detailed to use them for any kind of preparation.

CONCLUSION

The results of the survey as well as the quality of the student produced content are very encouraging and highlight that the advantages with this method are manifold. The students indicated that these class activities have promoted their creativity and improved their ability in explaining a complex engineering topic in relation to the CDIO Syllabus 2.0. In addition, the presented procedure show that students and teachers are working actively together towards a common aim: to establish deep and wide knowledge by using and creating student developed course material for continuous and individual learning. However, the CDIO Standard 8 asks not only for active learning but also for creating an awareness by the students about what and how they learn. This study shows that when letting students teaching they changed their attitude to learning, increased their motivation and giving their task a meaning: teaching fellow and next generation students.

FUTURE WORK

In the next step of our work the student created material will play an even more central role in the class and laboratory preparation, leaving more space for discussion and other activities during the available class-room time. The produced course-wiki, together with the videos, will deliver interactive and animated theoretical content to the students. To monitor and examine the students learning progress on a regular base during the course, short multiple choice test, using LISAM, will be realized. The questions will be based on the student developed problems generated the years before. With these activities we will take the next step towards the desired goal of a flipped classroom in TMMV12.

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