

# Flipped Learning in Engineering Education

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**Abstract** – Flipped learning is a developing concept in higher education and a new methodology ready for exploration. It is a new educational strategy that changes the traditional lecturing by flipping the classroom in the sense of listening the lectures at home and doing dynamic, group-based problem-solving activities in the classroom. This will engage the students in active learning, critical thinking and developing new studying skills.

This paper will address the current state of knowledge and practice in the flipped learning approach in engineering education by critically evaluating the existing researches and summarizing the findings. The search for empirical articles included electronic databases for engineering education in the Web of Science. Most studies reported high student satisfaction and increased performance in a flipped classroom environment. This paper will also serve as a guide for future studies and reflect the major achievements of flipped learning models over the traditional lecture-exercises model in engineering education to support and advance the student learning process.

**Keywords** – Flipped classroom, Engineering Education, Flipped learning, Inverted classroom, Engineering subjects.

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## 1. Introduction

Developing technology has made information more accessible and has necessitated the delivery of the increasing quantities of information in accord with individual's learning needs. Besides this, the development of adaptive systems to form structures that are shaped in time with the needs of individuals has gained speed [25]. The technological activity conditions the use of knowledge. It is through activity that both the structure and substance of technological knowledge can be identified, and hence, generalised to instruction [23]. As the schools became crowded, a great number of classes emerged, and the concept of collective teaching was adopted no longer differentiating teaching in such a process. As the academic achievement tests emerged, it became apparent that there were differences among students; as a result, the differentiation of teaching became an inevitable necessity [26]. As technologies and internet based learning are becoming easily accessible and as the focus on integrating technology into education increases, interest in flipped learning is growing everyday more and more.

Flipped learning is a form of blended learning that has become a prominent new instructional strategy and trend within the last ten years [1]. In a flipped setting, students learn new material outside the class via online video lectures and make notes of questions or concerns they may have. Meaning, studying at home and the traditional 'homework' normally done at home is then completed in the next class session where professors can provide students with more collaboration, customized guidance, and opportunities to apply what they learned in their homework. However, empowering and using the flipped learning is not an easy job that can be simply achieved through a combination of online learning and face to face problem solving activities. It requires a more of sophisticated comprehension of effective teaching methods to deal with the shift from the traditional to the flipped learning and the ideal adjustment of technology as a feature of this change [2]. That method became much more important in the action in many applications, as it is stated in the Flipped Learning Network (2012) that observed rising of the number of members on FLN- social

media site from 2500 teachers to 9000 teachers in one year 2011/ 2012 [24].

Professors' teaching engineering faces the challenge of balancing fundamental engineering theory with the knowledge of the tools to perform these tasks. They are forced to teach the latest and greatest software but never sacrifice the fundamentals and to increase class enrollment and grow these programs but growing programs lead to reduced contact time between professor and students [3].

Flipped learning appears to be especially appropriate to engineering education due to its capability of combining learning theories, problem – based learning exercises, instructional lectures and methods founded upon behaviorist principles [4], [5].

Flipped classrooms help two-way communications between professors and students. It meliorates interpersonal and intrapersonal skills of the students. Utilizing the latest technology gives them an opportunity to learn in an improved way by having all the materials in their hands whenever and wherever they want. Methods that enable progressively active learning to the students are: flipped classroom, think pair share and peer instruction.

Numerous schools and universities adopted the flipped learning model as it provides opportunities for expanded peer communication and more profound engagement with the material.

Despite this increasing interest, there does not seem to be an agreement on what flipped learning is and how effective it is in improving students' learning. Therefore, it is time to analyze and synthesize research findings to describe the current state of knowledge and inform on future research and development efforts [5].

## 2. Article Selection Process

To ensure that relevant studies were located, 101 articles published on the Web of Science were examined, 75 proceeding papers and 26 articles comprising 78 on education research, 42 engineering, 14 computer sciences and some in other fields. The keywords searched in the database included 'flipp\*' (which can derive flipped or flipping) learning and 'engineering education' both in topics section, and the year selected were from 2014 to 2017.

## 3. Flipping the Classroom

In a traditional way of learning, students try to catch what is being said by the professor at the very moment when he teaches. They cannot stop it, rewind it, or listen to it again, nor reflect upon what is being said, and they may miss valuable parts of the

material because they are trying to write down the professor's words [6].

On the contrary, the concept of flipped learning is to provide to students lectures in a video format and other supportive materials to review as their homework, get the maximum of it, and then, use the next class time for in-class activities and problem solving exercises.

This can create more class time and not lose education time by having students take notes at home and do the work in class. The greatest advantage of providing the lecture in this format is that students can review the videos several times [7].

Hughes [8], highlighted that there are many ways that a classroom can be flipped. However, the most common way to apply the flipped classroom approach is to encourage students to view the recorded lectures or read course materials outside the class and then meet to engage in problem solving, discussion and practical application exercises with their instructor and other students in the class. Hughes also suggested that moving the lecture out of the classroom may involve selecting course content, deciding the organization of content, choosing multimedia to deliver content, creating materials and making the materials available to the students.

As indicated by Talbert (2014) [9], for a flipped classroom experience to be effective, it ought to incorporate the following:

1. Very organized pre-class assignments which are equipped towards presenting the students with the new theoretical notions.
2. Tools for responsibility to guarantee that students will finish the required pre-class assignments and out-of-class work.
3. Activities should be well planned and designed, attractive for the students to engage with during lecture time.
4. The lines of correspondence all through the course should be open, so the students can communicate freely with their professor.

From this point of view, it is evident that a comprehensive and coherent pedagogy should be implemented to address the limitations experienced in the information systems' curricula over the past years [10].

According to Gnaur (2015) [11], the faculty collaboration should be among the following:

- Subject specialists;
- Pedagogical experts;
- Learning technologists.

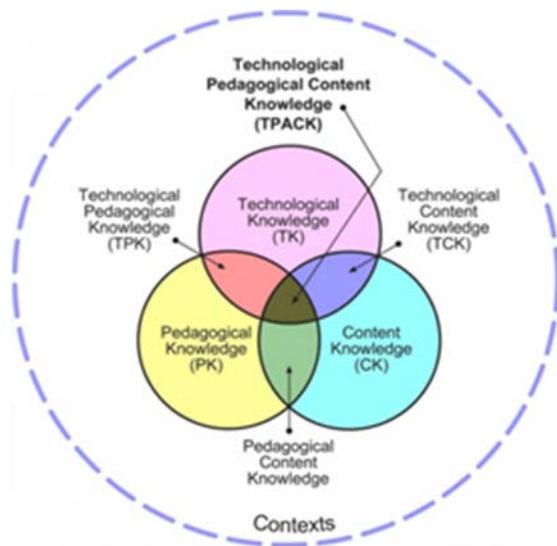


Figure 1. Technological pedagogical content knowledge (TPACK) (Retrieved from: <http://tpack.org>)

### 3.1 Four pillars of flipped learning\

The four pillars of F–L–I–P are flexible environment, learning culture, intentional content and professional educator [12].

Flipped classrooms take into consideration an assortment of learning modes; instructors often physically revise their learning space to adjust the exercise or unit, which may include team work, independent study, research, performance and assessment.

In the flipped learning model, there is a purposeful move from an instructor focused classroom to a student – centered methodology, where in-class time is intended for investigating topics and issues in greater profundity and conceive bigger learning opportunities. Students are not anymore the product of teaching but they are the center of learning, where they are effectively associated with knowledge formation through chances to participate in and assess their learning in a way that is personally significant [12].

Instructors that teach in a flipped classroom evaluate what content they have to teach specifically, because lectures are an effective tool for teaching particular skills and concepts, and what materials students should be allowed to explore first on their own outside of the classroom. In the flipped learning model, skilled professional instructors are more important than ever, and often more demanding, than in a customary one.

## 4. Student perspective and performance

Studies have demonstrated that students are bound to remain in school if they have clear objectives, are active learners, and are participating actively in all the activities and exercises [27] [13]. At the end of the day, students learn more when they are strongly involved in their education and have chances to apply what they are studying and learning. Students likewise benefit when they are occupied with the teaching and learning of their peers, for example, team work, peer audit, study groups and peer teaching in and out of the class [14]. The students overwhelmingly supported utilization of flipped-based (FB) teaching methodology compared to the lecture-based (LB) approach because it promoted cooperation and hands-on activities during class time [15].

Findings revealed that students were familiar with online recordings as a learning asset; they had positive past experiences with using them and were ready to take part in a flipped classroom [16]. That is the reason why for them it is very easy to adjust this new way of learning.

In general, the students seemed to value the flipped classroom design, despite the fact that they identify some difficulties and areas of enhancement [17].

## 5. Findings in the related studies

The studies included in this review were published from 2014 to 2017. Most of the studies were on the undergraduate program, first year, second, third and fourth and few of them on high school and master degree. The studies also included a range of subjects such as electrical engineering, circuits, computer science, mathematics, robotics, systems design, descriptive geometry, computer graphics, and so on. In one experiment conducted by Chao [18] two K11 classes with ninety one 17 year old students were divided randomly in two groups, one experimental and the other one control group for the study. An 8 week pre – and post-test quasi experimental study was structured and designed to evaluate the students. The outcomes confirmed the effectiveness of the flipped learning approach because there were found significant differences between the experimental and control groups in terms of students' results. In the experimental group, students' learning attitudes, motivation and self-evaluation were improved. In conclusion, the outcomes demonstrate that the flipped learning approach positively affects the exchange of learning. Based on the findings obtained, given are recommendations for the improvement of future K12 engineering education instruction using the flipped learning approach.

Another study by Munoz-Merino et al. (2017) [19], says that the utilization of Massive Open Online Courses (MOOCs) is expanding worldwide and brings a revolution in education. MOOCs are typically driven by short video lessons, automatic correction exercises, and the technological platforms that can implement gamification or learning analytics techniques. The results demonstrate that students enhanced their grades significantly when utilizing MOOCs technology, and the student fulfillment was high regarding the experience and for most of the distinct provided features, and there were great dimensions of interaction with the platform (e.g., the number of completed videos or proficient exercises), and furthermore the activity distribution for the different themes and types of activities was appropriate.

To overcome the issues found in the existing flipped classrooms and assess flipped classroom using a database engineering course in a master's program, Chiang and Wang (2015) directed a study that utilizes the College and University Classroom Environment Inventory to investigate the learning performance of the newly proposed in-flipped classroom strategy. The outcomes demonstrate that students in an in-flipped classroom manifest better individualization than those in a traditional classroom and have increased interest in collaborative learning. The study additionally finds that students are more easily engaged in lectures and develop self-directed, self-regulating, and self-determined skills through this strategy [20].

Voronina made an experiment with 25 students that were on first year of their studies on the Faculty of Electromechanical and Mining and with four professors from the Department of Descriptive Geometry and Graphics in St. Petersburg University. The outcomes demonstrated that since 2012, flipped learning has become very popular not only among school instructors, but also among professors of engineering universities. She presented a combination of qualitative and quantitative research of flipped learning models in the field of engineering education: students' attitude towards flipped classroom, the importance of teaching materials, as well as the role of professors' identity have been recognized.

The research demonstrated that there are no scientifically based and tested programs, projects, instructional materials, for teaching students' descriptive geometry engineering and computer graphic and computer geometry utilizing flipped learning approach [21].

Khan and Ibrahim (2017) have made a long term experimental study to see the impact of flipped learning strategy in college technology courses. This experiment is used to evaluate self – efficacy and

perception based on their preferences of learning. To compare the adequacy of flipped classroom versus traditional one selected topics were taught utilizing the two techniques. The learning materials in the flipped classroom included video recordings, post-tests and surveys. These materials were accessible online for the students. The results show that flipped classroom approach made a statistically significant difference in the self – efficacy. The discoveries from this study can be utilized to implement flipped learning approach in other college-level technology and engineering courses [15].

Johnson (2015) analyzed how using flipped classroom, peer communication, and just-in-time teaching are used to make learning of a programming subject easier. He led an experiment trying to enhance further the learning condition in a basic campus course on object – oriented programming and design given to students that are studying computer science and engineering, first year. He analyzed the quantitative impacts of the experiment to a class comprising of 70 students taking the course with flipped learning methodology and a control class of 57 students taking the course in the conventional way. The final exam was the same for both groups, also the marks, and the results were: 81% of the students in the experiment class passed compared to 60% in the control class. Additionally, the share of students' having good grades was 58% in the experiment class compared to 32% in the control class. In this manner, not only did the share of students passing the course increase by a third, but also the share of students passing with good grades almost doubled [22].

Another example of research that showed that flipped learning has been effectively implemented and both teachers and students saw some benefits in terms of improving students' learning experience is the project conducted on Middle East. It included 11 modules at undergraduate and postgraduate studies drawn from seven departments across a wide variety of subjects including Engineering, IT and Business studies. Assessing the pilot project has involved a triangulation of data gathering instruments including utilization of semi-structured interviews with the module leaders, lesson observations and focus group discussions held with students.

## 6. Implications for future research

### 6.1 Sequential courses

Sequential courses did not have statistically observable differences. Future work could explore if pedagogy loses effectiveness as students become increasingly familiar with it.

## 6.2 Alternate instructors

The studies should show how alternate instructors have impact on the results of the students. The flipping of classrooms should be investigated with the same instructors over course, with different instructors, and when different instructors are rather first time teaching or more experienced.

## 6.3 Course workload

The course workload should be carefully investigated and provide students with a careful introduction to the new teaching method during the first week of class and maintain equal course workload among different sections.

## 7. Conclusion

The general idea behind applying flipped classrooms is to ensure that student graduates with the knowledge they need to succeed and to allow educators to be more hands-on and do what they love... teaching the engineers of the future.

The new strategies must be adjusted in the engineering education. It is essential to implement the data and communication techniques like flipped classroom, peer communication and think pair share. By incorporating these strategies in the educational program, learning process of the students will be more effective and interesting in engineering education.

Overall, based on this short review, almost all active learning environments perform better than the traditional lecture. Studies need to continue to provide details regarding the integration of out-of-class and in-class activities so that there is more information regarding good practices and guidelines for flipped classes in engineering education. It is imperative to comprehend the current practices in order to shed light on future implementations and that is why more qualitative and quantitative research should be done to recognize how the potential of the model can be amplified.

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