Flipping The Classroom to Increase Students' Engagement and Interaction in a Mechanical Engineering Course on Machine Design

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Abstract—This paper focuses on engaging students in engineering education and provides a case study to exemplify one way of doing this proposing wikis as the main technology for delivering the content and collaborative problem solving as the main approach for working in class. In particular**,** we flipped part of an undergraduate course on Machine Design following specific design principles. The pre-course content was consisted of existing material, videos, texts and appropriate URLs. This was delivered through a wiki on the wikispaces platform. In class students worked individually and in groups on several types of problems, participating also in a peer review activity. We analysed interaction data recorded by the wiki as well as questionnaires exploring students' perspectives on the particular educational experience. Preliminary results of this pilot study provide evidence about the potential of the flipped classroom in activating students and in increasing interaction within the class.

Keywords—flipped classroom, wikis, problem solving, machine design, mechanical engineering

1 Introduction

Information and Communication Technologies create new opportunities for students to interact with their peers, faculty, and content [1]. This challenge demands a fundamental rethinking of the educational experience both for students and teachers in higher education [2];[3]. Specially in engineering education that, as stated by Goodhew in [4] '...is about imagining and understanding and predicting, as quantitatively as possible, why and how an engineering objective can be realized and delivered', students' involvement in the learning process is more than necessary.

In this line, flipping the classroom in engineering classrooms is a proposal that has taken a lot of attention lately suggesting the replacement of teacher led instruction with in-class activities for students that focus on higher-level knowledge processes [5];[6];[7];[8];[7];[10]. Preparatory work for students is necessary before class providing an opportunity for students to gain first exposure prior to class.

Although several approaches for implementing a flipped classroom have been reported in higher education as well as in engineering education, results remain contradictory lucking to propose specific design principles to guide the development of effective learning environments [4]. Research in the area concentrate on [10] (a) the type of technologies used to engage the students concerning the content or its delivery, (b) students and staff acceptance of the model, (c) educational outcomes arising from a flipped classroom, (d) design considerations and theoretical underpinnings.

In this study, conducted in the context of a Machine Design Course on the "Welded Joints" topic, we aim at contributing to the area by experimenting with content and activity design for pre and in class sessions, classroom orchestration as well as with wikis as the main technology for content delivery. The approach seems promising for mechanical engineering and machine design, since students usually face difficulties on the topic due to the strong geometrical and morphological character of the subject (e.g. forms, shapes, details, dimensions etc.) and the simultaneous development of abstract or intellectually perceived entities (e.g. stresses, strains, fractures etc.) which, nevertheless are critical. To help the students, the teacher has no other choice but to mainly rely on visual representations. Pictures and videos can lead to clear understanding of the physical model which is often either absent or difficult to observe during operation. Animation can be used to associate the development of invisible effects to particular causes. All these can be mastered through suitable analysis of aptly chosen case studies. In such a course, enhanced by visual media, finding the right pace could be an issue for the teacher since a more "vivid" presentation may be unduly accelerated and therefore difficult for the students to follow [13]. This approach of teaching Machine Design is an evolution of the "blackboard" based class which, although technologically upgraded, cannot transcend the long set boundaries of a traditional lecture.

Several studies have also pointed out that hands-on experience on Machine Design, which could be obtained through problem-based or project-based courses [15], can contribute to a significant improvement of understanding and learning. Based on these studies that point out how well a given project may lead to the achievement of the required learning outcomes [16], hands-on projects have been introduced within a traditional classroom format of lectures, tests, and homework [17]. Coming to the flipped classroom model that we applied to flip part of an undergraduate course on machine design, a specific problem typology for designing in-class activities was adopted whilst the main platform for delivering content for pre-class activities was a wiki. In order to assess the usefulness and applicability of the method in higher engineering education we collected and analyzed data coming from two sources, students' perceptions as well as interaction data coming from the wiki. Preliminary results provide positive evidence about the features of the flipped classroom that yielded benefits for students and the learning process. This paper extends work presented by the authors in [19]. The paper starts with an Introduction on the necessity for using learner-centered approaches in engineering education as well as with the main challenges for teaching machine design. Then in Section 2 a review of studies of introducing the flipped classroom model in engineering education is presented. In Section 3 the proposed flipping approach is described. Section 4 presents a pilot study on flipping part of an undergraduate course on machine design at the department of Mechanical Engineering Educators at the School of Pedagogical and Technological Education during the spring semester of the academic year 2015-2016. The methodology used, the data collection and analysis process followed as well the results of the study are presented and discussed. Finally at the last Section the main conclusions about the potential of the flipped classroom approach adopted in actively engaging students in problem solving tasks as well as future research plans are discussed.

2 Flipped Classroom in Engineering Education

Engineering education tends to shift its focus from a strictly theoretical emphasis to a balance between applied mathematics, engineering sciences and hands-on activities [14]. Lately, the flipped classroom model has attempted to address this challenge proposing more class time for active learning approaches by leveraging accessibility to advanced technologies to support access to online content such as video lectures and multimodal resources prior to in-class sessions so that students are prepared for more interactive and cognitive demanding activities. Although research on the aspects of flipped classroom that explicitly benefit engineering teaching and learning is in the first steps, several proposals have been already submitted in the literature.

Lucke, Dunn and Christie [5] flipped part of a third year engineering Fluid Mechanics course and conducted a study with 44 students in order to allow sufficient time to fully engage with a student-response system (Top Hat) and other classroom activities. The particular approach demonstrated a substantial increase in the level of student engagement, motivation, active learning and attendance, although they did not appear to reflect on any large increase in students' academic performance.

Warter-Perez and Dong [6] focus on how to design interactive activities for in-class sessions presenting a framework for integrating Collaborative Project-Based Learning (CPBL) in the educational process and proposing specific projects on hardware design that devote approximately fifty percent of the class time. These projects are considered to supplement the lectures in the class. They also propose the introduction of pre-project, inquiry-based learning activities along with a pre-project design assignment in order to get the students prepared for the in-class projects. These projects are submitted before the in-class section and discussed through the beginning of the class. The authors also share lessons learned about strategies for designing and conducting effective activities, including grading strategies and classroom management. Preliminary results on the impact of CPBL on student learning outcomes suggest that less lecturing can actually lead to more effective learning.

Zappe et al. [7] experimented with a flipped undergraduate architectural engineering class following specific design principles: (1) lecture content is removed from the classroom and delivered to students via on-line video, (b) more active learning, such as problem solving, happens during class. Based on students' feedback, active learning and additional project time available in class improved their understanding, however they would prefer some use of traditional lectures to be maintained.

A more comprehensive research of Kim et al. [8] studied three different flipped classes, one of an engineering course, and analyzed the impact of the flipped classroom using the Revised Community of Inquiry as the main theoretical framework.

This research concluded to nine general design principles for the flipped classroom organised around the four presences of the Revised Community of Inquiry framework. The first three ones are: provide an opportunity for students to gain first exposure prior to class; provide an incentive for students to prepare for class; provide a mechanism to assess student understanding. The other six design principles were developed as new suggestions for creating flipped events to better foster student-centered learning.

All the above studies elaborate on how to engage students during pre-class and/or in-class sessions proposing different teaching and learning approaches leading to general principles. The value of these principles on different disciplines remains an open issue. As far as technology is concerned, this is mainly focused on technology used for the content development underestimating the content delivery platform and the role such a system could play in involving students on the learning process.

3 How to Flip the Classroom: Our Approach

Aiming to take advantage of the flipped classroom in engaging students in Machine Design, we decided to flip part of the relative undergraduate course following the design principles proposed in [11]. The machine part selected was "Welded Joints". Welded joints are very common but also important machine elements. The future Engineers need a broad knowledge of the different types of welded joints along with their advantages and disadvantages in regard to various categories of applications. They also need to understand the failure modes of the welded joints and how to create mathematical models in order to prevent failure by ample yet economic dimensioning.

Following the flipped classroom model, the course content is divided in:

a) the *pre-class content* including mainly pre-existing resources such as video, notes, slides, as well as appropriate web recourses, that students are expected to study through the preparation phase,
b) *in-class activities* including a variety of problems based on Jonassen's typology [18] such as logical, decision and design problems, and debates.

In class, interaction is orchestrateed around collaborative problem solving and peer-assisted activities. Students work individually and in groups to solve problems and initial feedback on the solutions proposed come from their peers.

3.1 Flipping a part of the Machine Design Course

The above model was applied to the design of two lessons, the first with theoretical orientation and the second with practical orientation. The first lesson focuses on theory concerning the types and relative functionalities of welded joints as well as on the basic concepts required for the analysis of welded joints, whilst the second one has a practical orientation focusing on the methodology for welded joints dimensioning. Each lesson was organised in a pre-class and an in-class section. For each in-class section, a pre-class content package was prepared and uploaded to a wiki developed in the wikispaces platform (see Fig.1). The preparation phase (pre-class section) required an estimated 30 to 45 minutes effort at home.

Learning objectives of the *first lesson* include the familiarization of the students with the different types of welded joints, their morphological and geometrical features, their special characteristics, their properties and their applications. By the end of the lesson, students are expected to be able to identify the basic types of welded joints and relate them to their standard symbols. They are also expected to identify and describe the parts or areas of different types of welds. They should understand the advantages and disadvantages of a welded joint compared to other types of joints e.g. bolded joints. Although all welded joints are based on the same concept, i.e. partially melting the metal parts in contact to produce a common connecting mass, they can be distinguished according to their form and/or their manufacturing process. Resulted categories of welded joints can be associated with specific applications. A weld, being actually a miniature metallurgical process, contributes to the development of special crystal structures into the material, highly affecting the quality of the joint and especially its ability to bear loads. The implications to functionality, safety and economy of the final product will be studied at the second lesson but they are certainly based on the theory introduced in first lesson.

Students often find it difficult to acquire a solid understanding of all this knowledge during a traditional lecture and not all of them are able to "connect all the

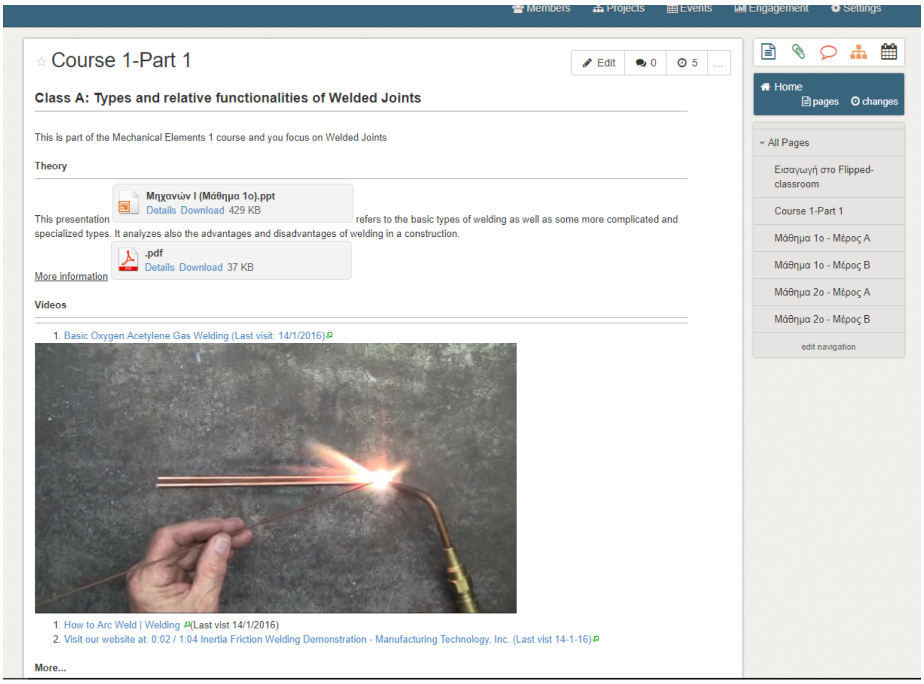

Fig. 1. The wiki environment providing content for the preparation phase

dots". Usually they expect to achieve it later, during homework. Some of the students seek help on the topics that they have not fully understood –and they are certainly encouraged to do so - but it is not so rare for others to withhold this fact.

Flipped classroom has provided a different framework, within which students' familiarization with the fundamental concepts of the welded joints is supported in various ways at the first lesson aiming to prepare them for the more quantitative and demanding second lesson. The pre-class content of the first lesson, is divided into two parts that consist of various types of resources. In the first part of the pre-class content students are acquainted with welded joints. A presentation, serves as an introduction to the topic, presenting the various types of welds along with the advantages and disadvantages of each type in relation to certain applications enriched by selected images and graphics. The student has full control of the presentation, so it's possible to stop on a slide for as long as one needs to, go forward or backward. This might take about 10 to 15 minutes. A text follows covering the topic of stress and strain developed in the material due to the extreme heat conducted in order to melt it. After that, and not necessarily right away, the student has the opportunity to watch three (1 to5 minutes long) instructive videos presenting in detail three welding processes: oxyacetylene welding, electric arc welding and friction welding. In the videos the student can watch the steps of the processes in detail and get a lot of information about required means, quality considerations and also safety precautions.

The second part of the pre-class content is devoted to the morphological characteristics of the welded joints and how these are achieved. It refers also to important best practice rules and also to the quality characteristics of the welded joints. A presentation is provided followed by a video and a link to a web resource. The video is a 9 minutes lecture presenting in detail the morphology and geometry of various kinds of welds. A relative text can be found in the proposed website giving the students the opportunity to acquire information through different and supplementary media.

The pre-class work for the first lesson is expected to last no more than 45 minutes in total. The students are expected to come in-class well prepared to exchange information and also to test, expand and deepen their knowledge. They are expected to be better prepared to interact with the teacher and peers, and to cope with more complex problems that require critical thinking. In-class, several types of problems such as design and justification problems, diagnosis of problematic circumstances, decision making on specific situations, are proposed based on Jonassen's typology [18].

In brief, the *pre-class content* consists of texts, videos, web resources arranged in a specific order. The aim of this content was to clearly present the types and relative functionalities of welded joints and also to familiarize the students with basic concepts required for the analysis of welded joints. The *in-class section* starts with discussion focusing on the students' questions that appeared through the study of the pre-class content and continues with problem solving activities [18].

The *second lesson* has different learning objectives. Having a basic knowledge of the welded joints the students are expected to deal with their analysis and design. For the engineer to design means to optimize i.e. to come up with a set of dimensions which will ensure an optimal combination on safety and economy, by taking into account the functional requirements of a machine element –resulted from its intended use– and the physical properties of the materials. Then students should be able to understand the failure modes of the different types of the welded joints. By using mechanics and material strength theory, they are expected to formulate a particular mathematical model which may adequately represent the relative physical model of the joint. They should also have the mathematical skills to solve this model and end up with a final result.

Students may face difficulties to each one of the previous topics. Some of the students don't have the strong mechanical or/and mathematical foundation required for the task of modeling. Some others have forgotten the relative theories. For all of them Machine Elements is actually one of the first multidiscipline courses they attend in their education and they basically need to learn how to cope with the challenges that emerge i.e. to apply their knowledge of various subjects in order to resolve a problem and conclude to a solution that can lead to the actual construction of a working product. A typical lecture on machine elements modeling may resemble to a bombardment to a novice student.

Flipped classroom provides the student with the opportunity to "brush up" their knowledge and strengthen their theoretical background required for the analysis and design of welded joints during the pre-class section. To this end, the pre-class content of the second lesson is also divided in two parts, the first of which deals with the two simplest cases of weld loading, tension and shearing. A presentation with a synopsis of the theoretical background related to the development of tensile and shear stresses in various types of welded joints, is provided. A comprehensive mathematical aid with all necessary equations is also provided. Moreover two videos (6 and 5 minutes long, respectively) concerning the mechanics of tension and shearing are available. The second part of the pre-class content deals with bending of the welded joints, a loading more difficult to approach, which may lead to failure. This part has a structure similar to the first one, comprising of a presentation, a mathematical aid and a video.

Pre-class work for this second lesson is expected to last no more than 35 minutes. The students are expected to be more aware of the modelling methodology and ready to apply it with the assistance of the teacher to even more complex loading cases. In-class students solve problems, pose questions to clarify all the issues which they might have found difficult to understand. In both lessons, during in class activities, the students have the opportunity to work in pairs or as a team. Teamwork helps them gain by each other's queries and point of views.

In brief, the *pre-class content* contained both short theoretical texts on stress development on welded joints, followed by relative videos, and solved problems providing the methodology for welded joints dimensioning. The *in-class section* was devoted to exercises requiring dimensioning of welded joints subjected to specific loading schemes.

Case Study in Machine Design

In this pilot study twelve students of the 6th semester, both male and female (two in the first lesson and three in the second one) voluntarily participated. Students had to participate in two subsequent lessons and prepare each one devoting about half an hour before the face to face meeting (in-class section). They had also to complete questionnaires reflecting on their experience.

The scope of this study is to explore the value of the flipped classroom for teaching machine design to mechanical engineering students as well as the sharing of content and activities between the pre-class and in-class sections that better serve the expected learning outcomes. All types of content seem to be necessary: theory, multimedia content, hands-on activities, problems to be solved. But which is the right "recipe" for a flipped classroom context? In particular the research questions of this study are:

- How the technology used to support content delivery may benefit students and educators?
- What are the students' perceptions of the value of the flipped classroom?

3.2 Methodology

A short introductory briefing was held a week prior to the first lesson, providing some necessary guidance and practical information about the method of flipped classroom and the technological platform of the wiki. Specific instructions about how to access and participate to the wiki adopted for delivering the pre-class content, were also provided. The two lessons were organized, one day apart from the other, on the 5^{th} and 6^{th} of April 2016, and the in-class section lasted two hours each. Guidelines for the preparatory phase (pre-class section) were also sent to the students by e-mail before the first lesson.

First lesson. In particular, in the pre-class section of the first lesson, students had to study a presentation on welded, to watch four (4) videos and to read the theoretical text provided. They could also visit several web resources proposed for more information. Then, the *in-class* section was organized in three parts:

a) students had to complete a questionnaire about the pre-class experience consisting of several questions such as how long they devoted in studying the content, how difficult it was to follow the content provided, how helpful it was, how ready they feel for solving problems in class,
b) discussion on questions that arose through the preparation study,
c) completion of an assessment multiple-choice questionnaire covering basic theory on Welded Joints,
d) individual and group problem solving activities.

In particular, students were proposed to work individually on the following problems:

- *Design problem*: Specify a case where welded joints are preferred to screwed or bolted joints and a case where welded joints are not suitable.
- *Decision making problem*: Specify three cases where arc-welding, gas-welding and pressure-welding are used.

Then working in pairs students examined the solutions of their peers and provided feedback. Those students that hadn't been prepared enough, they didn't provide a solution. Then the students worked in groups to solve the following problems:

- *Diagnosis problem*: Solve a particular technical problem on welded joints.
- *Troubleshooting problem*: Explore a particular case and define risks associated with a certain welded joint configuration.
- *Troubleshooting and Diagnosis problem*: Explore a particular case, state and justify two guidelines used in welded joints' geometry configuration.

The solution of each group was presented in the class and reviewed from the other groups. At the end of the first in-class section, instructions were provided to the students about how to prepare themselves for the second lesson (pre-class section).

Second lesson. Through the preparation phase of the second lesson students had to study a presentation including:

a) theory on the development of stresses into the welded joints and the relevant failure modes and
b) solved exercises highlighting the stress analysis and basic dimensioning methodology of the welded joints.

They had also to watch two videos (3' each) relative to tension and shearing.

The second in-class section started with a discussion on questions arose through the preparation phase. Actually, there were many questions that students couldn't answer by themselves. Then the students worked in pairs to solve exercises on analysis and dimensioning of simply or multiply loaded welded joints. The students were supported and eventually assisted by the teacher.

At the end of the second lesson, the students completed a questionnaire assessing their 'flipped' learning experience.

3.3 Data collection and analysis

Two types of data were collected and analysed (a) students' actual behavior data coming from the wiki platform (see Fig.2, Fig.3 and Fig.4), (b) teacher's observation and (c) the questionnaires completed by the students reflecting their perceptions on the flipped classroom experience. In particular, the data collected were:

a) interaction data from the wiki that were used as an objective measure to evaluate students' participation in pre-class activities,
b) students' behavior during the in-class sections mainly coming from the teacher's observation and
c) two questionnaires, the first, pre-class questionnaire, assessing students' perceptions on the usefulness and time spent for pre-class preparation (provided at the beginning of the first in-class section) as well as the second, the in-class questionnaire, provided at the end of the second in-class section assessing students' perceptions on the usefulness of the particular approach versus the traditional one. Students responses to both questionnaires were analyzed and compared to the interaction data collected through the wiki since they reflect the actual students' behavior.

3.4 Results

Students' interaction with the wiki platform. Wikispaces keeps analytics for students' interaction behavior (see Fig.2, Fig 3, Fig.4). These data can be used to monitor students' behavior. Especially Fig. 2 represents 'Engagement' data for each user referring to the type of actions performed such as reading, writing, page saved, the last 30 minutes. This information provides qualitative information about students' interaction that is particularly useful in case students are allowed to contribute to the content development process.

Fig.3 represents the number of views on each page. These data provide indications of users' behavior during the lessons as well as of the content quality of each page assuming that the number of visits reflects the usefulness of the content. As illustrated in Fig.3 all the pages were equally visited, with the page with the content of the Lesson 1 - Part 1, having the most visits, i.e. 28.

The 'Statistics Overview' data illustrated in Fig. 4 can be exploited to 'check' students' participation during the lessons since access is provided by date reflecting views per day. In Fig. 4 - the diagram 'Views 4/2016' illustrates the number of views (axe y) during April (axe x). Thus, as we can see during the two days of the lessons (5th and 6th of April), the views are quite high. Especially most views appear before the first in-class section from the 3rd to the 5th of April, with the maximum value one day before (the 4th of April).

Also, in Fig. 4 - the diagram 'Unique visitors 4/2016' illustrates the number of users that accessed the wiki (axe y) on each particular day of April (axe x). The two visitors before the 3rd of April are the professors uploading the content. As we can see in the

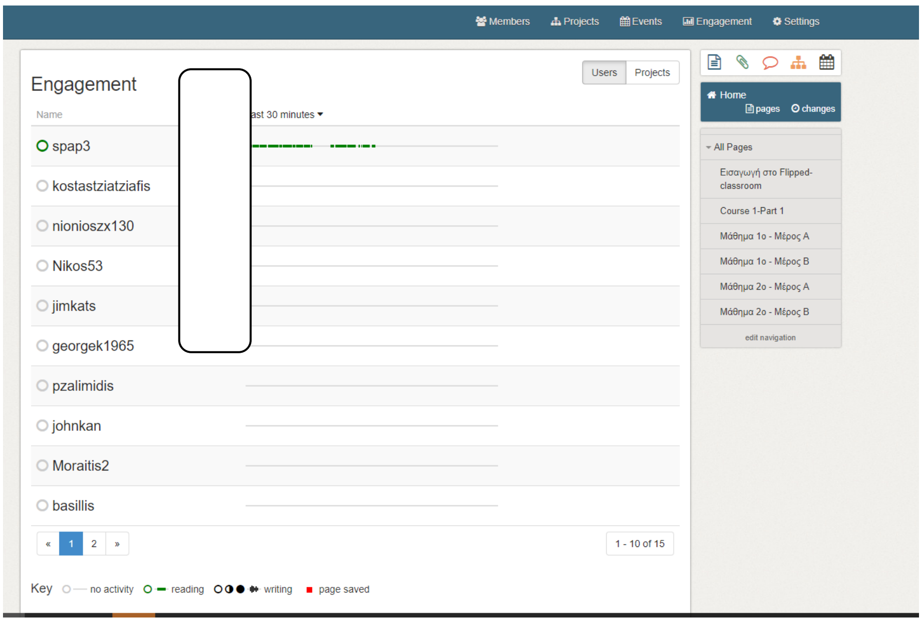

Fig. 2. The wiki environment providing 'Engagement' data for each user.

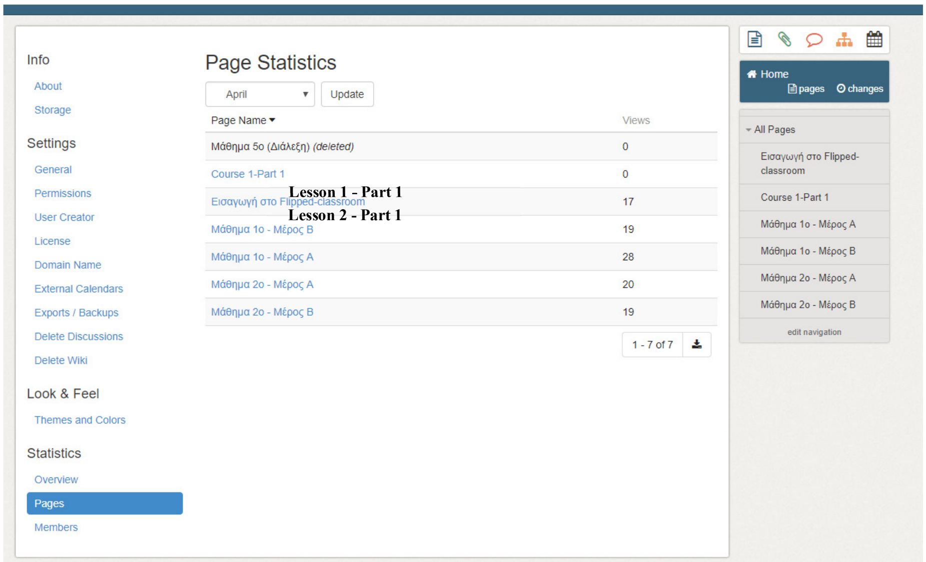

Fig. 3. The wiki provides 'Page Statistics' data referring to number of views on each page.

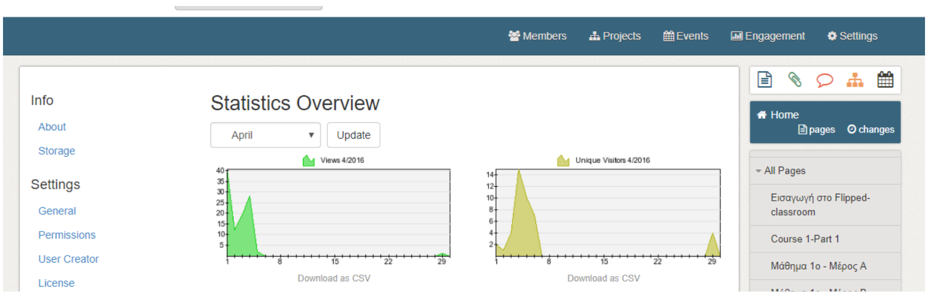

Fig. 4. Diagram 'Views 4/2016': Users' visits on the wiki on particular dates & Diagram 'Unique visitors 4/2016': Number of users (visitors) accessing the wiki on particular dates.

diagram, most users (14 students) accessed the wiki before the first class on the 4th of April. We also note that students accessed the wiki, although less times, between the two lessons (on 5th of April) but also after the second class (on the 6th and 7th of April). One reason for the decrease on accesses between the first and second classes is that students had already downloaded some of the content. Another issue is that they hadn't much time from one class to the other, so some students prepared themselves for both lessons once. However, it is quite interesting that students kept visiting the wiki after both lessons. This may reflect that their interest to the topic increased and they continued to work on the specific topics.

Students' perceptions about the value of the flipped classroom. In particular, students' perceptions about the *usefulness of the content* provided through the wiki at the pre-class phase and the effort they devoted appear in Table I where students' answers to the initial questionnaire are provided. The answers appearing in Table I have been coded based on students' responses since most questions were open-ended. Most of the students note that they studied the content from 15' to 45' (see Table I, Q1) although one of the students noted that he didn't understand the topic because he didn't have enough time to spent (see Table I, Q3). Actually this is also confirmed by the interaction data coming from the wiki.

About the usefulness of the content, most students found it helpful (see Table I, Q3) and understandable (see Table I, Q4) although some questions raised. Seven out of ten students feel prepared to respond to all or most of the challenges of the in-class activities after having completed the preparation phase (see Table I, Q5) whist the other three feel partially able to respond.

Table 1. Students' answers to the pre-class Questionnaire

Question 1			**15''**	**30''**	**45''**
How much time did you devoted to study the available content of the first class;			5	4	1
Question 2			**Small**	**Normal**	**Much**
The amount of content provided at the preparation phase was			1	8	1
Question 3				**Yes**	**No***
Did the videos and the web resources contributed to your understanding of the topic?				9	1
*No: *not enough time to spent*					
Question 4	**1**	**2**	**3***	**4**	**5**
To what degree did you understand the available information; Give '1' for 'Not at all' and '5' for 'Excellent'.	0	0	2	0	8
*3: *I have some questions*					
Question 5			**Yes**	**Most***	**Some****
I can solve the problems/activities that will be provided today.			5	2	3

**Most: Most of them

**Some: Some of them

Most of the questions discussed at the beginning of the first in-class section were from those students that hadn't watched the videos. The answers came from their peers who were more prepared (they had watched the videos and study the content and web resources provided). There was also a question focusing on more advanced topics (welded joints quality and its implications); this was discussed with the professor.

Moreover, through the in-class sections the well prepared students were active contributing to the initial discussion answering the questions raised at the preparation phase, working on activities and providing feedback to their peers. In particular, during the first activity of the first lesson, the students were asked to formulate a documented opinion related to the use of the welded joints in specific applications and on that basis to make appropriate decisions. Almost all students reached the right conclusions and most of them accompanied their answers with full and clear justification. During the second activity, students had to relate the dangers posed by the use of poor quality welding. More than half of the students showed that they had clearly understood the causality between the quality characteristics of a weld and its modes of failure. The third activity was devoted to the good practice of welding, asking students to choose the rules that should be applied to specific applications and justify their choice. In this activity, students' answers have shown that they were aware of the *raison d'être* of these rules and faced no difficulty choosing the appropriate rules on a case-by-case basis. In all these activities, there was a remarkable participation of those students that had completed the preparation phase.

Those students that were not well prepared, although they tried to work on the activities and contribute to discussions, they didn't provide solutions to the main activities. As they noted, they didn't feel 'safe' to do that. The main gains for these students came from class interaction since their peers could highly support them. Students, even in higher education, are 'afraid' of making 'mistakes'; this prevents them from expressing themselves, posing questions, ideas, etc. Nevertheless, these students found the process particularly beneficial as they had the opportunity to participate in all the demanding in-class activities of the second lesson with the support of their peers.

Students' perceptions about the flipped classroom experience. At the end of the second class students completed a final questionnaire to evaluate the in-class experience as well as the whole flipped classroom experience (see Table II). Students suggest that in-class activities were of middle difficulty, not easy or too difficult (see Table II, Q1). They consider that the flipped classroom can be successfully implemented in higher education (see Table II, Q3) and most of them seem (7 out of 12) to prefer the flipped one (see Table II, Q4). However half of the students (6 out of 12) consider that both methods i.e. traditional and flipped classroom, have advantages and disadvantages (see Table II, Q2), and some of them (3 out of 12) need more experience to select among the two methods (see Table II, Q4).

It is also interesting to note that the main advantages of the method that students acknowledge (see Table II, Q5) relate to the students' active involvement through the whole experience (pre-class and in-class sections). Thus, students seem to appreciate the fact that they get in the class having some knowledge that enables them to be actively involved undertaking responsibility of their learning. They also seem to enjoy interaction and collaboration with peers in the problem solving context providing positive evidence about the design of the in-class experience.

4 Conclusions

In this research we explored the flipped classroom model for teaching machine design in undergraduate mechanical engineering students. Actually, initial results provide evidence about how flipped classroom as an alternative framework to traditional classroom, managed to support student's comprehension of the fundamental concepts of the welded joints and prepare them for the more quantitative and demanding problem solving activities.

As far as the technology used for content delivery, i.e. the wiki, it proved to be an easy to use platform for both students and educators. Moreover, due to the analytics

Table 2. Students' answers on the in-class Questionnaire

Question 1	**1**	**2**	**3**	**4**	**5**
How difficult the class activities were for you? Give '1' for 'Easy' and '5' for 'Too difficult'.	0	0	8	4	0
Question 2				**Yes**	**Not Sure***
The flipped classroom is better than the traditional one.				6	6
*Not sure: *Each one has advantages and disadvantages*					
Question 3				**Yes**	**No**
Does this method can be successfully implemented in higher education?				10	2
Question 4			**Yes**	**No**	**Not sure***
Would you prefer the flipped to the traditional classroom?			7	2	3
*Not sure: *I need more classes to decide*					
Question 5					
Which are the advantages of the flipped classroom method? collaboration with peers in the classroom that provokes ideas interchange the preparation phase that supports understanding in classroom the preparation phase that supports problem solving activities in the classroom the problem solving activities in the class that support theory understanding					

maintained from users' interaction with the system, it can be also used (a) to monitor the learning process providing useful information about the type of interaction that students have with the content, and (b) to evaluate the content. An interesting and more challenging future research direction is to study students' involvement in the content creation process since wikis allow collaborative authoring.

Moreover, the results of the study provide evidence about the potential of the flipped classroom method in promoting students' active involvement in the classroom and increase of their self-confidence. Students undertook the responsibility of the preparation phase (pre-class section) and they were actively engaged on problem solving activities in class. Students acknowledged the usefulness of the flipped classroom method. In both lessons, during in-class activities, the students had the opportunity to work in pairs or as a team. Teamwork helped them gain by each other's queries and point of views.

Moreover, since we explored the possibility of involving students in problem solving tasks, a first result that needs further investigation is what type of problems can support in-class learning based on the lesson orientation, theoretical or practical. Several types of problems that were posed at the first in-class section actively engaged students in the learning process whilst at the second class which had a more exercise-based orientation, the learning experience was more teacher centered. This first observation combined with students' preferences towards more collaborative and highly interactive activities lead us to rethink of the way of organising activities around several types of problems instead of exercise solving sessions.

Our future plans include the development of content for the whole semester in order to test the value of problem solving tasks as in-class activities and the relevant content for the preparation phase. Finally we plan to focus on the learning process and on how to enable students work in autonomy and in groups on problem solving tasks.

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