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Students' perceptions of the flipped classroom model in an engineering course: a case study

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ABSTRACT
The flipped classroom model is an innovative educational trend that has been widely adopted in the social sciences but not engineering education. In this model, an active instructional approach shifts the educational strategy from a teacher- to a student-centred approach. The purpose of this study is to compare the learning outcomes of engineering students attending a flipped-model section of the Dynamics of Structures course with students attending a traditional, lecture-based section of the same course taught by the same instructor. The results confirm previous research showing that test scores in the flipped course sections were slightly higher than traditional sections. Although the improvement in test scores was statistically insignificant, student statements indicated that the flipped model promoted a deeper, broader perspective on learning, facilitated problem-solving strategies and improved critical-thinking abilities, self-confidence and teamwork skills, which are needed for a successful engineering career.

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1. Introduction

In the past two decades, engineering colleges and programmes have faced considerable pressures to reform their educational approaches, delivery and assessment as employers have criticised new graduates' poor analytical performance, low level of critical-thinking skills and deficiency in soft skills. Studies have suggested that a significant proportion of engineering graduates lacks the essential skills for a successful career (Kumar and Hsiao 2007; Nair, Patil, and Mertova 2009; Baytiyeh 2012; Felder 2012). To improve the quality of engineering education and better prepare students for successful careers, the Accreditation Board for Engineering and Technology (ABET) identifies specific outcomes that graduates must meet for programmes to earn accreditation. These criteria include the ability to communicate effectively; to identify, formulate and solve engineering problems; and to function on multidisciplinary teams. However, it is difficult to effectively teach and assess many of these criteria through the classroom setting or traditional, formal lecture settings. Proactive, problem-based learning methods can be effective at helping students fulfil the ABET criteria (Felder and Brent 2003). The adoption of problem-based learning, however, is hindered by the dense curriculum for engineering programmes, to which adding any new elements likely would be problematic (Bishop and Verleger 2013). These persistent challenges necessitate the reform of the traditional, lecture-based model of instruction and the adoption of active-learning approaches.

Active learning is generally defined as any instructional method that engages students in the learning process. Students do meaningful learning activities and think about what they are doing (Bonwell and Eison 1991). Evidence shows that engaging students in active learning improves

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students' learning outcomes, motivation and attitudes towards learning (Bransford, Brown, and Cocking 2000; Eison 2010; Freeman et al. 2014). Active-learning techniques, such as teamwork and discussion, can increase engineering students' engagement, encourage them to develop a deeper interest in the subject material and motivate them to improve technical, personal and interpersonal skills (Prince 2004). Moreover, active learning stimulates the critical-thinking and problem-solving abilities essential for a successful engineering career (McKeachie 1972; Bransford, Brown, and Cocking 2000).

Developments in active-learning approaches and innovations in instructional technology have given rise to the flipped classroom model (Thompson 2011; Bergmann and Sams 2012). In this approach, instructors provide online material for students to read, watch, outline, summarise, understand and present on their own so that class time can be dedicated to student-centred learning activities, such as problem-based learning and inquiry-oriented strategies (Lage, Platt, and Treglia 2000; Wood et al. 2001; Thompson 2011; Bergmann and Sams 2012). A flipped classroom can support blended learning (Cornelius and Gordon 2008) that combines the use of Internet technology and face-to-face learning (Garrison and Kanuka 2004). The literature reveals that the flipped classroom model can improve higher-order thinking skills, promote teamwork activities, enhance problem-solving skills, optimise use of class time and facilitate teacher–student and student–student interactions (Estes, Ingram, and Liu 2014). However, implementation of this approach in engineering education at the university level has been limited so far.

The purpose of this study is to compare the learning outcomes of engineering students taking a flipped-model section of a course entitled Dynamics of Structures course with those of students taking a traditional, lecture-based section of the course taught by the same instructor. Feedback from students in the flipped section supports the effectiveness of implementing this teaching style in engineering courses.

2. Inadequacy of lecture-based model to prepare students for successful engineering careers

Researchers and educators have shown that the traditional, lecture-based course model is ineffective and outdated (Bligh 1998; Vita 2001). Lectures are a unidirectional method of transferring information, lack the benefits of discussion and questions and can result in poor learning outcomes (McIntosh 1996). Although lecture-based instruction might arouse students' interest in some topics, clarify textual material and be adapted to individual learning preferences, it places students in a passive, not active, role, which hinders their learning progress. In fact, a lack of interaction is considered a major limitation of this approach (Munson 1992). As well, lectures tend to produce poor student feedback, disengage students from the learning process and assume a satisfactory level of student understanding. Studies have shown that student attention declines significantly within 10 minutes of class beginning (Hartley and Cameron 1967; MacManaway 1970) as students have an average attention span of 15–20 minutes (Stuart and Rutherford 1978). Passive learning in lecture settings often bores students and denies them rich educational experiences (Bligh 2000). Bergmann and Sams (2012) showed that students can read and learn information on their own when motivated but need instructors to guide them problem-solving, facilitate their learning processes and show the connection of theories and concepts to real-world applications.

Despite rapid engineering innovations and technological advances, the lecture-based approach dominates the educational methodologies, presentation and teaching in most engineering courses. The lecture-based style is quite unsuitable for preparing students to succeed in this challenging, demanding profession. This dry, boring, authoritative style of presenting engineering subjects has led to negative perceptions of engineering among college students, low enrolment in engineering courses and poor retention of engineering students (Marjoram 2013). For instance, the lecture-based approach does not adequately address problem-solving and teamwork skills, which are critical components of engineering education. Reliance on in-class lectures and homework exercises to develop these skills has contributed to the unnecessary drop-out of many newly admitted engineering students and resulted in poor test performance and failing grades.

There is increasing, clear evidence that students learn better when they take an active role in the learning process (Davis 1993; McKeachie 1999; Cooper and Robinson 2000; Lord 2001). According to Twigg (1994), recent studies have shown that most college students are active learners who need learning experiences that engage their senses. A substantial body of research on student-centred, active-learning strategies supports their effectiveness at increasing student learning and achievement (Prince 2004; Michael 2006). Active learning is associated with improved academic performance (Hake 1998; Knight and Wood 2005; Michael 2006; Freeman, O'Connor, and Parks 2007; Chaplin 2009), student engagement, critical-thinking skills and attitudes towards learning (O'Dowd and Aguilar-Roca 2009). After problem-based, active learning in science courses, for example, students reported learning more, improved attitudes towards class and significantly less confusion (Akinoglu and Özkardes-Tandogan 2007).

3. Flipped classroom model – literature review

The flipped model has long been used in non-science classes, but recent developments in video and Internet capabilities have led to increased interest in this format in science, technology and engineering (Tune, Sturek, and Basile 2013). The model has existed for years (Novak et al. 1999; Lage, Platt, and Treglia 2000; Mazur 2009), but studies on its pedagogical effectiveness are relatively rare at the college level, where the flipped classroom model has only recently been introduced and implemented (New-Media-Consortium 2014). Mazur (1997) implemented the flipped teaching based on the strategy of peer instruction. This interactive teaching method adapts a student-centred approach and flips the traditional classroom by moving information transfer outside the classroom and bringing information assimilation into the classroom (Mazur 1997; Crouch and Mazur 2001). Class time is devoted to the construction of meaning rather than the transmission of information (King 1993).

The flipped classroom model is built on various instructional foundations that are student, not teacher, centred. Theoretical justifications of the flipped classroom typically focus on the disadvantages of using classroom time to deliver lectures. These justifications are primarily found in literature on student-centred learning, which draws on the theories of Piaget (1967) and Vygotsky (1978). Constructivism provided the source for the theories of problem-based and active learning (Grabinger and Dunlap 1995). A key feature of the flipped classroom model is the maximisation of learning opportunities through one-on-one interactions in the classroom. This student-centred instruction gets students more actively involved in the learning process.

The flipped classroom model has been shown to foster active learning (Berrett 2012; Zhang, Wang, and Zhang 2012) and improve the quality and efficiency of teaching and learning processes (Sparks 2011; Demski 2013; Estes, Ingram, and Liu 2014; New-Media-Consortium 2014). When the flipped classroom approach was implemented in an electrical engineering class, Papadopoulos and Roman (2010) noted that additional content could be covered without sacrificing the overall quality of the course and that students progressed through material faster, understood topics in greater depth and helped other students in the class. Regarding student performance, test scores surpassed those in the traditional learning environment.

In 2009, the faculty at California State University, Los Angeles, flipped the freshman and sophomore Introduction to Digital Engineering course. The intention was to increase opportunities for collaborative, project-based learning in response to perceived limited professor–student interaction and dominance of passive learning in engineering classrooms. A post-course analysis found that flipping the classroom seemed to be effective at helping students understand course material and develop design skills (Warter-Perez and Dong 2012). These findings were supported by satisfaction surveys and focus groups in which more than 70% of students said the class learning environment was more interactive, and all students strongly agreed that the new model helped them improve their hands-on design skills and learn content better.

In a similar study conducted at the University of British Columbia, Deslauriers, Schelew, and Wieman (2011) implemented the flipped model in a section of a large lecture physics course and found that students in the flipped section had higher attendance and engagement. In another study on the flipped approach in higher education, instructors teaching an introductory calculus course at the University of Michigan at Ann Arbor guided students through exercises and asked them to work with their peers to discuss and present solutions (Berrett 2012). Students in the flipped section made gains at twice the rate of students in the traditional section (Berrett 2012). In a third study, the implementation of the flipped model in a biology class at the University of Washington resulted in significant improvements in learning (Freeman, O'Connor, and Parks 2007).

Tanner and Scott (2015) demonstrated that the flipped model had a positive influence on students' attitudes towards learning in a systems-analysis course. Students also reported deeper understanding of the theoretical concepts and their applications (Tanner and Scott 2015). Mason, Shuman, and Cook (2013) implemented the flipped model in a senior-level course in an undergraduate mechanical engineering programme and compared these students' exam performance and teaching perceptions to those of a similar student cohort taking the same course in a traditional, lecture-style setting. The results of this study are encouraging: students in the flipped section demonstrated equal or better quiz and exam performance and higher scores on design problems, adapted to the format fairly quickly and expressed equal or greater satisfaction (Mason, Shuman, and Cook 2013).

However, few research studies disclosed some limitations of the flipped classroom. As such, Davies, Dean, and Ball (2013) as well as Strayer (2012) indicated that there was no significant difference in student performance between flipped classrooms and traditional classrooms. Strayer (2007) who surveyed university students on learning environment noted that, despite the innovation and cooperation aspects of the flipped classroom, students were less satisfied with the structure of the class where it was speculated that the variety of learning activities in the flipped classroom made students 'lost' (20). Toto and Nguyen (2009) also noted that students were easily distracted when watching the video lectures and suggested to have additional classroom time for problem-solving and hands-on activities while video lectures can be used to share theories, examples and problem solutions. Other researchers believe that one disadvantage of the flipped classroom model is that it relies on students' self-motivation where students will be required to spend more time in front of a computer screen (Du, Fu, and Wang 2014). Also, students in poor areas may have technical problems in terms of the internet and may not possess the latest technological tools and applications that the flipped classroom requires (Du, Fu, and Wang 2014; Ramírez, Hinojosa, and Rodríguez 2014). Another downside of the flipped classroom model conveyed by engineering students in Mexico was the lack of instant feedback provided by the instructor (Ramírez, Hinojosa, and Rodríguez 2014).

4. Theoretical framework

The available literature suggests several models for the flipped classroom where each has a different focus: content delivery (Bergmann and Sams 2012), learning cycles (Gerstein 2011), weight of physical and virtual (Staker and Horn 2012). However, all of these suggestions do not identify the components needed in a flipped classroom and the relations between these components. After tracing the relationship of different student-centred learning theories, Bishop and Verleger (2013) defined the flipped classroom as an educational method consisting of two parts: (1) interactive learning activities inside the class and (2) computer-based individual instruction outside the class (5). Abeysekera and Dawson (2015) defined the flipped classroom as the following three dimensions: (1) most transmission of information occur out of the class time, (2) class time is dedicated for activities that involve social interaction and (3) students are required to prepare all the assigned work to take advantage of the in-class activities (3). For the purpose of this study, we use the flipped classroom definition as a set of pedagogical approaches that include the following (Love et al. 2014; Talbert 2014; Gilboy, Heinerichs, and Pazzaglia 2015):

- Highly structured, pre-class assignments geared toward introducing new theoretical concepts
- Means of accountability to ensure that students complete the required pre-class assignments and out-of-class work
- Well-designed sense-making activities to engage students during lecture time
- Open communication throughout the course, allowing students to interact freely with the instructor
- Internet technology enabling students to access unlimited resources and learning materials and communicate with their instructor and peers

5. Methodology

This section provides details about the engineering education at the Lebanese University, course design and method used to assess the learning outcomes of the flipped classroom approach.

5.1. Engineering education at the Lebanese university

Though Lebanon is considered one of the most prestigious higher education hubs in the Middle East, teaching styles remain quite traditional, as it predominantly employs a lecture-centred approach and focuses on theories, memorisation style and analytical methods. This traditional approach does not provide the interactive learning environment needed for future engineering careers. Curricula are highly structured, with no option for students to take electives or interdisciplinary courses to enhance their soft skills.

Admission to the faculty of engineering at the Lebanese University (the only public university in Lebanon) is based on a challenging entrance exam where records reveal that the success rate does not exceed 30%. Because this is a tuition-free institution, only students who are well prepared can be admitted and can succeed in this highly competitive programme. The admitted students to the Bachelor of engineering have to complete an intensive 5-year coursework and a comprehensive final project. The faculty of engineering follows the old French system in which students are required to take 10 courses per semester, a total of 20 courses per year. The passing grade of each course is 60/100 and students must successfully complete 17 out of the 20 required courses. Students of the same cohort attend the same courses till the graduation and no electives are offered. Therefore, students in any selected course have no differences in average academic abilities.

5.2. Course design

Since 1995, two sections (CIV192A and CIV192B) of the two-credit Dynamics of Structures course for seniors at the Lebanese University have been taught in the traditional lecture style. Table 1 provides

Table 1. The structure and topics of the dynamics of structures course in both sections.

The topics covered in the course	Duration	# of quizzes	# of Homework
Introduction: defining terminology, review math, stiffness, mass moment of inertia	1 week	0	1
Deriving the equation of motion of single-degree of freedom (SDOF) system	3 weeks	3	3
Determining the Free, harmonic, periodic and impulse response to SDOF systems	3 weeks	3	3
Problem-solving session and midterm	1 week	0	0
Deriving the equation of motion of continuous and discrete multi-degree of freedom system	3 weeks	3	3
Determining the frequencies and the free, harmonic and periodic response of MDOF system	3 weeks	3	3
Problem-solving session Comprehensive final exam	1 week	0	0

detailed information regarding the topics and structure of the course. It was taught in a weekly 2-hour session, and student performance was evaluated based on weekly quizzes, a midterm and a comprehensive final exam.

In the fall of 2015, the course professor transformed the CIV192A section from a lecture-based model to the flipped classroom model. Students in this section were not aware of the teaching method that will be implemented before they start the semester and they were not allowed to change the section later. Given the rigid system at the Lebanese University, students admitted through the 5-year engineering curriculum have exhibited outstanding performance record and expected to possess similar average academic abilities. The structure of the course (see Table 1) was the same for both sections, but the CIV192B section retained the traditional teaching and learning style. Section CIV192A had 21 students (9 female, 12 male), and section CIV192B had 24 students (10 female, 14 male).

In the flipped section, CIV192A, instructional materials that had been shared and explained by the professor in face-to-face lectures were recorded using voice-over PowerPoint. The professor decided to use voice-over PowerPoint as being an uncomplicated and effortless technique taking into consideration that this course section was an experiment to test the level of students' acceptance of the flipped method implemented for the first time in the college of engineering. Previous research has showed that short videos were preferred by students (Zappe et al. 2009; Ramírez, Hinojosa, and Rodríguez 2014) and therefore the slideshows were approximately 10 mns each. The resulting slideshows were uploaded to the professor's website, so students could review them and the explanations at their own pace. The professor's website also included the course syllabus and the weekly assigned readings (PDF files) and homework problems corresponding with the slideshows. Also, other resources and learning materials were available on the website through the university library along with free sources from the internet databases. Before each class meeting, students were expected to watch the assigned slideshow, read the online materials and solve the homework problems. Each week, new section was available on the website including lectures and assignments related to the next theoretical concepts to introduce. The content of the website as well as of the assignments was highly structured to ensure the students' learning progress. A quiz was given at the start of each class to make sure that students have completed the required pre-class assignments and out-of-class work. Afterward, one student was selected randomly from the class to give a brief presentation on the content of the pre-class assigned slideshow. This practice was intended to hold the students accountable for their own learning process. Later, specific activities were designed to engage students as the following: first, students were divided into groups of three to four to discuss and help each other better understand the concepts. Groups were instructed to identify specific questions for which they needed deeper explanations. Meanwhile, the professor monitored the on-going group discussions to ensure the progress of learning. Then, the professor launched an open discussion in which all the groups interacted, and the professor guided students to find answers to the identified questions. In the remaining time, students solved problems in groups under the professor's supervision and guidance.

Moreover, a mailing list was created by the professor that includes the emails of all students in the flipped section allowing them to interact freely. Throughout the course, students were using this mailing list to send questions to the professor and to each other and consequently all students were receiving the answers provided.

5.3. Instrumentation

Twelve quizzes, the midterm and the final exam from both sections were graded and compared to identify any statistical differences. Also, after the final exam, a survey with four open-ended questions was distributed to the CIV192A students to explore their views of the learning experience in the flipped classroom. Students were told that the survey was anonymous and that its objective was to evaluate the flipped classroom model and identify the strengths or weaknesses of using it in an engineering course. The four open-ended questions were:

(1) How this method has added to your learning experience? Please explain.
(2) Would you like to take another course using the same approach? Please explain.
(3) Would you advise other students to enrol in a course that follows this model?
(4) Do you think that this model is successful in engineering courses? Please explain.

Students' responses were analysed inductively using the constant comparative method (Creswell 2003; Bodgan and Biklen 2007). Data were coded for key points and patterns related to the learning progress and students' views of the flipped classroom model.

6. Results and discussion

This section presents and discusses the results and quantitative and qualitative data collected for this study.

6.1. Tests grades

Table 2 displays the average assessment scores and corresponding standard deviations. Because the result of an individual quiz does not reflect the student understanding of the topic area, quizzes were grouped into three for each topic area as shown in Tables 1 and 2 to provide an accurate learning assessment (assessment1 = quizzes 1,2,3; assessment2 = quizzes4,5,6; assessment3 = quizzes 7,8,9; assessment4 = quizzes 10,11,12). The scores show that on the first assessment including the first three quizzes, traditional-section students scored better than flipped-section students. A paired samples *t*-test was performed for the four assessments in the flipped course section (A) to investigate students' learning progress. There was a significant difference in the scores of assessment1 ($M = 77$, $SD = 4.5$) and assessment2 ($M = 81$, $SD = 4.9$); $t(20) = -3.529$, $p = .02$. The comparisons between the remaining assessments 2–3 and 3–4 were not statistically significant ($p > .05$). These results indicate that students in the flipped section might have struggled to adjust to the new style of learning early in the semester but did adapt to it, based on their improved quiz scores in the rest of the semester.

One interesting observation was demonstrated in quiz #7 related to the equation of motion of multi-degree of freedom of discrete structural system. The development of equation of motion for a multi-story building requires the computation of both inertia and stiffness matrices of the structural system. The calculation of each structural element's stiffness in a given level is essential for creating a spring-mass model of the building and in the computation of the stiffness matrix. Both course sections (A and B) were introduced to the same example of stiffness computation of a four-levels concrete building and were able to draw the model of the structural system to calculate the stiffness matrix of the building. However, when students were given a model of four-levels building and the values of stiffness elements and asked to draw a structural system that represents that model, students in section A averaged 82/100 while students in section B averaged only 75/100. This observation reflects that students in section A (using the flipped model) have developed better knowledge

Table 2. Quizzes averages and standard deviations for traditional and flipped sections.

	CIV192A (Flipped)		CIV192B (Traditional)	
	Ave.	SD	Ave.	SD
Assessment1:Quizzes 1–3	77	4.5	81	4.8
Assessment2:Quizzes 4–6	81	4.9	80	4.4
Assessment3:Quizzes 7–9	84	5.4	80	4.7
Assessment4:Quizzes 10–12	82	4.5	76	4.8

in connecting physical systems to models and vice versa which is a critical concept in engineering practice.

Table 3 compares the performance outcomes of students in both sections. Students in the flipped section had higher average scores for quizzes (2%), the midterm (5%) and the final exam (3%) than traditional-section students. The independent-samples *t*-test for the quiz, midterm and final exam scores in both sections was not statistically significant ($p > .05$). This increase in scores was not meaningful for students' grades and aligns with the findings of previous studies in which the teaching style of the flipped classroom model was implemented (Strayer 2012; Davies, Dean, and Ball 2013; Findlay-Thompson and Mombourquette 2014).

6.2. Students' perceptions

All 21 students in the flipped section answered the open-ended questions. In coding the responses for key points and patterns, four main themes emerged: self-regulated learning, problem-solving and critical-thinking skills, self-confidence and teamwork skills. The coded themes are explained in the following sections, using excerpts from students' comments.

6.2.1. Self-regulated learning

A theme consistently expressed by most respondents was the notion of self-regulated learning, as described by one student:

> I make a schedule for each day. I organize my time and select the materials to go through, read and do the assigned exercises. I enjoyed this learning style because I experienced my own learning progress. Sometimes, I watched the same video twice to understand the concepts, but I did it at my own pace.

Another student comments:

> The most important thing is that I was learning on my own. It was a very challenging environment because much information had to be analysed and linked with previous materials. I really learned a lot on my own.

One student adds:

> This course appeared very difficult in the beginning and was very demanding. After a while, I started to feel that I had acquired a deep learning of the materials and mainly because I was learning on my own by organizing my tasks and objectives.

These responses show that the flipped classroom model helped students become self-regulated learners. This type of learning emphasises students' autonomy and control of the learning environment as they become responsible for information acquisition and other learning outcomes (Zimmerman 1990; Paris and Paris 2001). The flipped classroom model gives students the freedom to access instruction at any time and at their own pace (Fulton 2012). Enfield (2013) speculated that the flipped classroom approach provides students with an engaging learning experience while effectively helping them learn the content, increasing their sense of self-efficacy and ability to learn independently. Self-efficacy is the belief that one is competent to handle the task at hand and that difficult tasks are challenges to be mastered rather than obstacles to be avoided (Bandura 1986). Self-efficacy and the motivation for self-learning are necessary in engineering careers which require continuous learning. Self-regulated learning strategies are the most needed skills in the evolving engineering

Table 3. Averages and standard deviations for both sections.

	CIV192A (Flipped)		CIV192B(Traditional)	
	Ave	SD	Ave	SD
Average Quizzes	81	4.4	79	6.1
Midterm	77	4.7	72	10.1
Final exam	74	6.3	71	6.2

profession as they equip engineers with the abilities to engage in lifelong learning and to transfer skills, knowledge and abilities from one domain to another.

6.2.2. Problem-solving strategies and critical thinking

Another consistent theme throughout students' answers was problem-solving skills and critical thinking. One student explains:

> This model enhanced my skills through problem-solving strategies. Working on the assignments on my own before class helped me in analysing, synthesizing, evaluating information. … I believe that all the discussions in the classroom with the professor and with my peers fostered my critical thinking skills.

Another student states:

> Engaging in classroom debate to find the correct solutions was very beneficial. The professor created an environment that encouraged discussion in class. The activities in class with student-generated questions after reading the materials were very effective at understanding how to solve problems and to link information together.

Finally, a student observes:

> The way the course was designed pushed me to revisit the course materials and connect the theories and concepts to find the right solutions. This course fostered my problem-solving and critical-thinking skills through conceptualizing and evaluating information. Also, the reflections on our learning helped me a lot.

Siller (2001) showed that the implementation of critical-thinking pedagogy for sustainable development concepts makes a significant contribution to the education of engineering students. Dewey (1915) speculated that the integration of problems into the classroom triggers students' curiosity and stimulates learning and critical thinking. Kurfiss (1988) argued that critical thinking is embedded in questioning assumptions and seeking alternative views. Guiding students is an important component of instruction in a flipped classroom, and the design of discussions, reflection and questions is intended to foster the advanced skills needed by engineering students. The respondents' comments show that they were challenged to look for solutions when they encountered a complex situation. An active-learning environment fosters the critical-thinking and problem-solving skills essential to successful engineering careers (Bransford, Brown, and Cocking 2000). Twigg (1994) contended that most college students are active learners who need learning experiences that engage their senses. This learning approach helps students develop good problem-solving skills, including for handling open-ended problems, while acquiring strong technical knowledge and critical-thinking abilities.

6.2.3. Self-confidence

A theme repeatedly highlighted by students was the notion of self-confidence and responsibility. One student comments:

> I am very confident with what I learned. This course was very well structured and well designed, which helped me be responsible of my learning progress.

One student states:

> I am impressed with the amount of information I learned in this course because I was treated as responsible for my own learning. When we come to class, we were prepared for all scenarios, and we became more confident of our academic performance through the class discussions.

Another student notes:

> Now, I have discovered my talents, and I know how I can implement my ideas. I feel very confident of my skills, and this course gave the opportunity to feel more responsible for my own schedule and the outcomes of the tasks in my hands.

This theme indicates that students were given the opportunity to control their own learning and felt proud of taking responsibility for their learning progress and gaining confidence in the information they learned. Students valued exploring and improving their skills while engaging in meaningful learning. Enfield (2013) reported that students became more confident in their ability to learn a new technology without formal instruction after learning in a flipped classroom. Previous researches have shown that learning independently fosters self-confidence (Vrugt, Lanereis, and Hoogstraten 1997; Bailey and Hill 1998; Heywood 2005). A study on 1387 first-year engineering students at Purdue University showed that self-efficacy affected their confidence in succeeding in the Problem-Solving and Computer Tools course (Hutchison et al. 2006). Future engineers will encounter challenges – identified as communication, responsibility and self-confidence for Lebanese engineering graduates during the transition from university to career (Baytiyeh and Naja 2012) – and implementing the flipped classroom model could promote the self-confidence needed in this challenging career.

6.2.4. Teamwork

Participants repeatedly mention teamwork as an advantage of this teaching style. One student states:

> I was very confused with modelling multi-degree of freedom systems. I started contacting my peers to work together on some problems, which helped me a lot. Also, the in-class discussions and work in groups with my peers helped me understand details of the materials.

One student notes:

> This course helped me in learning how to work in a team. I learned that there are several alternative solutions, and people possess different perspectives. … I learned to listen to others and to understand others' views, especially through the group work sessions.

Another student states:

> Working in a team and sharing ideas were very valuable for all of us. Communicating with other students, sharing views and discussing the materials helped the whole class benefit from each other's expertise. Everyone was ready to help everybody else.

These comments show that students learned that they could collaborate to learn together and broaden their thinking in teamwork. Active-learning techniques, such as teamwork and discussion, have been shown to increase students' engagement, encourage them to develop a deeper interest in the subject material and motivate them to gain technical, personal and interpersonal skills (Prince 2004). These skills, which are highly needed by engineering students, have been highlighted in engineering classes when implementing the flipped classroom model. These findings are consistent with previous studies showing that teaching following a flipped classroom approach allowed students to acquire expertise from several people during classroom time (Papadopoulos and Roman 2010; Fulton 2012; Warter-Perez and Dong 2012).

7. Limitations and recommendations

This study includes only a limited number of students enrolled in one course of civil engineering. Open-ended questions, though useful and convenient for understanding students' perceptions and lived experience during the course, they are not enough to generalise the findings. Gathering data from a larger number of participants may be useful to establish validity and to gain a more complete picture of the performance of students during their learning process. For future research, it is recommended that students in the traditional section of the course receive a similar survey so that their responses could be compared to those of the students in the flipped section. It is also recommended that future studies perform a pre-test for both sections in the first week of the semester to measure the level of knowledge students have for the course and to ensure that no differences in academic performance abilities between both sections. Moreover, future studies can examine gender differences across sections regarding their performance as well as their perceptions towards the flipped method.

Very few private high schools in Lebanon have started to implement the International Baccalaureate curriculum that encourages independent learning, communication and self-management skills. Although the majority of students who are admitted to the public Lebanese university have graduated from high schools that follow the traditional Lebanese curriculum, it is recommended that future studies compare the perceptions and performance of traditional students with their classmates who have been exposed to student-centred experience in K-12.

8. Conclusion

This experimental study shows that the outcomes of the implementation of the flipped classroom model in an engineering course were largely positive. Although students in the flipped section might have struggled in the beginning of the semester, the assessment scores showed that they adapted quickly to the new style of learning and no significant difference was found in student assessment scores performance between the flipped and traditional sections. The comments provided by the students in the flipped section reveal that this teaching style can enrich students' learning experience and help develop the professional skills needed for successful careers in engineering, including self-learning, problem-solving, critical thinking, self-confidence and teamwork.

Although the findings of this study are not novel in the engineering field, the implementation of the flipped teaching method in the Middle East region has been limited and its progress in higher education has been remarkably slow. Participants in this study are graduating seniors heading to a new experience of work or graduate studies and therefore they cannot be assessed only by grade performance. The learning experience assessment exhibited through their self-perceptions reveals that students at this level are eager for a new learning approach that facilitates their transition to the challenges of engineering profession. This experiment was intended to expose engineering students to such learning styles as well as to promote this practice of teaching among engineering professors in the region.

In the mixed outcomes from previous studies on this model, professors remain the major factor in its success and must implement creative solutions to prepare engineers for their future careers. Further research is needed to confirm these observed outcomes and validate the advantages of this model in engineering education. Given that there is no single ideal teaching or learning styles, the lecture remains a common instructional instrument to deliver information. However, a heavy reliance on the traditional lecture style without incorporating interactive approaches that improve problem-solving, critical-thinking and teamwork skills will only prepare newly graduated engineers to fail in the transition from college to career. The findings presented in this article may inspire engineering professors to employ the flipped model in their classes, to judge what works best for their students and to share their negative and positive experience with colleagues so that educators can learn more about the advantages of this approach in preparing students for successful engineering careers.

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No potential conflict of interest was reported by the authors.

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