STUDIO TEACHING MODEL FOR AN INTRODUCTORY ENGINEERING PHYSICS COURSE ON CLASSICAL MECHANICS

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Abstract

Studio teaching approach is increasingly adopted as an alternative to the standard teaching methodology. It allows a better active learning setting for students to increase their participation inside the classroom while lecturing time by teachers is substantially reduced. This new methodology has been tested in many universities around the world and has proved its effectiveness. In this paper we present our design, experimentation and evaluation of using studio teaching for the introductory engineering physics course on classical mechanics over two consecutive academic years. Our studio teaching model led to an overall relative improvement in class performances and a substantial decrease in students' absenteeism rate. Students' satisfaction surveys show an overall acceptance of the new methodology despite few complaints about the duration length of the studio sessions and the workload in class.

Keywords: Studio teaching; Active learning; Physics teaching; Introductory engineering physics course; General Physics I.

1. INTRODUCTION

Studio teaching approach for physics instruction was first initiated by the Rensselaer Physics Education Group [1]. This methodology is characterized by integrating course lectures and lab experiments in a common technology enhanced class environment. In the studio teaching approach lecture time is reduced to a minimum while emphasizing student centered, active, and collaborative learning. The model generates a high level of faculty-students interaction [1]. Hands-on activities, computer tools and multimedia materials are extensively employed in the studio physics environment to allow students to take part in their own learning. Students' increased interaction with peers and instructors in the classroom is a key factor improve directly their knowledge by sharing ideas and working on problems together. A large number of schools have adopted the studio teaching and have adapted it to their particular circumstances as an effective teaching style [2]. Student-Centered Active Learning with Upside-down Pedagogies (SCALE-UP) is an innovative

approach of studio teaching that aims at improving the way engineering courses are taught at Al Akhawayn University in Ifrane (AUI). The first experiment was done on a physics class (PHY1401) to see how effective this new methodology can be. This approach can also be used in different courses such: Introductory Calculus, Electrical Circuit, Mechanics of Materials, and Statics for Engineers, Dynamics, and Thermodynamics.

Section II presents the goals of studio teaching methodology. Section III describes the characteristics of the model used for our physics class, including the characteristics of the classroom and its environment, the schedule and the activities used. Section IV presents the syllabus of the course using studio teaching as a learning pedagogy and section V presents a comparison between the studio teaching methodology and the traditional way of teaching in terms of students' absenteeism and grades along with students' satisfactory surveys results.

2. GOALS OF STUDIO TEACHING

Using studio teaching methodology in a physics class aimed to provide students with a better understanding of physics. The approach used provides them with a specific knowledge of physics principles and concepts which allows them to know where each of those principles needs to be applied. Students therefore acquire the ability to use and recognize the use of concepts when solving problems and exercises. This approach would help students to develop the ability to apply concepts to new contexts and to translate their conceptual understanding to multiple representations (using words, equations, graphs or diagrams). On the other hand, studio teaching will develop expert-like problem solving skills in a way that students should develop the ability to plan a solution. They also should be able to use a strategy like a goal in any context. Furthermore, students should be able at the end of each chapter to solve different kinds of problems including the challenging problems. Another goal of the studio teaching methodology is to develop laboratory skills; by knowing how to recognize the apparatus that they need to use for each experiment and be able to make measurements. They should also have the ability to design, execute, analyze and explain scientific experiments. Additionally, students should develop their technology skills by using simulations and developing mathematical modeling of physical situations; they should learn technology skills related to networking computers and search engines and technical software applications. Another goal of studio teaching is teaching students how to present or write about their understanding; as they need to share ideas with their peers and be able to explain and prove their knowledge. Last but not least, students should develop cognitive attitudes and beliefs that would help them understand physics concepts.

3. CONCEPT LEARNING

3.1. Characteristics of a studio Classroom

The plan of the classroom is a critical thought for showing studio-style classes, since in studio teaching physics all class time is held in a single classroom, the room must have equipment that support all the activities including lectures group works and laboratory experiments. Classroom management is extraordinarily supported if the classroom configuration likewise empowers cooperation inside and between groups gatherings, especially when a group needs assistance and the instructors are busy with other groups. Furthermore, the classroom layout must encourage dispersing and gathering of activities materials like assignments or lab apparatus. The room needs also to be able to exhibit set-ups that are too costly, risky or time consuming for students to do themselves. For these reasons, studio multimedia classrooms require understudies to have the capacity to allow students to [7]:

- Work in groups gatherings of 2-4 students.
- Have access to computers and the internet.
- Have access to equipment to perform experiments.
- Participate in class discussions.
- To be able to display work to peers.

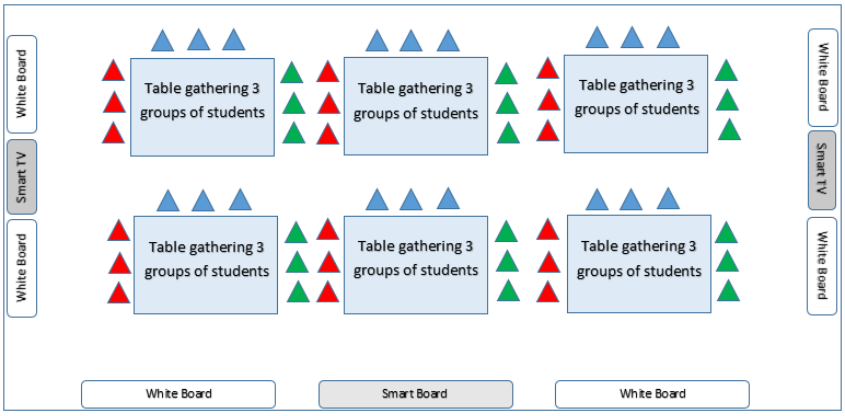

Fig. 1: Schema of the studio classroom at Al Akhawayn University

Fig. 1 presents the set up of our studio classroom. Every table gathered three groups of three students. A smartborad is located at the center of the classroom in which professors and students can present and share their work from their computers using VIA application. This can also be done using the smart TVs located at the right and the left of the classroom. The classroom has also six white board in which professors can explain concepts or corrected examples either to the whole class or to specific groups having difficulties.

3.3. Classroom Environment

Studio teaching physics class is characterized by fewer lectures. Students learn by working in groups; many activities are given to students to emphasize on improving their interaction with their peers. Students are given projects to work on during class time. At the same time, instructors are there to assist them in any problem that they may encounter while trying to solve the problem, nevertheless students are the ones who have responsibility of learning. Class activities expand on each other which give a dynamic and coordinated learning condition that accentuates individual scholarly improvement and content learning.

A. Schedule and management of a studio class

Classes work best if scheduled in 2-3 hours blocks [7]. A typical studio class include occasionally brief lectures that are given by the instructor, but more time is dedicated to one or several group projects that students need to work within their group, by discussing their problems with their colleagues reporting to their instructors while reaching any milestone. Group activities work best when each group has 3 or 4 students. Assigned homework are also given to support class activities [7]. In our case, students used to meet with their professors for a 3 hours session twice a week, with a 10 minutes break at the middle of the session.

B. Classroom Activities

A number of studies were done in order to check what are the current models of students' intellectual development and implications for a classroom, the most known research was done by Felder and Brent, in which a description of those models was given. In their paper, they directly encourage the use of student-centered learning environment for engineering course. Those classes push students to challenge themselves by having all the responsibility to learn all the different concepts using different activities provided during class time [2]. As a matter of fact, there exist different ways that can be used to teach students what they need to know, but each method is different from another in terms of how student's abstraction perceive their knowledge. An example of that is the difference between reading a text and seeing or doing an experiment; the more ascend the cone, concrete experience drop out. This can be summarized as "the more you do, the more you learn" [3].

The highest attention is dedicate to group work when it comes to student-centered classrooms. All students are required to contribute to solve assignments and activities, this is why instructors can adjust groups as needed if poor progression is noticed or if some students overwhelm or take a "free ride". When groups are gathered to figure out how to cooperate and how to center and to advance toward venture objectives, instructors must provide direction and excitement. This short time is important as some students may find it difficult to adjust to this new style of learning. Instructors must deal with each student independently as the stress level may differ between students, to goal is always to make each individual responsible of their learning.

It is fundamental for this type of classes to have activities in which group can check at the solutions of other

groups in order to amplify the amount of learning. In fact, sharing of information makes students learn better, so they are required to have those types of discussions in which they can ask questions and explore new areas of interest. Students work in small groups of usually three people; to emphasize discussions between groups, each three groups are gathered in one table to allow them those types of discussions [7]. Students can therefore compare results, but also exchange ideas and ask questions to their colleagues, especially when instructors are working with another group. The entire sessions create a portion of the best teachable moments of the entire semester.

Table 1 presents the numbers of all types of activities given to physics students throughout the semester. As the lectures became shorter, the learning was based on the application of these activities. Diversifying the types of activities was done on purpose in order to make sure that every student is able of learn the concept in a better way.

Software activities distributed to students were based on Tracker. This software is a free video analysis and modeling tool [8], with which students were required to work. For each Tracker assignment, students had to download the required video from the website "http://physics.highpoint.edu/_atitus/videos/". This has to be done before coming to class. The assignment was also sent to students as a set of different analysis questions. The list below are the titles of all Tracker activities:

- Video Analysis of Uniform Motion
- Video Analysis of Projectile Motion
- Video Analysis of a Bicycle Wheel in Uniform Circular Motion
- Inertial and Non-inertial Reference frames
- Video Analysis of Constant Force
- Velocity of the Center of Mass of a System
- Collision Analysis Comparison
- Conservation of Angular Momentum of a Spinning Figure Skater

Table 1. Total activities for one semester

Activity Type	**Total number**
Class chapters' activities	21
Software activities	8
Experiments	7
Homework	12
Group Quizzes	6
Individual Quizzes	6

Most of the assignment were taken from the same website gathering the videos. As our physics course focuses more on kinetics and kinematics, the use of the Tracker software is an important tool in the improvement of students understanding. Assignments are done in groups. Students can then compare their results and project them so that the whole class understands the concept to be studied.

Another important type of activity is experiments. As a matter of fact, one experiment was done by students for every chapter to help them understand all the concepts taught. Following is the list of the experiments done in our physics class:

- The measurements of Mass, Length and Time
- Vectors and Equilibrium

- Free Fall Experiment
- Atwood's Pulley
- Work and Energy in a Simple Pendulum
- Elastic Properties of Deformable Bodies
- Buoyant Forces

The main characteristics of studio teaching is that all activities have to be done at the same place in which the course in taught. For that purpose, many of the lab material was transported to the ST physics class, in order to allow students to do their experiments with their respective groups.

4. SYLLABUS AND COURSE PROGRAM

The course in which the Student-Centered Active Learning was applied at Al Akhawayn University was Physics I. This is a calculus-based physics course required for all School of Science and Engineering students. It focuses mainly on mechanics including: Kinematics, Forces, Newton's laws of motion, Work, Energy, Momentum, Impulse, Rotation, Gravitation, Elasticity, Period motion and Fluid mechanics.

With the new approach, the course emphasized on rigorous problem-solving in physics using interactive instruction, educational software, computer applications important for science and engineering students, and cooperative learning. Students enrolled in this course had the responsibility to think and to perform hands-on tasks. Key concepts of new material were discussed in short lectures. A great amount of time was dedicated to collaborative work. In fact, social interactions are critical to scientists and engineers. Most employers value this type of work, since most good ideas grow out of discussions with colleagues.

Concerning the grading policy, attendance counted for 5% of the grade, 15% was dedicated to quizzes and assignments while class activities and laboratory counted for 25%. Students then had to pass three tests, 1st and 2nd tests (midterm evaluations) which contributed to 30% of the grade and the final test was worth 25%. As mentioned before, the course focused on group work. For that reason, students were divided into groups of three and each table gathered three different groups. Class activities were assigned to students so that they work on it with their respective groups. Groups were changed after each test.

Each week, students had two sessions of physics. The duration of each session was 3 hours, which makes it a total of 6 hours per week. After each session, students had an extra half-hour in which they could ask questions or discuss any matter related to the course. These questions sessions were not part of the office hours available for the students. A typical week program was usually introduced by a short lecture in which new material was presented to students. After that, practice exercises were given to the groups so that they can apply what was just explained. After getting familiar with the concepts, groups had to do simulation activities. As Physics I focused more on mechanics, most simulation and analyzes were done using Tracker software. This latter allowed students to study different motions such as one dimensional motion, projectile motion, uniform circular motion, etc. At the end of the week, students were required to do is a laboratory experiment in which they could check and apply the concepts studied.

5. EDUCATIONAL IMPACT

The purpose of this research was to check the efficiency of the studio teaching methodology; considered as high-tech and expensive compared to traditional methodologies which had more focus on lecture instead of activities. For that reason, a comparison of students' performance was done. The samples taken for this comparison were students who took Physics I taught with this new approach, this was during Spring 2017, Fall 2017 and Spring 2018 semesters. The second sample were students of the previous semester; which is Fall 2016, in which the same course was taught using the traditional methodology. The first thing that we noticed is that only two students of the Spring 2017, Fall 2017 and Spring 2018 semesters dropped the course after the first test, while four students dropped the course taught during Fall 2016 semester.

Another aspect in which comparison could be made is the attendance record. In this comparison, students' attendance records was compared with attendance records of Fall 2016 in order to check effectiveness of studio teaching. As depicted in fig. 2, more students tend to have zero or one absence while using the new methodology. This can be explained by the fact that students with the studio teaching approach are required to do many activities during class time. Those activities are graded which pushes them to attend and to work on them in an effective way within their respective groups. This way students are more involved with the course and practice a lot to understand the concepts and to think on some difficult problems.

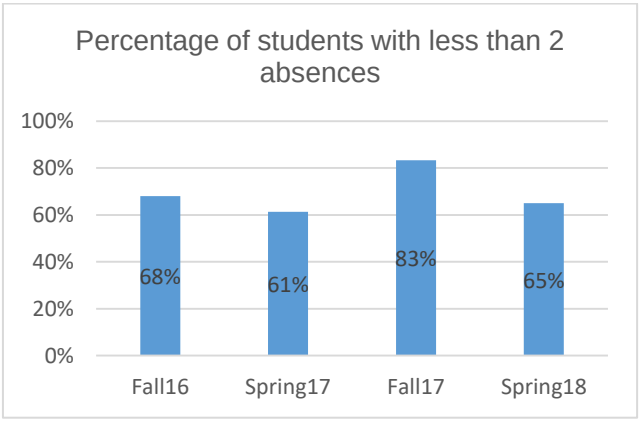

Fig. 2. Attendance record comparison

Next step was the grades' comparison; grades for Test 1 and Test 2 were compared. Fig. 3 and Fig. 4 present two comparison graphs. The first one concerns grades for the first test for all samples and the second one are the grades for the second test. From both graphs, one can notice that students' grades from the studio methodology follow a more normal distribution compared to students' grades of Fall 2016 semester in which the traditional way of teaching was used. Another important observation is that students tend not to be familiar with the new methodology, which made their Test 2 grades better than Test 1 grades. In fact, for Fall 2017, the rate of students passing the test increased from 47% in Test 1 to 79% in Test 2. Same thing can be noticed for students of Spring 2018 semester as the same rate increased from 20% to 74% this proves the effectiveness of the methodology; we can therefore conclude that students perform better in studio classes. This cannot be really seen in Spring 2017; which was the first semester in which the new methodology was used, because it was a transitional semester in which the methodology was not fully set.

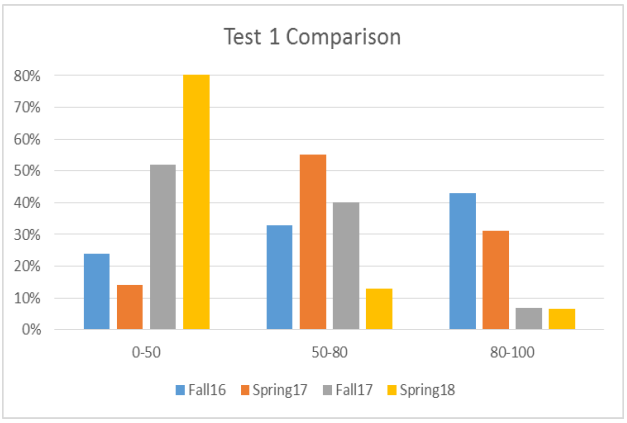

Fig. 3. Assessment of students for Test 1

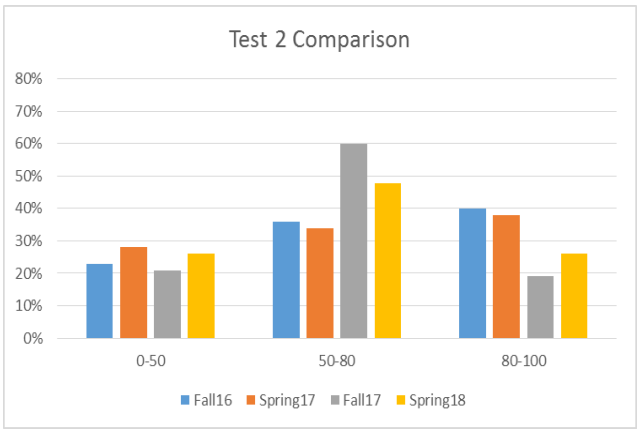

Fig. 4. Assessment of students for Test 2

6. STUDENTS' FEEDBACK

Last but not least, as instructors we wanted to check how comfortable students were with this new methodology. For that purpose students were asked to fill a survey at the end of the semester. For Spring 2017, we received 46 responses, which represent 83% of the total number of students who took the course on that semester. For Fall 2017, the number of replies represented 73% while we got 85% of replies for Spring 2018. Table 2 presents details about statistics of the three surveys.

Table 2. Surveys' statistics

Spring 2017	Fall 2017	Spring 2018
• Total number of replies: 46 • 83% of the total number of students enrolled. • 80% of the students were freshman students while the remaining 20% were sophomore. • 39% of the students were female, while 61% were male	• Total number of replies: 31 • 73% of the total number of students enrolled. • 48% of the students were freshman students while the remaining 52% were sophomore. • 39% of the students were female, while 61% were male	• Total number of replies: 39 • 85% of the total number of students enrolled. • 77% of the students were freshman students while the remaining 23% were sophomore. • 54% of the students were female, while 46% were male

The surveys gathered different questions aiming to assess the effectiveness of the studio teaching methodology. The first question was a direct one in which students were asked to rate the new methodology in a scale of 5. For Spring 2017, 56% of students were satisfied and only 15% students rated it as being a poor methodology. For Fall 2017, 67% of students were satisfied with studio teaching while the number of unsatisfied student decreased to 10%. Regarding Spring 2018, 64% of the students were satisfied and the number of unsatisfied students decreased to 8%. Fig. 5 presents in detail these results.

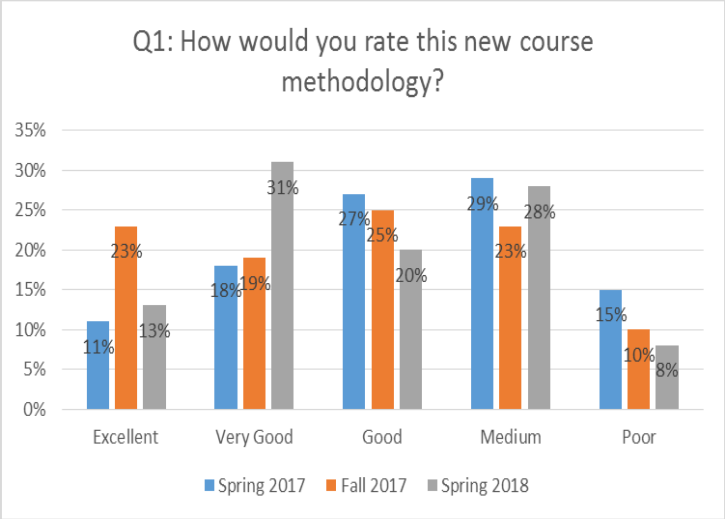

Fig. 5. Students' rating for the studio teaching methodology

On another question, students were asked which activity helped them learn physics better. As depicted in Fig. 6, students tend to like doing experiment and chapters' activities. In fact, for Spring 2017, 27% of students preferred doing experiments and 35% of them felt that chapters activities were more helpful for them. For Fall 2017, 52% of students learned better with experiments and 29%. For the third semester, 33% of students voted for chapters' activities, the same rate was registered for experiments, which again proves the effectiveness of the studio teaching methodology as the learning is achieved by the different activities students work on.

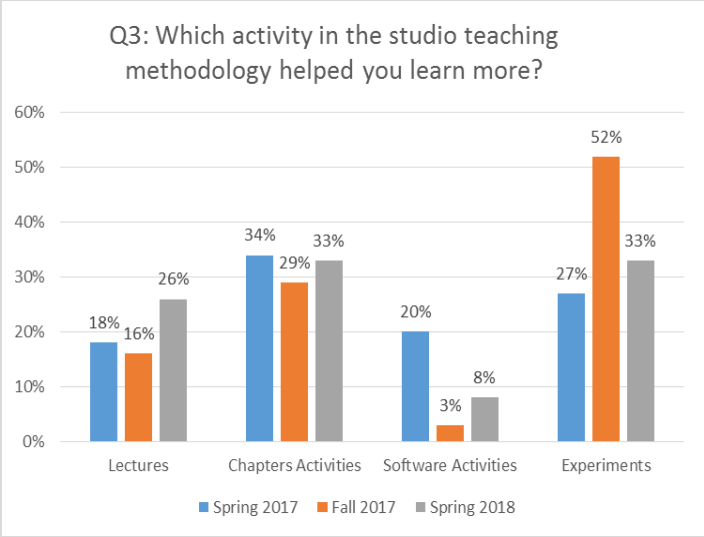

Fig. 6. Students' assessment of studio teaching activities

Last but not least, students were asked if they were willing to take another course that uses the studio teaching methodology. As for the first experience, the total number of students who responded positively reached a total of 46%, while on the second experience 65% of students preferred the new methodology and 64% in the third semester. This has been represented in Fig. 7.

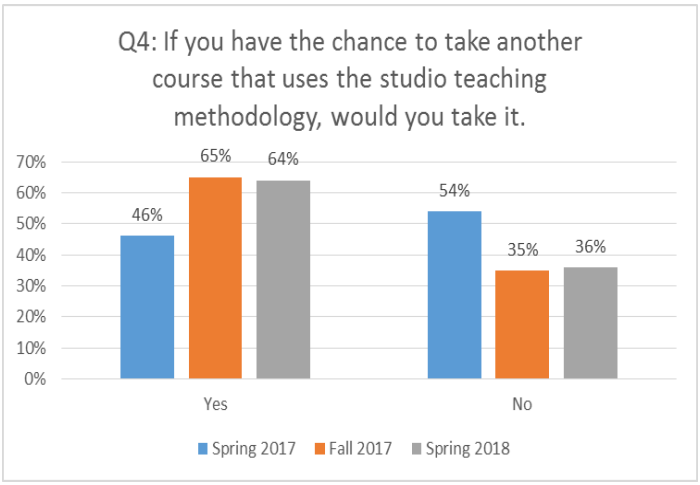

Fig. 7. Students' percentage of wiliness to take other courses using the studio teaching methodology

The only thing that students complained about is the length of each session, as they have to make a lot of efforts during it, which makes them feel tired at the end. Otherwise, some students complained about their teams and said that they would have preferred to choose their teams. However, this is one of the main characteristics of the studio teaching methodology; students need to learn how to work with different kind of people, this would prepare them to real engineering work.

7. CONCLUSION

Studio Teaching for Engineering Programs is a new methodology that has been used by different worldwide universities, using different specifications, but with the same goal; encourage the involvement of student by making them more active during the course. The experiment done of using the studio teaching methodology in an introductory physics course for engineering have shown how effective this approach can be for students, even though they find it long and tiring. In fact, we did not notice a much difference in the distribution of grades except that it had a more normal distribution when compared to grades of students who took the same course with the traditional methodology. We also noticed that students can be lost at the beginning not knowing how to perform well with the new methodology, but have proven that they can do better throughout the semester, as the number of passing students increased from Test 1 to Test 2 using the studio teaching methodology. By this study, we have proven that getting students to work on new activities

and new software help them understand more the concepts they are taught in lectures. Experiments allow them to get their hands on practical things, which help them to be comfortable with any challenging or real life problems. The main output of the studio teaching class is the soft skills that students learn apart from physics concepts, including self-dependence, data analysis, team work and IT (Excel and Tracker) and this has been proven by the students' satisfaction survey, in which many students voted for the studio teaching methodology for physics.

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