Abstract
This paper presents how a new integrated innovative educational approach and shows how it helps students to improve their learning and understanding of the different concepts and thus to get better results in the subject and to achieve the desired outcomes. The approach is applied to core subjects taught in the Bachelor Degree in Chemical Engineering at the Technical University of Madrid. Different methodologies have been integrated and used as: flipped classroom, peer instruction, gamification, augmented reality, case-based learning, design thinking. In order to implement the mentioned methods, the following educational material has been developed: screencasts, concept tests, board games, augmented reality applications and simulations besides the traditional lecturing material (slides and text). Preliminary results show high student motivation, higher participation in class and better academic results.

Keywords: active learning, adaptive learning, flipped classroom, gamification, peer instruction

1. Introduction
Universities appeared more than 900 years ago, since the beginning lecturing has been, and still is in many places, the usual way of teaching. In the last 30 years new theories have appeared challenging the traditional approach. There is a change of paradigm as instruction now is seen as focused on learning and not on teaching and besides in this new paradigm an instructional method that engages students in the learning process seems fundamental. The importance of interest and motivation in education is not new, back in 1913 prof. John Dewey wrote an essay titled “Interest and effort in education” (Dewey, 1913) where he indicated the influence of interest to achieve better results in education. The way our brain and cognitive processes work are still research subjects, everybody has experienced how differently we learn things depending on our interest in them (Renninger and Hidi, 2016, Harackiewicz et al., 2016, Shin et al., 2019). Active learning can be defined as “instructional activities involving students in doing things and thinking about what they are doing” (Bonwell, 1991) or as “any instructional method that engages students in the learning process” (Prince, 2004). Previous approaches related to the implementation of active learning can be found in (Wilson and Jennings, 2000; Belcher, 2003; Beichner et al., 2007 or Nelson et al., 2019). The approach presented in this paper is closer to the format presented in Pirker et al. (2014).
2. Motivational Active Learning Integrated Approach

2.1. Motivation

Chemical Engineering is a Bachelor’s Degree that includes the design of industrial processes that turn raw materials into valuable products. Moreover, many of the processes within chemical engineering involve complex operations, which should be considered in order to formulate more adequate designs. It needs a thorough understanding of how the different unit operations are included in a chemical plant and what are the implications of changing operation variables in a process. All these concepts are difficult to grasp for many students and they stay in a quite passive attitude, so a different innovative approach has been implemented in order to increase students’ understanding, motivation and participation. The focus is on learning (instead of teaching) and motivating (or engaging) the students on the different subjects.

2.2. Objectives

The main objective is to foster a student-centred learning methodology. A motivating active learning integrated approach that allows a personalized evolution of the student. This objective is decomposed in the following subobjectives:

- Implement a new student-centred learning methodology
- Increase student motivation and participation in class
- Increase the understanding of the more complex concepts by the students
- Increase student results and the outcomes acquired
- Increase student acquisition of transversal competences
- Increase student awareness of the importance of sustainability
- Increase student soft skills capabilities: creativity, leadership, communication and teamwork
- Make the students aware of the importance of self-learning

The purpose of this work is to promote an active learning based on the joint use of several methodologies (flipped classroom, peer instruction, gamification, augmented reality, case-based learning, design thinking) in several subjects of the Chemical Engineering Degree at the Technical University of Madrid. Specifically, this approach has already been implemented in Process Control (4th course), Process and Product Design (4th course), Chemical Reactors (3rd course) and Chemical Engineering Lab III. Of course, not all the objectives are worked on with the same intensity in all the mentioned subjects.

2.3. Methodologies

Following the used methodologies are presented. Their use in the different subjects is commented on section 3.

2.3.1 Flipped Classroom

In this methodology educational material is provided to the students in advance of the lecture. The student has to learn by himself the contents of the topic that will be further discussed in class. The material developed has been mainly educational videos/screencasts. It has been complemented with traditional material such as slides or texts. One of the important benefits of this methodology is that it allows to spend more time in class for specific, more complex, parts of a topic. In order to decide what concepts are more difficult, flipped classroom must be combined with other methodologies like
peer instruction. In this way, the students are the ones who establish what is being harder
to understand instead of the teacher

2.3.2 Adaptive learning & Peer Instructions
Adaptive learning and peer instruction are implemented using concepts tests. These tests
are presented at the beginning of the class. Individual comprehension can be evaluated in
this way. After the test, the students gather in small groups and think about the more
difficult topics, then the tests are run again and finally the teacher explains the topic in
detail.

2.3.3 Gamification
The purpose of gamification is to improve the classroom experience, it helps to motivate
the students and what they learn is fixed more deeply (and thus more easily recalled
afterwards). This is a very valuable methodology, but it has to be used carefully, as there
is a risk that the students focus more on the “game” than on the learning process.

2.3.4 Team work & peer learning
In peer learning the students explain things to each other without the teacher being
involved. Student learn from their peers. This is implemented mainly dividing the class
into small groups and then an activity is presented to them. It can be a problem that solved
by each group or a laboratory practice. In some cases, the solution of the problem (or the
results of the practice) is handed to other group which corrects and evaluates it.

2.3.5 Learning by doing
When using learning by doing (meaning that the students not only listen and watch), the
student effectively does something that allows him to understand the theory or validate
it. This methodology is very efficient as the students retain more easily what they learn.

2.3.6 Traditional teaching
In this methodology the approach is lecturing using slides to explain, usually, theory. In
order to promote class participation and involvement, some blanks are in the presentation
and some quizzes are also inserted where the students see the results in real time.

2.3.7 Case-based reasoning, Design thinking.
Open problems are presented to the students (mainly in the process & product design
subject). These problems are very focused on sustainability and on working the SDGs
(Sustainable Development Goals)

2.3.8 Augmented reality
Finally, the last methodology used is augmented reality. Different videos and guides have
been prepared for the equipment used in the Laboratories. The students know how they
work and besides they have access to the description of the task they have to follow.
Auresma software has been used for Augmented reality.

It is important to stress that the main idea is to use several methodologies in a subject, in
this way the student is more alert, motivated and keen to learn and fix what they learn. In
order to implement the mentioned methods, the following material has been developed:
screencasts, concept tests, trivia contest, simulations, augmented reality material and
case-based studies besides the traditional lecturing material (slides and text). Fig.1 shows
the methodologies used to motivate and engage the students.
3. Application to Chemical Engineering

3.1. Process Control

In this subject all the methodologies have been applied but case-based reasoning. This was the first subject where this integrated approach was implemented. The following material has been developed: more than 50 videos/screencasts (using ActivePresenter software), more than 300 questions for concept tests (using Classtime software), a board game (called Triviachis, a mix of a quiz game and a dice game) where the students divided in groups play between them in a tournament mode, augmented reality for use in the instrumentation lab and finally an Operator Training Simulator (implemented in Excel and using Aspen Dynamics) for learning by doing.

3.2. Process and Product Design

In this subject also many methodologies have been used and implemented. It is important to remark that this one has worked intensively the objective of sustainability. Fig. 2 shows how the different methodologies are related and have been approached in this subject. Educational material is comprised of more than 40 videos (mainly devoted to Aspen Plus), several Case-based reasoning scenarios focused more on creativity, communication and team work. The gamification has been implemented in a role-type game, where students play different roles (client, engineering company, contractors, etc).

Figure 1. Integrated methodologies used to foster student motivation and learning.

Figure 2. Methodologies and soft-skills applied in process and product design having sustainability as the leit motiv.
3.3. Chemical Reactors

This subject has also developed a lot of educational material related mainly to flipped classroom (using Active presenter), peer instruction with the creation of more than 150 tests (using Kahoot and Mentimeter software).

3.4. Chemical Engineering Lab III

Aurasma has been used to create real and virtual images and videos of the different equipment to be used in the Lab, like batch distillation, absorption or chemical reactors.

Table 1 summarizes the different techniques that have integrated in the subjects presented in this work.

<table>
<thead>
<tr>
<th>Subject</th>
<th>Flipped classroom</th>
<th>Adaptive Learning &amp; Peer Instructions</th>
<th>Gamification</th>
<th>Teamwork &amp; peer learning</th>
<th>Learning by doing</th>
<th>Case-based reasoning</th>
<th>Design thinking</th>
<th>Augmented reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process control</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td>X</td>
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<tr>
<td>Process &amp; Product Design</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Chemical Reactors</td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
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<tr>
<td>Chemical Eng. Lab</td>
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<td>X</td>
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</tbody>
</table>

4. Results

The implementation of this integrated approach in core subjects of Chemical Engineering is being very well accepted by the students. Although the application is very recent (3 years in process control, 2 years in the other subjects) there are some indicators to quantify in some manner the results achieved. Table 2 shows the academic results obtained in Process Control. The methodology was applied in 2017, the results (average and number of students that passed the subject) show a significant improvement, although more important than the marks are the students opinion about this new way of learning. In Chemical Reactors a survey was conducted (with Likert levels), the results obtained were:

- Do you think that this methodology facilitates learning? 70% answered yes
- Are you satisfied with this methodology? 75.1% are satisfied or very satisfied
- Are you satisfied with the educational material (quality, contents, usefulness)? More than 90% said they were satisfied or very satisfied.

Table 2. Process control academic results since 2015

<table>
<thead>
<tr>
<th>Year</th>
<th>Average grade (out of 10)</th>
<th>% Passed</th>
<th># Students</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018</td>
<td>7.3</td>
<td>83</td>
<td>43</td>
</tr>
<tr>
<td>2017</td>
<td>7.4</td>
<td>91</td>
<td>54</td>
</tr>
<tr>
<td>2016</td>
<td>6.8</td>
<td>67</td>
<td>39</td>
</tr>
<tr>
<td>2015</td>
<td>5.6</td>
<td>72</td>
<td>43</td>
</tr>
</tbody>
</table>

The results are only of one-two years measurements so they have to be taken with caution but they seem quite promising and they show that this is the way to proceed.
5. Conclusions

New innovative education methodologies are not just a hype but a true improvement over traditional ones. Different methodologies have been presented in this work. All and every of them are valuable and can be used to improve the learning experience. But the main goal we seek is to engage our students in the learning process, to motivate them, and for that what best fits for a new way of teaching or more precisely a new way of learning is to integrate different methodologies (flipped classroom, peer instruction, gamification, augmented reality, case-based learning, design thinking). The main drawback is the amount of time and resources needed to develop all the material. Although this effort is compensated over time (as most of the material is reused) it would be more than desirable to have a shared platform in internet where teachers from over the world can share chunks of knowledge that others can reuse and take advantage of. To conclude, the use of motivational active learning will make the students more motivated, participative and more interested in what they are learning and thus enhancing their performance.

References


Belcher, J.W., 2003. Improving Student Understanding with TEAL. MIT News. 16(2), 7–11


