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Motivational active learning: An integrated approach to teaching and learning process control

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ABSTRACT

Process Control is a course that needs a thorough understanding of how the different unit operations work and what are the implications of changing operation variables in a process. This paper presents how education innovation can help 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 Process Control Course is taught in the Bachelor Degree in Chemical Engineering at the Technical University of Madrid. Different methodologies have been integrated and used in the course as: flipped classroom, peer instruction or gamification. In order to implement the mentioned methods, the following material has been developed: screencasts, concept tests, trivia contest and simulations besides the traditional lecturing material (slides and text). First year results show high student motivation, higher participation in class and better results (marks) in the subject.

1. Introduction

Lecturing has been the usual way of instruction since universities were founded more than 900 years ago. There are theories emphasizing the need of changing this approach to allow the students develop their understanding. Active learning, understood as an instructional method that engages students in the learning process, seems fundamental in the new teaching/learning paradigm which is student-centered. Freeman et al. (2014), did a meta-analysis study where they demonstrate that active learning increases performance in STEM (Science, Technology, Engineering and Mathematics) disciplines. Active learning is not new, several formats have been developed along the past two decades like: Interactive Engagement (Hake, 1998), Studio Courses (Wilson and Jennings, 2000), Student-Centered Activities for Large Enrollment for Undergraduate (Scale-Up) Beichner et al. (2007) or Technology-Enabled Active Learning (TEAL) developed by John Belcher at MIT (Belcher, 2003). All of them have reported better student results than the traditional approach. Our methodology is closer to the Motivational Active Learning format presented in Pirker et al. (2014). New education methodologies exist to tackle this new way of teaching.

Basically, active learning seeks to have interested and motivated students. The importance of interest in education is not new, Columbia University professor John Dewey indicated it in his essay "Interest and effort in education" more than 100 years ago, Dewey (1913). The role of interest in education and its influence in getting better academic achievement is still a research field as it is shown in the works of Harackiewicz and Hulleman (2010), Silvia (2006) or Renninger and Hidi (2016).

To apply active learning, different techniques can be used, one of the most used, Lucke and Dunn (2017), is flipped (or inverted) classroom. It can be defined, as stated by Lage et al. (2000): "Inverting the classroom means that events that have traditionally taken place inside the classroom now take place outside the classroom and vice versa". This definition is somehow limited and we prefer the definition given by Bishop and Verleger (2013): "[. . .] is a new pedagogical method, which employs asynchronous video lectures and practice problems as homework, and active, group-based problem solving activities in the classroom. It represents a unique combination of learning theories [. . .]". Another methodology that is gaining acceptance in education is game-based learning or gamification. It has been recognized and used in different domains like marketing, politics, business, IT, health and fitness, etc (Hiltbrand and Burke, 2011, Burke, 2012). Several studies like Bodnar and Clark (2014), Dicheva et al. (2015), Barna and Fodor (2017) explore the impact of gamification in students at higher education getting positive and promising results. Peer instruction (PI) is an active learning technique that has been used for the last 25 years in Physics Education,

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Bundle et al. (2017), and it has been more recently incorporated in other fields of education. In Vickrey et al. (2015), they review research in several disciplines like physics, biology, chemistry and computer science regarding the effectiveness of PI, they conclude that this pedagogy overwhelmingly improves students' ability to solve conceptual and quantitative problems. Peer learning has also been recognized as a useful educational strategy, students learn explaining their ideas to others, is can be described as a moving beyond independent to interdependent learning (Boud et al., 2001). Almost every learning methodology can be included in the active learning approach, in this work the abovementioned techniques have been used along more traditional ones (as learning by doing, team work or traditional teaching).

This paper is focused on using the abovementioned techniques to implement active learning in the subject Process Control. Some previous experiences can be found in the literature related to applying the flipped classroom to this subject, like in Marlin (2017) but it is basically only based on this methodology. Our approach, although applying the flipped classroom technique, extends this method with the use of other learning experiences as gamification, peer instruction, peer learning or learning by doing.

2. The active learning integrated approach setup

2.1. The motivation

How to select the best control structure for a distillation column or a reactor? How many degrees of freedom does a process have for control? How to develop a P&I (piping and instrumentation) diagram starting with a process flowsheet from scratch? These questions are addressed and explained in the course Process Control. The course is oriented to develop and understand the control strategies of the different equipment found in the process industry (heat exchangers, reactors, distillation columns, absorbers, furnaces, compressors, etc.). Besides, students have to know how to build the plantwide control strategy for a process based on the flowsheet and a brief description. This means that students need a thorough understanding of how the operations to be controlled work and the implications of all the units in a process. These relations and concepts are difficult to grasp for many students and the classical teaching methodology where they stay in a quite passive attitude does not provide good results. This is the motivation to implement a different innovative approach, to get an improvement in the students understanding and participation. The focus is on learning (not teaching) and engaging (or interesting) the students on the subject.

2.2. The objective

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

- Implement a new student centred learning methodology
- Increase student motivation, interest in the subject
- Increase the understanding of the more complex concepts by the students
- Improve student results and the outcomes acquired
- Make the students aware of the importance of self-learning

2.3. Educational material

The following material has been developed to implement the active learning integrated approach.

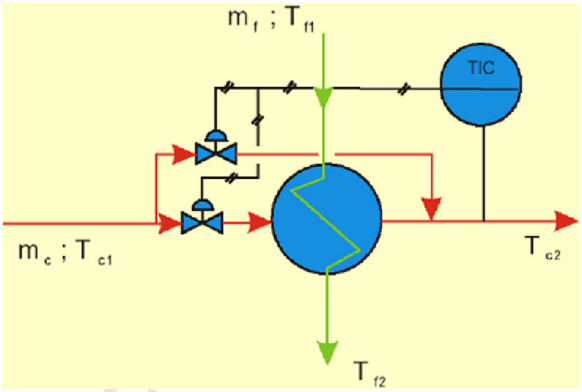

Fig. 1. Concept test example for the topic Heat Exchangers.

2.3.1. Concept tests

These correspond to the contents of the different topics of the course. They are designed to check the students understanding. They are multiple choice questions, like the one shown in Fig. 1. The course has 10 topics and around 30 questions have been created for each topic. These questions are used in the flipped classroom and gamification methodologies.

Next figure shows a control scheme where the valves:

a) Must have the same pressure drop
b) One must have greater pressure drop than the other
c) Both must be fail open or fail close
d) One must be fail open and the other fail close
e) a) and c) are correct
f) b) and d) are correct

2.3.2. Gamification material

A board game (*Triviachis*) has been designed, it is a combination of a trivia quiz game and a Spanish board game (called Parchis) that uses a board and dice. Fig. 2 shows the board and questions. Solved P&Is with missing information and errors have been generated to be used as gamification and peer learning material.

2.3.3. Screencasts

Educational videos have been recorded for every topic (using *ActivePresenter*– atomisystems.com/activepresenter). The videos have a teacher narrative to explain the main concepts of the lessons and they have a lecture-like format. This is a very valuable material as it allows the student to assimilate the concepts prior to the classroom and they are available for reviewing as needed depending on the learning evolution of the student. Videos solving problems (basically developing the control structure of a process) have also been recorded. Fig. 3. shows a snapshot of the explanation of Valve Position Control. The recorded videos are of short duration (around 5 minutes). These are the main material for flipping the classroom.

2.3.4. Slides & text

This is the traditional material that was previously developed and used in past courses. The slides of every topic are available before the lecture although they may have some missing information so the teacher can ask questions about it in class to promote participation (after the lecture, the complete slides are provided). Along with the slides, a textbook as well as additional reference material is provided. This is used for the flipped classroom and traditional teaching methodologies.

2.3.5. Simulations

An operator training simulator (OTS) has also been developed. It has a HMI (Human Machine Interface) as shown in Fig. 4. It allows

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