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Active Learning Experiences in Engineering Education

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Active learning is a broad concept that is used to refer to educational approaches designed to make students participate rather than passively listen, "anything course-related that all students in a class session are called upon to do other than simply watching, listening and taking notes" (p.2) [1]. To this aim, a single methodology or a combination of techniques may be the best suitable option for a particular course and learning objectives [2; 3]. The students are actively or experientially involved in the learning process which leads to "greater student responsibility in the learning process, greater motivation and a more satisfactory final result for all those involved in the process" (p.9) [4].

Effective implementation of active learning requires teacher preparation on pedagogical perspectives [5; 6; 7; 8]. There are many possible forms of active learning, including: problem-based learning, project-based learning, challenge-based learning, service learning, gamification, and game-based learning. Flipped teaching approaches are also related to active learning because the passive part of the teaching process is carried out at home and the classroom time is oriented to activities rather than lecturing, sometimes connected by intermediate micro activities related to both classroom and home lessons which is the case of Micro Flipped Teaching [9].

Project-based Learning (PBL) is an instructional approach that adapts curriculum concepts and objectives through a project, representing then a "key strategy for creating independent thinkers and learners" (p.39) [10]. Active learning through project-based learning experiences show that "high success rate in the learning outcomes allows to state that the students acquire the instrumental and systemic competences (...) as well as interpersonal skills such as collaborative work." (p. 8) [11], important for engineering processes [12] like software development and relevant for increased motivation of engineering students [13].

For this special issue, we have clustered the selected eleven papers (out of the fifty-seven received contributions) around five active learning experiences: project-based learning (PBL), flip classroom, collaborative and cooperative work, active learning in pre-college and graduate courses, and faculty development on active learning.

Project-based learning

In 2017, IJEE published an issue on The Learner in Engineering Education that included several outstanding articles on PBL, where it stands for project-based learning as well as problem-based learning [14]. The acronym PBL denoted problem-based learning since 60's [15; 16]. However, over the last ten years, that acronym has been used for both project-based learning and problem-based learning to unify the learning principles [17]. David and Marshall's paper "Epistemological Tension in Project-Based Learning: Fabricated and Propagated Knowledge through Practical and Formal Lenses" aims to characterize students' epistemological beliefs around a PBL civil engineering course. This is a qualitative study that collected data from in-class observations, group interviews (mid-point and end of course) and a survey results (beginning and end of course) of 32 students enrolled in a project-based introductory civil engineering course. It is promising that the identified initial epistemological tensions could be resolve by the end of the semester. Moreover, students found value in active learning and recognized their learning outcomes. Llorca et al. paper "Learning Room Acoustics by Design: A Project-Based Experience" and

Zhang, Xie and Li paper "Project Based Learning with Implementation Planning for Student Engagement in BIM Classes" present a teaching implementation and a framework process design of Building Information Modeling (BIM) project execution planning (PEP) for capstone with the integration of PBL and real-world project information. Innovation consisted on the integration of project-based learning in a BIM-PEP framework to broaden architecture students' understanding of acoustic problems. ICT support is also of concern when introducing active and technology-based education [18; 19], for example, Ferrandiz et al. present their finding when a new ICT tool is introduced in an active learning environment course. In particular, the authors focus on the performance consequences depending on the introduction design. This mixed methodology study used quantitative data to assess students' performance and qualitative data to gather the why of those results. Authors conclude that the earlier integration of PBL and BIM students gain a better understanding of the concepts involved.

Flipped classroom

Active methodologies like those proposed by Flip Teaching promote peer to peer learning. Due to diversity of students' knowledge and expertise, dialogic interactions between them fosters a deep concept understanding, linkage and contribution to collective intelligence establishment between students and teachers [20; 21]. However, it has been reported that MOOC model may have some limitations and constraints that limit its potential [22]. In this section, Alario-Hoyos paper entitle "Redesigning a Freshman Engineering Course to Promote Active Learning by Flipping the Classroom through the Reuse of MOOCs" uses materials produced for a MOOC for students to prepare outside the classroom (before class) to devote in-class time to discussion and deeper understanding of the concepts, as in a flipped classroom strategy. In this way, students prepare before class to devote time for hands-on and productive peer interactions during class, while for the instructor, receive information about concepts or ideas that need to be revisited or discussed further in the classroom.

An interesting variation of flipped classroom [23; 24] incorporates activities outside of the classroom that require application of knowledge that has not been discussed in the classroom yet, that is, team members collaborate in- and out- side of the classroom to continue reflecting, constructing knowledge and making decisions in a collective way. Fidalgo Blanco et al. paper "Enhancing the main characteristics of active methodologies: a case with Micro Flip Teaching and Teamwork" propose a model for teamwork that combines Flip teaching, cooperative methodology to follow the acquisition of the teamwork competency and a social network for the virtual layer.

Collaborative and cooperative work

Cooperative and collaborative work has been implemented and well documented for several decades showing that teamwork is more effective that competition and promotes an environment that enhances intrapersonal skills [25; 26]. There is research about cooperative and collaborative learning that uses technology to enhance learning [27], classroom seating to promote collaboration [28, 29] facilitate the and formative assessment [30]. The two papers discussed here present a comparison between two teaching strategies or students' cooperation through two technologies. Pastor et al. paper Learning in Engineering through Design, Construction, Analysis and Experimentation moves from a traditional classroom to a CHA-PBL (cooperative hands-on active problem-based learning) in two consecutive courses Continuum Mechanics and Strength of Materials of the third academic year of an engineering bachelor's degree. The students have already covered the theoretical basis that allow them to solve projects that combine practice, theory, simulation and experimentation in accordance to the Educating the Engineer of 2020 initiative.

The advantages of mobile devices and its applications in education [31; 32; 33] stress out the level of penetration of this technology in the classroom. Pereira´s paper "Motivating users to online participation. A practice-based comparison between Moodle Forums and Telegram groups" compares and contrast student's participation in a Moodle forum versus a Telegram group to foster cooperation in the development and solution of problems. The author states that it is important to know the advantages and disadvantages of each tool to better select when, how, and for what they can be better used.

Active learning in pre-college and graduate courses

Other topic of interest is improving students' interest and development in engineering areas, before enrolling an engineering undergraduate program and after completeness of their bachelor's degree [34; 35]. The advantages of mentoring [36; 37] combines with active learning to improve student's attrition. On one hand, Bosman et al. present a mentoring program for minority pre-undergraduate students that uses active learning techniques and participatory action research (photovoice and photo-elicitation) to improve students communication skills and increase success rate of underrepresented students (improve resiliency). On the other, Baekgaard and Lystbaek propose a framework for active learning about research in engineering education that they have implemented in a post-graduate course. This framework characterizes research design in four elements: Purpose, Research, Outcomes and Evaluation (PROE), which provides a scheme for interrelation, alignment, interaction and adjustment of research processes. These papers thus show the wide range of understanding where active learning approaches are being studied and evidenced.

Faculty development in active learning

The final covered topic is about a faculty development program in active learning using a combination of active learning techniques [38; 39] as a complement for the introduction of active learning methodologies [40; 41]. Dominguez et al. paper "Professional Development Program to Promote Active Learning in an Engineering Classroom" describes the faculty development program implemented in the School of Engineering at a private university in Chile and shares some evidence of the change in perception about teaching from the participant faculty and about learning from their students. This three-semester long program combine different individual and group activities, short and long active learning activities implementations from the participants, follow-up and observations from the instructors, uses reflection as a self-regulation tool and aims to build a community of practice to transform the culture of teaching and learning.

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