ACTIVE LEARNING IN ENGINEERING EDUCATION: EXPERIENCES IN ASIA AND EUROPE

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Abstract

Active learning aims to build knowledge and skills by doing going beyond traditional, passive classroom instruction. The advantages of active learning are many. It facilitates the retention of new knowledge. It goes beyond the goals of memorizing and understanding concepts, building student capacity on analyzing new information, applying it in practice, and explaining it to others. It builds high order thinking skills that are transferable to the real world.

Despite the advantages of active learning it, is not widely applied in practice. This is particularly the case in South East Asian countries. Lack of or inadequacy of physical infrastructures is a significant obstacle. Even when labs do exist, the equipment is outdated and limited in the software that it can support. There is a lack of openly available software applications that can be deployed in educational contexts as complementary learning tools. Limited instructor training on how to exploit IT and to combine it with emerging learning pedagogies further discourages the deployment of active approaches in the classroom.

This work presents an educational intervention that aims to introduce active learning as a strategic educational approach in engineering higher education in Europe and Asia. The educational intervention has a vertical design and aims to address the obstacles that inhibit the wide spread adoption of active learning. The intervention includes the development of digital active learning labs at 12 universities in Asian countries. It further involves the development of a digital active learning platform that acts as a repository of active learning activities based on digital applications such as learning games and simulations accompanied with guidelines for educators on how to best integrate them in the classroom. And finally, it includes instructor training on active learning concepts as well as the use of the physical labs in educational contexts. Instructor training takes place at the individual universities through face-to-face training sessions and through on-line webinars. Experiences from the deployment of the proposed intervention demonstrate that when adequately supported through infrastructure and training the introduction of digitally supported active learning practices contributes to the development of industry demanded skills among students while it builds instructor capacity on innovative learning design.

Keywords: problem based learning, active learning, serious games, simulations.

1 INTRODUCTION

Active learning aims to build knowledge and skills by doing going beyond traditional, passive classroom instruction. The advantages of active learning are many. It facilitates the retention of new knowledge. It goes beyond the goals of memorizing and understanding concepts, building student capacity on analyzing new information, applying it in practice, and explaining it to others. It builds high order thinking skills that are transferable to the real world.

Despite the advantages of active learning it, is not widely applied in practice. This is particularly the case in South East Asian countries. Lack of or inadequacy of physical infrastructures is a significant obstacle. Even when labs do exist the equipment is outdated and limited in the software that it can support. Labs often include only computers as workstations and not emerging IT such as VR, robotics, and more. There is a lack of openly available software applications that can be deployed in educational contexts as complementary learning tools. Lack of instructor training on how to exploit IT and to combine it with emerging learning pedagogies further discourages the deployment of active approaches in the classroom.

This work presents an educational intervention that aims to introduce active learning as a strategic educational approach in engineering higher education in Europe and Asia. The educational intervention has a vertical design and aims to address the obstacles that inhibit the wide spread adoption of active learning. The intervention is introduced in universities in Malaysia, Vietnam, Cambodia, Pakistan, Nepal, Greece, Bulgaria, Portugal, Estonia, and the UK.

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The work presented is being implemented in the context of Capacity Building in Higher Education project ALIEN: Active Learning in Engineering Education [1] funded by the Erasmus+ program of the European Commission.

2 AN ACTIVE LEARNING INTERVENTION FOR ENGINEERING EDUCATION

Project ALIEN aims to introduce active learning as a strategic pedagogical approach in engineering higher education. Active learning is a learning approach in which students learn with means that go beyond listening [3]; students build knowledge by writing, discussing, or engaging in solving problems [4]. Active learning can be deployed both in and out of the classroom through activities that may include role playing, exploration, collaboration, visiting sites of interests, solving problems, and more. It can be applied in diverse ways; however some common characteristics of active learning approaches include an emphasis on critical thinking, placing the responsibility of learning on students, participating in open ended activities, participating in learning design, influencing the content and pace of learning, and more.

Active learning offers significant advantages in terms of promoting positive student attitudes towards learning, internal motivation, supporting lifelong learning, encouraging students to set their own learning goals, and emphasizing understanding as opposed to data, which reflects a passive transmission of knowledge [5], [6]. Active learning promotes higher order thinking skills. Bloom’s taxonomy presents a pyramid of learning in which the first achievement in the learning process is remembering information, which is followed by the more evolved process of understanding. More evolved steps in Bloom’s pyramid include the higher order thinking skills of applying new knowledge, analyzing, evaluating, and creating new knowledge by synthesizing existing. Active learning contributes to the development of the higher skills in the hierarchy through activities that encourage learners to build knowledge by doing and to use knowledge in a manner that simulates real world processes. In this respect, active learning connects learning to real life and helps students transfer knowledge from the academic environment to the world of work [7].

Active learning has applications in STEM education, by allowing students through to better understand concepts through direct engagement with educational principles. However, it is applicable in wider and diverse sectors, including medicine, law, social sciences, and entrepreneurship.

In engineering education, active learning is particularly relevant as it helps build skills that are relevant in industry through learning activities that are inspired by the real world and motivate students to introduce solutions to actual challenges in industry and society. Active learning helps build problem solving capacity by encouraging students to combine knowledge from diverse fields to address complex challenges that are based on real world needs and are often open ended. It further builds soft, transversal skills such as critical thinking [8], fosters exploration that promotes independent learning, encourages group collaboration and presentation of solutions [9]. Active learning offers avenues for modernizing engineering higher education, bridging the skills gap between industry and academia. It helps build active citizens by empowering students to effectively address modern challenges.

This work introduces a vertical approach for promoting the uptake of active learning in engineering education. The approach addresses challenges that currently inhibit the adoption of active learning, which include:

- Lack of physical infrastructures in the form of labs.
- Unavailability of open digital educational resources for active learning in engineering.
- Need for keeping instructor skills up to date in relation to emerging technology-supported pedagogies.

The learning intervention addresses all three tangents aiming to facilitate the wider deployment of active learning in engineering.

2.1 Physical labs

Physical labs have been developed at 12 universities in Malaysia, Vietnam, Nepal, Cambodia, and Pakistan. The labs aim to make available to students infrastructure that will allow them to work in groups towards solving non-trivial engineering problems the solution to which requires the combination of diverse knowledge. The labs provide students with rich collaboration and exploration capabilities through computers, robotics equipment including Arduino ® and Rasberry Pi ®, smart TVs as a means for sharing information in class, digital whiteboards, VR equipment and supporting software, digital pads, 3D printers, and more. The labs are setup in a manner that encourages student collaboration in round stations at which students work on joint projects. The labs are being used in broad courses that range from human computer interaction to software engineering and more.

2.2 A repository of active learning simulations and serious games

A repository of digital tools that can support active learning activities allows students and instructors to access engineering content. The platform introduces services for educators, including the structuring and publishing of learning challenges that deploy digital tools in the forms of simulations, serious games, or applications. It further offers services for students, including the access to educational content. For all participants, the platform offers collaboration services in the form of discussions on topics related to active learning, such as problem-based learning methodologies and tools, active learning and software engineering, gamification in active learning, and AI and active learning. Over 120 learning activities that are based on digital content have been published in several languages with instructions for educators on how to best use them in the classroom to enrich active learning activities. The activities cover diverse topics including programming, network design, software engineering, electronics, digital game design, automatic control systems, security engineering, lighting, pollution modelling, mathematics and statistics, thermodynamics, structural analysis, and a lot more. The following picture shows a screenshot of the digital learning platform.

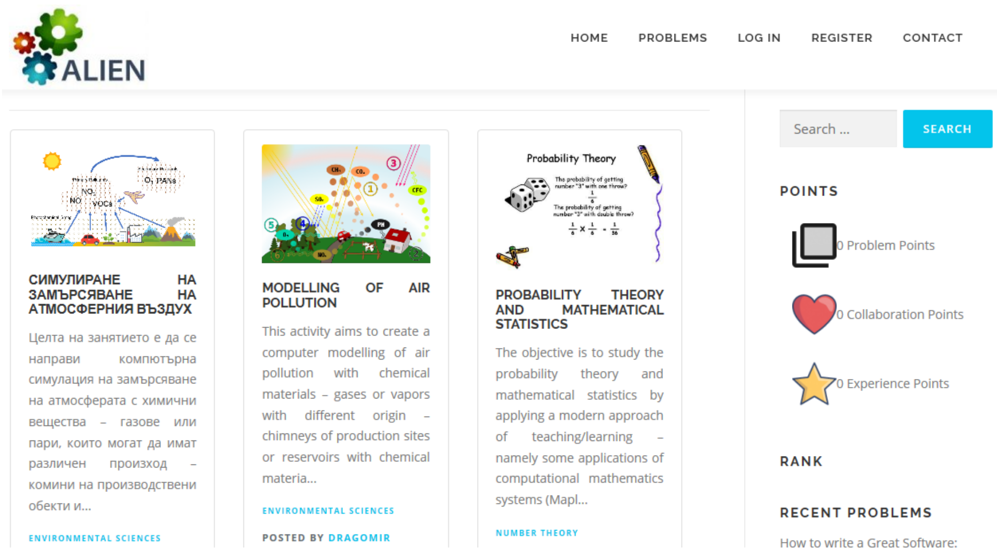

Figure 1. The ALIEN digital repository of engineering active learning content.

2.3 Instructor training

Instructor training sessions take place in an on-going manner at all partner sites. The process aims to build the skills of educators on applying emerging active learning methodologies by understanding the benefits of the approach as well as issues related to its practical application in the classroom. In addition, educators are trained on how to maximize the positive impact from the deployment of the physical labs in educational contexts. They are further trained on using the digital learning repository structured educational activities that take advantage of simulations and serious games to enrich interaction and exploration in the classroom. Educators learn how to publish structured educational content and how to lead discussions of students and peers in the platform forums. In addition to educators, training targets administrative and technical staff that supports the learning process. The idea is that migrating to an innovative learning paradigm, such as active learning, requires the training of all staff in an educational organization. Instructor training is a continuous process, with at least 4 to 5 events being planned at each partner site in Europe and Asia. It takes place mostly through face-to-face meetings; on-line meetings and international webinars are also organized.

3 PRELIMINARY CLASSROOM EXPERIENCES

The proposed learning intervention is currently being applied in practice at 17 universities in Greece, Portugal, UK, Estonia, Bulgaria, Malaysia, Vietnam, Nepal, Cambodia, and Pakistan. Deployment involves both the use of the physical labs by students as well as the digital learning services as a source of active learning educational content. Following are some preliminary results.

3.1 Results in Greece

In Greece, as in all European countries involved in this initiative, existing physical labs are being used. No additional labs have been developed. Piloting of the learning intervention involves the implementation of active learning activities in the labs using educational content from the digital learning repository. The services are used at the Department of Electrical and Computer Engineering of the University of Thessaly. Active learning takes diverse forms as it is adapted to the needs of independent courses. The method is widely used in the department. Examples of courses in which it is deployed include Technology in Education, which is an elective in the 3rd, 4th, and 5th year of studies and enrols approximately 140 students each year. Students apply active learning by exploring and presenting ICT-based technologies that offer advantages in learning and skill development of diverse groups. Technologies involved include the web, MOOCs, mobile learning, serious games, robotics, learning analytics, educational repositories, collaboration spaces, and more. Learning areas are broad and range from STEM education to languages, critical skill building, engineering, special education, and more. Another example in which active learning is being deployed is in circuit analysis, an obligatory 1st year course that enrols 180 students who build hands-on electrical circuits that meet predefined specifications. The reaction of the students towards active learning is very positive. This is no surprise in an engineering environment, in which students are eager to explore concepts in a hands-on manner. Active learning provides students with the opportunity to learn by doing and to be engaged in the learning process in ways that go beyond lecturing and include synthesizing knowledge, experimenting, collaborating, and defending ideas.

Figure 2. Students engaged in active learning at the University of Thessaly, Greece: demonstrating educational robotics (left), exploring an ICT lab at the University of Malaya, Malaysia (center), and building electrical circuits (right).

3.2 Results in Nepal

Active learning is deployed in selected courses of the Department of Electronics and Computer Engineering of Tribhuvan University. However, initiative has been taken to use active learning in other disciplines, such as operation research and management science, multi-criteria design analysis, and more, in the Department of Mechanical Engineering. Active learning is also applied in the Robotics Club at the Pulchowk Campus. The club involves multidisciplinary teams of students and faculty from the departments of Mechanical Engineering, Electronics and Computer Engineering, and Electrical Engineering. Active learning is used for the design and development of robots and automation. Active learning is further deployed at the Centralized Visualization System (CVS) lab. The CVS lab is used in project works of the Knowledge Engineering course offered in the 1st semester of the program. The course typically enrolls 20 students each year. Implementation of active learning involves group work in teams of 4 on the implementation of a knowledge-based system that would be useful at Tribhuvan University. Groups collaborate to retrieve information on the campus intranet, meet with experts in the domain, perform literature reviews, explore existing solutions, and synthesize this knowledge into a proposed service that they present to peers. Active learning provides students with opportunities build experience by working on projects that are inspired by real world challenges, introducing solutions that will benefit their educational community.

3.3 Results in Malaysia

Active learning is being deployed at the University of Malaya in Kuala Lumpur. Through this initiative the university developed the TEALS lab that includes workstations, writable surfaces for students to project ideas, interactive TVs as projectors, a 3D printer, and robotics equipment including Arduino® and Rasberry Pi®. Students develop robotics applications in the context of the Human Computer Interaction course, which engages over 150 students each year. Students work in groups of 6 to 7 towards designing an interactive game. They are further challenged to apply the knowledge built in the course to synthesize solutions to real life challenges using the lab equipment. The results of their work are published in a public digital repository. The lab is also used in courses Analysis and Software testing and Algorithm Design.

Figure 3. Students in the TEALS lab of the University of Malaya.

4 CONCLUSIONS

This paper presented an active learning intervention for engineering higher education. The intervention aims to enrich interaction and engagement in the classroom through a vertical approach that addresses the challenges that discourage the adoption of active learning despite the benefits of the approach in relation to building knowledge that is applicable in industry and promoting its transferability to the real world. The intervention includes the development of physical labs, the design and implementation of a digital repository of active learning content in the form of simulations and serious games, and instructor training for facilitating wide adoption. The intervention is deployed at 17 universities in 10 countries in Europe and Asia with very positive preliminary findings that demonstrate high student engagement and hands on experience building.

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REFERENCES

[1] The ALIEN Project Portal, on-line at http://projectalien.eu

[2] B.S.Bloom, D. R. Krathwohl, B. B. Masia,"Taxonomy of educational objectives: The classification of educational goals", New York, NY: David McKay Company, 1956.

[3] C. Bonwell, Charles, J. Eison, "Active Learning: Creating Excitement in the Classroom. Information Analyses", ERIC Clearinghouse Products (071), pp. 3. ISBN 978-1-878380-08-1. ISSN 0884-0040.

[4] D.C. Berry, M.G. Miller, L.M. Berry, "Effects of Clinical Field-experience Setting on Athletic Training Students' Perceived Percentage of Time Spent on Active Learning", Journal of Athletic Training, Apr-Jun 2004, 29(2), pp. 176-184.

[5] J. Michael, "Where is the Evidence that Active Learning Works?", Journal of Advanced Physiological Education, Dec 2006, 30(4), pp. 159-67.

[6] W.C. McGaghie, S.B. Issenberg, E.R. Cohen, J.H. Barsuk, D.B. Wayne, "Does Simulation-based Medical Education with Deliberate Practice Yield Better Results than Traditional Clinicla Education? A Meta-analytic Comparative Review of Evidence", Academic Medicine, 86(6) pp. 706-711. Doi: 10.1097/ACM.0b013e318217e119 PMID:21512370.

[7] D. Stein, "How a Novice Online Learner Experiences Transactional Distance", Quarterly Review of Distance Education", 10(3), pp. 305-311.

[8] D.A. Kilroy, "Problem-based Learning", Emergency Medicine Journal, 21(4), pp.411-413, doi 10.1136/emj.2003.012435 PMID:15208220.

[9] H. Awang, I. Ramly, "Creative Thinking Skill Approach through Problem-based learning: Pedagogy and Practice in Engineering Classroom", International Journal of Social Sciences, 3, 18–23, 2008.

[10] The ALIEN Project Digital Repository of Engineering Digital Content, on-line at: https://virtual-campus.eu/alien/.