Review of: "Implementing Simulation Software to Develop Virtual Experiments in Undergraduate Chemical Engineering Education"

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The paper and the obtained results are very interesting and promising. The contribution has educational relevance, especially considering the modern discussion around new teaching methodologies in higher education. The presentation is clear, but the paper needs some improvement to be published: the motivation aspects can be more concise, and some details of each example and result discussion can be intensified to demonstrate the outcomes. The paper has a very good expression of the English language, disregarding one or two typing issues.

In order to offer a real scenario of the proposed education resources, the developed examples and test procedures need a few more technical details, and more information should be added.

Virtual labs are very effective in improving several professional skills, especially for chemical engineers. Nevertheless, enhancing real-time experimental activities can improve other specific skills as important as the former ones. The authors should avoid using any kind of prejudice that opposes virtual labs with experimental activities. They are different resources with different benefits that can coexist in higher education. Therefore, some specific phrases that suggest that experimental activities are not beneficial in a chemical engineering course should be rephrased. Even considering all the difficulties inherent to operating and maintaining experimental activities, they will not be replaced by virtual lab experiments. Although the use of virtual labs presents many important and technological benefits, the authors cannot forget that practical experiments can offer cognitive-based learning skills and are important as part of chemical engineering courses. Some of these prejudice examples presented in the present paper are listed below:

- “reducing equipment-related anxiety” is presented as a benefit of the use of virtual lab experiments;
- “Traditional laboratory practices do not have activities to prepare the student to be a future practicing scientist”
- “Conducting the experiments at different temperatures is not practically possible in..” – could be replaced by “..is more difficult to be implemented ...”
- “…complex mixture of terpenes is not feasible as the” – could be replaced with “..implies on using health hazardous safety equipaments and infrastructures hardly feasible in university installations..”

Nevertheless, the idea of ignoring time and risk issues as potential resources in higher education increases the gap between mathematical algorithms and reality. Undergraduate students usually complain about not having enough practical experience during their higher education courses. Although virtual labs have a very good response in training certain skills, if one is to deal with a real process plant professionally, they might have severe difficulties.

The introduction chapter can be reviewed in order to be more concise and avoid repetition. There are several phrases cited as motivation for the utilization of virtual lab resources that are presented more than once along the article. Such as,"..vital tools in higher education to improve the metacognitive skills and research ability of students…"; "…offer an alternative methodology to assess peer learning, teamwork, and the learning experience of students"; "Developed virtual labs will improve the knowledge of the students, enhance their learning skills, motivate them to work in teams, help in peer learning, and assess their self-efficacy…"; "Virtual experiments are useful to visualize critical engineering concepts and analyze the effect of various parameters on an engineering process.";

The use of the developed virtual lab during the COVID-19 crisis was essential to maintain students attached to the university and sustain their higher education investment. Nevertheless, after the crisis situation, the effectiveness of these educational resources as the only option to teach chemical engineering concepts has been continuously discussed. Maybe the authors could be more specific about situations where the developed virtual lab can be used.

The distillation example is very well described and built, due to its connection with a wet lab experiment. Using both activities to compare results obtained in the wet lab experiments and the virtual lab helps students to consolidate the phenomena, including the theoretical concepts.

The authors are correct to affirm that "Simulation is distinguished from a virtual lab". Nevertheless, the UNISIM examples could present some graphs of the possible results (similar to those shown in the process control example). The exact procedure that students have to follow to achieve their goals can be enlightened to present specifically the difference between simulation and virtual lab examples. It is not very clear how the students interact with the virtual labs.

In the Matlab/Simulink example, the virtual lab developed as a complimentary resource to teach process control is very simple and cannot be distinguished from a classic process control simulation problem. The presented interface is very simple, and the values used to set some process parameters (tauf, tau (that in the next paragraph is presented as Taup), and taum) could be justified with the citation of some process examples. The explanation of the process control results (ex. PI controller - oscillatory behavior decreases with higher values of Taui) is easily obtained in literature and could be replaced by more specific results that present how students interact with this example interface or enlighten how the students interact with the virtual lab and not only with the final data results.

Although the percentage of higher grades increased over the years, the percentage of lower grades also increased. Several aspects of the assessment evaluation results should be increasingly discussed. Also, with the Covid-19 crisis (2019-2020), the article is not specific about how exactly classes and activities were offered during this period (exercises were done at home?, which part of the activities was proposed to be solved in groups or individually, how students had access to the software itself, etc.).

The Analysis Assessment Methodology for Learning Outcomes chapter should present the number of samples that were considered. Although percentage values are significant, the number of students that answered the survey and/or had their

AY scores analyzed should be better specified. The results can be improved by offering some detailed information on the scenario where the authors are implementing these educational tools. Therefore, some information about the actual chemical engineering curriculum offered at B.M.S. College of Engineering can be presented. For example, when were the activities offered (were they for freshman or senior students), how many professors supervised these classes, what other activities were offered along with the discipline, what is an AY essay. Considering that the virtual lab examples developed in the present paper are strictly different in their teaching methodology (user interface, presented results, interaction with wet laboratory experiments, different), the survey results could be separated by each example presented in the paper.