STEM Education: Simulation Apps Prepare Students for Life Beyond the Classroom

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Once upon a time, teaching was easy — we had chalk and boards, practice problems, and homework assignments. Not much changed for many decades, regardless of the tools we worked with: pencil, slide-rule, or calculator. Undergraduate engineering curricula used electives and graduate-level courses to address hot topics and the latest must-know skills. Professors lectured (with or without Socratic discussions) and did a lot of derivations.

Our desire and need to improve student learning and better prepare graduates for a successful career led us to explore various pedagogical models such as problem-, project-, and inquiry-based learning (IBL). However, inquiry requires a significant time-investment, both inside and outside the classroom.

And who has time for that within lecture-based courses, where coverage of the material does not allow for much else? How can we increase the quality of undergraduate science, technology, engineering, and mathematics (STEM) education?

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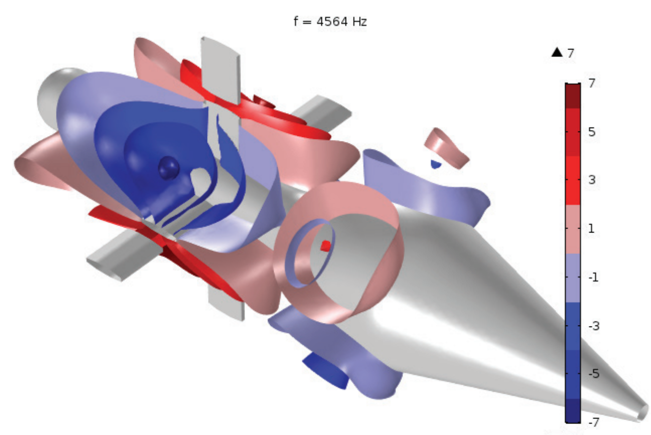
Our approach combines problem- and inquiry-based learning, numerical simulations and apps with the COMSOL Multiphysics® software, and emphasizes the importance of outside-of-class learning supported by effective reference materials and faculty mentoring. We also shifted away from focusing on the standard delivery of material and covered what is crucial for our students' success, which has resulted in more engaged students who, in turn, perform better academically.

At the University of Hartford, we embedded simulation-based design and IBL in two successive junior-year courses: fluid mechanics and heat transfer. Both courses were modified to contain scaffolded and contextualized simulations with application building that develop technical competency in modeling, a deeper understanding of thermofluids concepts by solving realistic technological problems, and writing skills by generating technical reports for each simulation. Apps involve creating a simplified interface that contains the full efficacy of the underlying model without exposing the end user to its complexity. In order to accomplish this, we decided to move away from graded and weighted homework assignments. The mastery of theory and analytical problems is accomplished by in-class discussions and self-study, while the assessment of theoretical knowledge and analytical skills is based on major exams over the semester.

Accreditation requirements and economic restrictions result in undergraduate engineering curricula that typically do not contain computational fluid dynamics (CFD) courses. However, our experience has found that the integration of mathematical modeling, numerical simulation, and visualization techniques profoundly impacted our students' performance inside the classroom and, furthermore, inspired their futures beyond academia.



Pressure isosurfaces in a typical multistream nozzle of a jet engine. Image courtesy of Prof. Ivana Milanovic, University of Hartford, Khairul Zaman and Christopher Miller, NASA Glenn Research Center, "Resonance & Tones in Multi-Stream Nozzle Flows", NASA Report 2017. Undergraduate students Iliana Albion-Poles and Jeffrey Severino are continuing this work supported by the Connecticut Space Grant for Faculty Research.

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