An Immersive Environment for Advanced Learning in Undergraduate Fluid Mechanics [1]

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Background

Fluid Mechanics is a required Engineering Science (ES) course in several engineering disciplines. Like most other ES courses, Fluid Mechanics requires extensive use of calculus. To facilitate progressive understanding, I typically introduce new concepts with the simplest form of the mathematical equations (e.g. no detailed calculus). Subsequent examples motivate and explore advanced mathematical formulations.

In nearly two decades of teaching Fluid Mechanics to undergraduates, I have identified two critical learning barriers:

i. ability to formulate and solve problems requiring use of advanced calculus, and
ii. ability to formulate and solve problems involving multiple fundamental concepts (e.g. concurrent application of mass, momentum and energy balances).

I address these challenges by solving advanced example problems in lectures and recitations. I adopt a Socratic Questioning approach, starting with conceptual questions and then delving into mathematical details. However, we explore only one or two advanced problems per topic due to time limitations.

To further develop advanced problem-solving skills, I assign homework problems flagged as "challenge" problems, along with a sequence of hints or steps. However, I have never been fully satisfied with the results. I believe that supplementing classroom instruction with an immersive learning environment will greatly help students to overcome these learning barriers and develop advanced problem-solving skills.

My motivations are twofold:

i. (i) The proposed learning environment will significantly improve upon mere printed hints, and
ii. (ii) students of this generation respond well to multimedia environments.

Objective

My goal is to develop and implement an immersive environment for self-directed advanced learning in Fluid Mechanics. I envisage a combination of YouTube video and PowerPoint animations to replicate an Interactive Socratic Questioning approach similar to what I employ in lectures and recitations.

Description

The learning environment will take a student through systematic steps for solving advanced problems. Each problem will begin with

- **Stage 1:** video or animations for visualizing the problem.
- **Stage 2:** will involve a series of questions that facilitate a high-level analysis of “cause and effect”. Students will enter answers to questions in animated PowerPoint slides. At the end of this stage, the learning environment will display their analysis and a “correct” analysis for comparison. Additional slides/video will go over examples of common errors in problem analysis.
- **Stage 3**: students will be asked to develop the overall mathematical formulation and steps needed to solve the problem. Hints may be obtained interactively. At the end of this stage, they will compare their formulation with a “correct” template to verify equivalence.
- **Stage 4**: mathematically challenging steps will be addressed with hints (e.g. “what you now have is a first-order ordinary differential equation for the velocity – recall that to solve differential equations of this type, you need to...”) provided either in animated slides or videos of my handwritten work with a vocal narrative.
- **Stage 5**: students will complete the calculations and write up their solution. After grading, I will post video solutions, with detailed vocal explanation accompanying each step. My eventual goal is to develop content within the immersive environment that will facilitate about two hours of advanced study and learning per week outside of the classroom. Students will be allowed to study and work in groups of three. I will replace some of the routine homework problems with these advanced problems. Since individual chapters in the course are covered over 2-4 weeks, routine homework assignments in the later weeks of each chapter will build upon problems from the immersive environment in previous weeks.

Assessment

I will perform experiments by using/withholding learning modules for different topics and collect the following data to evaluate the impact of the learning environment: (i) compare performance and student difficulties (quantified by number of students visiting office hours) on advanced problems assigned outside the learning environment – between topics for which the environment was used/withheld in previous weeks; (ii) compare performance (overall and on advanced problems) in mid-term and final examinations between topics for which learning modules were used/withheld. Since the project has a 2-year duration, there will be an opportunity to use a specific module in one year and withhold it in the other year, to further evaluate its impact. The groups of students in the two different years likely represent statistically similar populations.

Future Work

I will continue to refine the learning environment in subsequent years and submit a journal paper based on its implementation and evaluation, and potential applicability to other ES courses.

Groups audience:
President's Teaching Scholars Program