A Simple Yet Pedagogically Comprehensive Undergraduate Laboratory Exercise in Fluid Dynamics

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This work will be shared with the community through a presentation only (no full paper) format. Fluid dynamics is among if not chief of the most challenging subjects in an undergraduate mechanical engineering curriculum due to the complexity and breadth of its content. Perhaps for this reason, the course topics are often presented in a sequential fashion which students then proceed to compartmentalize rather than synthesize into a deeper understanding of the subject. To help students combat this tendency, an approachable but pedagogically rich hands-on laboratory exercise has been developed that integrates the topics of conservation of mass, conservation of linear momentum, the Bernoulli equation, and dimensionless groups. The apparatus involves a cylindrical container with a circular hole in the center of its bottom surface which upon being unplugged allows the fluid initially contained therein to drain by the action of gravity. The entire apparatus hangs from a force sensor to measure how the support force changes over time during this drainage event. A theoretical dynamic model for the support force is developed by applying the aforementioned topics and then used as a framework for interpreting the experimental results. Because this event is transient, students cannot follow their usual habit of making the steady state assumption when developing the mathematical model. Furthermore, the concept of the quasi-steady state approximation is introduced and comparison with the experimental results which allows students to see both its utility and its limitations. The diameter of the hole is varied to explore its impact on how quickly the fluid will drain from the container and a scale analysis of the differential equation model previously developed is used to identify the characteristic time scale for this system to foster connections with the students' intuition. This characteristic time scale also allows results for every hole diameter to be plotted using dimensionless variables so that they can be visualized on a single plot in a more compact and insightful manner. Ultimately, through a hands-on investigation of this one physical system, students are able to move beyond articulating a simple qualitative explanation to developing a complex quantitative predictive model that draws on multiple key course topics.