DESIGN AND DEVELOPMENT OF INTERACTIVE SIMULATIONS TO SUPPORT AN ENGINEERING TECHNOLOGY COURSE

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Abstract:

Online courses prove to be a convenient and effective way of learning, but educators still need to prepare the materials in a fashion so that students can have the best learning experience remotely. To this end, educators have adopted a variety of online teaching styles: video-based teaching, slide-based teaching, voice-recording, online office hours, discussion boards, and teleconference office hours, etc. However, without direct student interaction, teaching the practical aspects of engineering courses is still challenging. To study this problem and to explore a potential solution, a set of custom animations have been designed and developed in an engineering technology course. Specifically, the animations aim to present a variety of concepts of Applied Fluid Mechanics – such as viscosity, measuring viscosity through a falling ball viscometer, continuity equation, and pressure measurement. This paper will provide an overview of transforming basic fluid mechanics concepts into animations and simulations to support lecture materials. In addition to the design and development of the animations and simulations, instructions to guide students on what the animation is about and the examples to enhance students' procedural knowledge will be provided.

Introduction:

The flexibility of time and the location independency of online courses solve many scheduling problems and make education available to many more students who, otherwise, wouldn't have the chance. Hence, colleges and universities adopt more online and distance-learning courses every year. Despite the advantages, assessment of learning in distant learning is a challenge due to the asynchronous nature of interactions. In a traditional course setting, professor has the active role of teaching the material in class, and gets instant feedback from students by means of questions for unclear points. In online courses, however, the responsibility of learning is shared differently and the instant feedback may not always be available as students have different schedules: Students usually have 1 – 2 week time to go over the material on their own and ask any questions they might have. However, constant feedback is an important component of distance learning, and educators' encouragement is essential when it comes to constant feedback[1]. Constant feedback is a great way to ensure the quality of online learning. Sloan Consortium defined the five pillars of online learning as: "learning effectiveness, cost effectiveness, student satisfaction, faculty satisfaction and access"[2], where quality can be defined as the overlapping of these pillars[3]. This becomes especially important when solving mechanical engineering problems, which tend to be complex and often open-ended.

The process of solving a mechanical engineering problem has three components: problem definition, developing a sketch, and introduction of the equation[4, 5]. Educators developed and implemented simulations, animations; set up remote laboratories; and recorded videos to convey this process – and its components – effectively in on-line settings. For example, virtual and remote laboratories developed for different courses around the world – including virtual laboratory for teaching robotics[6]; virtual learning environment for the laboratory component of mechanisms and machine dynamics course[7, 8]; remote laboratory for circuit theory, sensor technology, and oscilloscope and function generator course[9]; and instrumentation platform for the computer-based instrumentation and control course[10]. In addition to remote and virtual labs, simulations and animations support online learning by promoting active learning.

In an effort to enhance the online education experience and to provide students a visual tool to understand the concepts better, a series of animations are designed and developed to be implemented for the online Applied Fluid Mechanics course in the Mechanical Engineering Technology Department at a state college.

General Course Description

Applied Fluid Mechanics is a 3-credit sophomore level course offered in the Mechanical Engineering Technology Department at a state college. Applied Fluid Mechanics course is a required course for Facility Management Technology – BS, and Mechanical Engineering Technology – BS, as well as AAS programs. The course covers viscosity, buoyancy, pressure and pressure measurement, energy conservation and Bernoulli's Theorem, Reynold's Number, laminar and turbulent flow, losses due to friction, flow measurements, drag, lift, flow of air in ducts, blowers and compressors topics. The course has a designated textbook and weekly homework assignments. For the online offering of the course quizzes and weekly discussion board participation questions will be provided in addition to the weekly homework assignments. To support the lecture materials and to provide students a visual of the concepts taught in class, a set of animations is created. These animations will also be referred to in the practice questions for the course.

Overview of Animation Module Design and Development

In order to create the animations, Scratch[1][11] – a programming language developed by MIT Media Lab – is used. Scratch is free programming software that serves as a platform to custom design animations, simulations, interactive art, etc. Users of Scratch can share their creations with others in the online community. For the Spring 2014 semester, the online Applied Fluid Mechanics course will employ three animation-based modules (Table 1).

[1] Scratch is developed by the Lifelong Kindergarten Group at the MIT Media Lab. See http://scratch.mit.edu

Table 1. Animation based modules for the experiments and the concepts covered by each module

Module Number	Concept
Module 1[12]	Viscosity, Falling Ball Viscometer
Module 2[13]	The Continuity Equation, Volumetric Flow Rate
Module 3[14]	Pressure Measurement in Fluids

Module 1 – Learning Viscosity of Fluids:

Viscosity is one of the most important concepts in Fluid Mechanics, and can be thought of as the internal friction of the fluid. The purpose of this module is to teach students the concept of viscosity and the concept of how Falling Ball viscometers work.

Module 1 Set-Up:

Module 1 has three same size containers with different fluids with different viscosities in them named as Fluid 1, Fluid 2, and Fluid 3. Different colors (green, blue and yellow) are used to help users visually differentiate between the different fluids as shown in Figure 1.

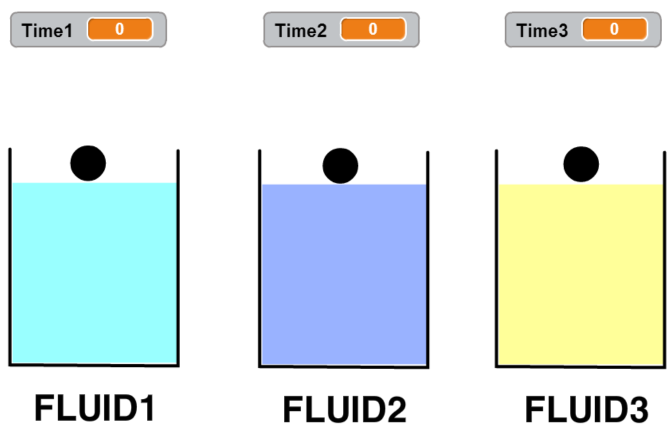
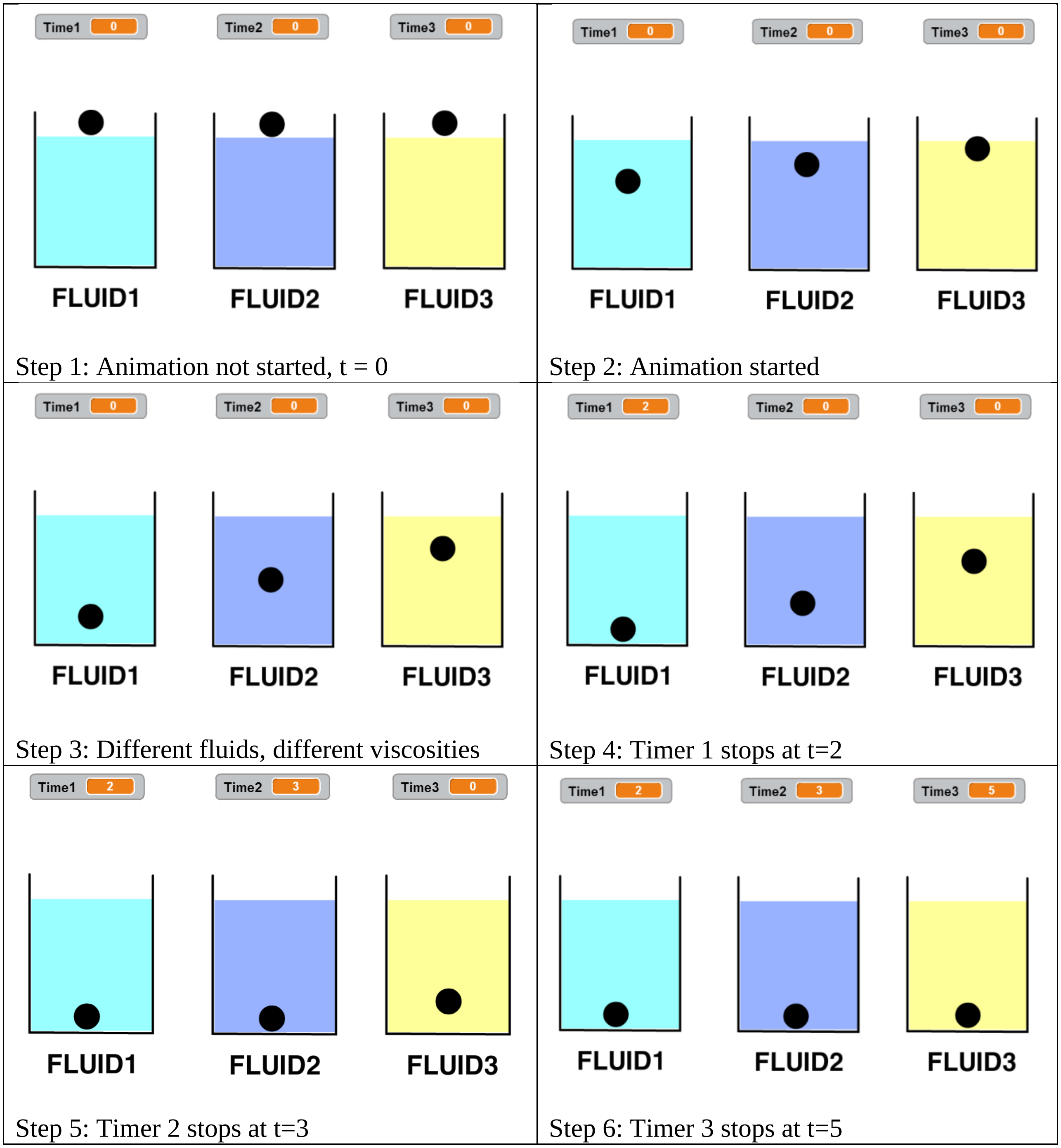


Figure 1. Module 1 Set-Up

To show the difference in the viscosities, a falling ball viscometer approach is developed. Animation will show three identical balls being dropped at the same time into three containers. Once the animation starts students will monitor three identical balls fall at different speeds in different fluids. Figure 2 provides an overview of the animation through the course of the animation time.



Step 1: Animation not started, t = 0

Step 2: Animation started

Step 3: Different fluids, different viscosities

Step 4: Timer 1 stops at t=2

Step 5: Timer 2 stops at t=3

Step 6: Timer 3 stops at t=5

Figure 2. Module 1 Animation overview

Module 1 Assignment:

The animation is designed serve more than a support tool for the instructor to teach viscosity: Once students understand the concept of viscosity, the module 1 animation will be used to solve

Falling Ball Viscometer questions. The viscosity of a fluid using the falling ball viscometer is calculated as[15]:

$$\eta = \frac{(\gamma_s - \gamma_f)D^2}{18v}$$

γ_s → Specific Weight of the Sphere

γ_f → Specific Weight of the Fluid

D → Diameter of Sphere

v → Velocity of the Sphere

At this stage, the instructor has the freedom to custom design the animation for a variety of different question presentations. Table 2 shows possible computational questions for a single fluid. Once students compute any of the following scenarios, additional questions can be provided on asking them to rank the fluids by their viscosities, specific weights or speeds, which provide a chance for students to review the animation and compare different fluids.

Table 2. Layout of possible computational questions for Module 1

Given	To Be Computed
γ_f , γ_s , D and v	η
η , γ_f , γ_s and D	v
γ_f , γ_s , D and v	D`
η , γ_f ,v and D	γ_s
η , γ_s ,v and D	γ_f

Module 2 – Learning the Continuity Equation

Continuity equation and the Bernoulli Theorem are two important, and related, concepts of fluid mechanics. The second module is designed to provide students a visual animation of how the diameter of a pipe and the velocity of the fluid flow within the pipe are related, as well as what happens to the velocity of a fluid when pipe diameter changes.

Module 2 Set-Up:

For Module 2 set-up, a pipe with a changing diameter is used as shown in Figure 3. The animation aims to clearly show the fluid flow, specifically the velocity changes, as the pipe diameter changes. To this end, the animation shows how yellow balls move through a pipe bottleneck: ball velocities change with the diameter change. The v_1 and v_2 counters on both sides of the pipe will show the velocities of the fluid once the animation starts. Figure 4 shows two different screenshots from the animation as the animation is in progress. As it can be read from the velocity counters, the velocities at v_1 and v_2 are 5 and 2, respectively. The animation doesn't specify a particular unit system.

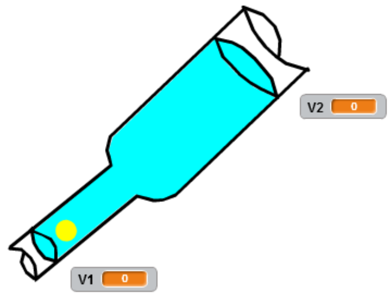


Figure 3. Module 2 Set-Up

Module 2 Assignment:

Module 2 assignment can be developed to teach the concept of continuity equation. The continuity equation is based on the principle of volumetric fluid flow (Q) staying same through the pipe even though the diameter of the pipe changes. The calculation of the volumetric fluid flow is shown as[15]:

$$Q = v_1 A_1 = v_2 A_2$$

v_1 and v_2 → Velocities at Diameters 1 and 2 A_1, A_2 → Cross sectional areas at diameters 1 and 2

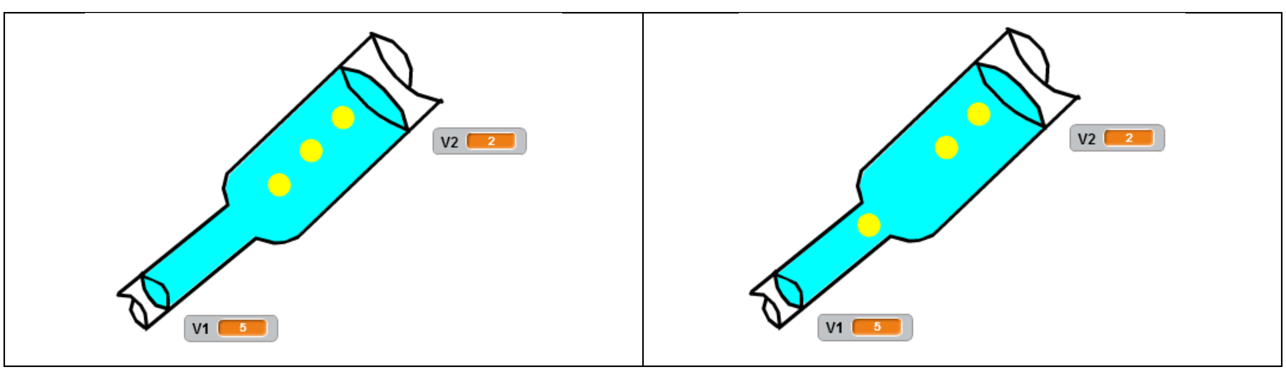


Figure 4. Module 2 animation overview

At this stage, the instructor can custom design the assignment for the students, by providing different set of known values and by obtaining the unknown through the use of the continuity equation. Table 2 provides a list of scenarios a question can be developed to be presented to the students where the continuity equation is used.

Table 3. Layout of possible computational questions for Module 2

Given	To Be Computed
v_1 and v_2 , A_1	A_2, Q
v_1 and v_2 , A_2	A_1, Q
Q, v_1 and v_2	A_1, A_2
Q, v_1 , A_2	A_1, v_2
Q, v_2, A_1	A_2, v_1

Module 3 – Learning the Fluid Pressure Measurement through a Manometer:

Pressure Measurement in fluids is a key concept when teaching Fluid Mechanics. A third module is developed to teach students the concept of fluid pressure, how to measure pressure and how pressure changes under a variety of conditions.

Module 3 Set-Up:

For the Module 3 set-up, a closed tank with a well type manometer is created as shown in Figure 5. To demonstrate the involvement of various fluids, fluids are color coded: as an example, grey can be used to represent mercury, blue for water, yellow for oil and the white area on top represents air.

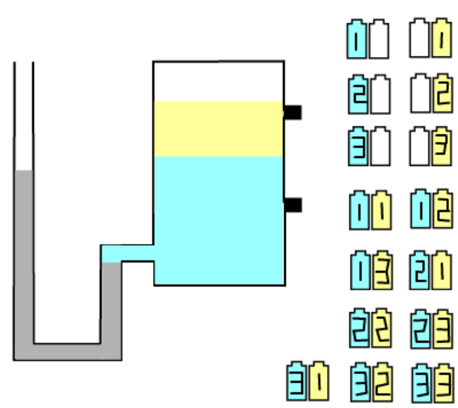


Figure 5. Module 3 Set-Up

On the right hand side of the experiment set-up there are pairs of container images with numbers 1, 2 or 3 on them. Each of these icons on the right hand side represents a condition for the experiment. For example: if the 1^{st} icon (1 blue 1 blank) is clicked, 1 serving of water is added to the tank. Alternatively by clicking the 5^{th} icon on the left column (1 blue, 3 yellow), 1 serving of water and 3 servings of oil can be added to the tank.

Module 3 Assignment:

Module 3 is developed to teach the concept of pressure measurement. In order to effectively measure pressure (P), students will need to know two components that affect pressure: height and specific weight of a fluid. Pressure calculation is shown as[15] :

$$\Delta P = \gamma h$$

ΔP = Change in Pressure γ = Specific Weight of the Fluid h = Change in elevation

Figure 6 shows an example of two different test conditions: on the left, 3 servings of blue (water) and 2 servings of yellow (oil) added to the system, on the right, 1 servings of blue (water) and 2 servings of yellow (oil) added to the system. When demonstrating these concepts, instructors have the freedom to change the type of the fluids and by adding different servings of additional fluids or by changing the height component. This module not only teaches the concept of pressure but also enables the instructor to demonstrate how parameters affect the pressure under different scenarios.

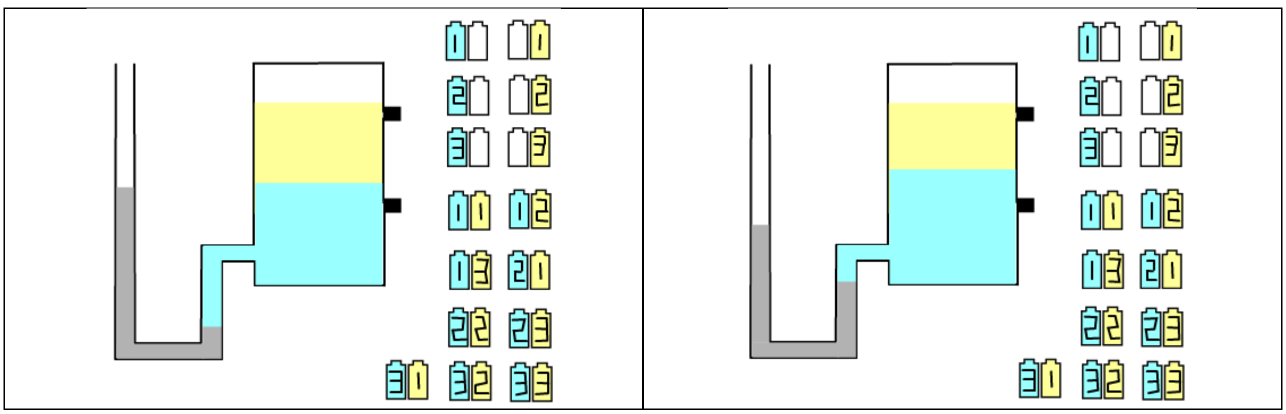


Figure 6. Module 3 animation overview

Conclusions and Future Work:

Simulations can be used to support engineering and engineering technology courses especially in online settings. This paper provides an overview of design and development of simulations using the Scratch[11] platform for Applied Fluid Mechanics course. The initial stage of the simulation development includes 3 simulations to be developed and implemented into the Applied Fluid Mechanics course in Spring 2014 semester. The next step will include the implementation of these modules into the online course, and collection of student feedbacks and responses. After the pilot implementation, additional simulations can be developed to further improve the course.

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