2006-1886: PRACTICAL CONSIDERATIONS FOR MINIATURIZED HANDS-ON LEARNING STATIONS

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Practical Considerations for Miniaturized Hands-on Learning Stations

Abstract: Believing student learning in technical courses is enhanced when using a working model of a system during class, we are left wondering how to do that. Most commercially available equipment is relatively expensive, and at the smallest, is scaled for the laboratory bench. Fluid mechanics and heat transfer equipment also requires utility hook ups. How do we by-pass these obstacles to create low cost units, with no external utility requirement, that can be placed on student desktops? How, for example, do we make a double pipe or shell and tube heat exchanger that a student could use in a lecture hall? Here we describe the considerations involved in designing a hands-on desktop demonstration unit – one that is useful in the standard classroom by small groups of students to quickly demonstrate most of the basic fluid and heat transfer concepts. The system serves to enhance qualitative understanding and can be used to measure quantitative information in minutes using hot and cold tap water reservoirs, gravity flow, non-electronic flow meters, manometers, pressure transducers and temperature probes with small-scale readouts.

Introduction

There is a well known need to re-visit the way in which engineers are trained to better prepare the next generation of engineers for the challenges of our changing society. [1] This can be done either by adding more courses, and thus more years, to engineering curricula or by utilizing alternate pedagogical techniques that can simultaneously enhance learning of core concepts and develop traditionally neglected 'soft' skills such as good communication practices.

Alternate pedagogies include cooperative, hands-on, active and problem-based learning. Usually these pedagogies are applied individually. Figure 1 shows the well known 'cone of learning' which links complexity of an activity to the amount of knowledge retained. [2] An implication of the correspondence of increasing complexity of activity with increased retention is that combining alternate pedagogies should increase learning effectiveness. In the Fluid Mechanics and Heat Transfer course of the Chemical Engineering program at Washington State University (WSU), we have been working on developing a novel approach that combines Cooperative (C), Hands-on (H), Active (A), and Problem-based (P) Learning pedagogies. We refer to this pedagogy as CHAPL and have discussed it in depth elsewhere.[3] A significant part of this pedagogy is the use of hands-on learning with dresser-sized modules containing an apparatus, water tanks, pumps, flowmeters, thermocouples, manometers and a whiteboard. Students are assigned an apparatus and must develop a learning exercise, including a reading assignment, quiz, and experiment, to instruct other students in the key concepts demonstrated by that apparatus. Due to the size and number of these modules, classes using this pedagogy must be held in a dedicated lab space. We have come to realize that one of the significant drawbacks to this method is the investment, in terms of space and equipment. Though we designed and built our current modules, it is possible to purchase a bench scale unit with similar attributes from a

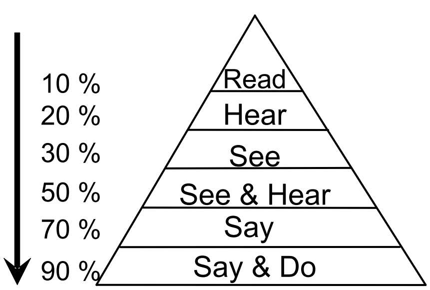

Figure 1. Learning Retention

commercial vender, albeit at a cost of up to $30,000. Any of these units simply are not suitably sized for a typical classroom or lecture hall.

For this reason we set out to develop a desktop scale version of our current modules. These Desktop Learning Modules or DLMs (patent pending) combine the capabilities of most of our existing units in a single one foot cube. We quickly realized that these new modules can also be used to augment the traditional lecture by providing brief hands-on activities or demonstrations. The biggest challenge is how to design a full range of capabilities in a desktop package and to do so without the need of external power or water facilities hook-ups. Herein we present the design considerations, special accommodations and resulting design parameters for such units along with their impact on classroom performance.

Considerations for Miniaturization and Combination

The design criteria for such modules are multiple. First they must be small enough that a number of them could easily be transported to most typical classrooms, and easily placed on the writing surface available to students in most lecture halls. Secondly, to avoid tripping hazards, they must not need to be plugged into an external power source. Third, to facilitate adoption they must be relatively cheap. Lastly they must hold a sufficient water reservoir to operate for about 10 minutes. In addition to these general criteria, in order to replace the existing larger modules the new ones must be capable of achieving a full range of laminar and turbulent flow regimes. We chose to include modules that reproduce Reynolds' experiment of dye injection into a flow stream; that have multiple flow measurement devices, such as venturi, orifice, and pitot meters; and that contain both a shell and tube and a double pipe heat exchanger sized so a measurable temperature change can be produced using hot and cold tap water as the feeds. Though it may not be possible to completely reach steady state in terms of steady temperatures profiles, the units must approach steady state in a relatively short time frame and at least give qualitative results for pedagogical purposes.

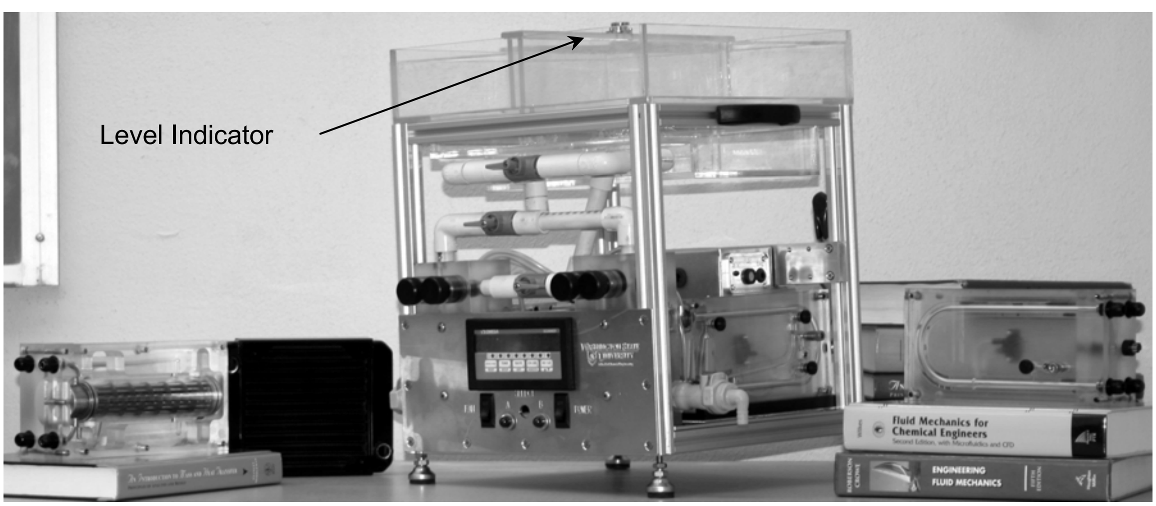

Figure 2: Desktop Learning Module

Such DLMs should have usefulness apart from application of the full CHAPL pedagogy typically used in the past in our laboratories. In other words one should be able to integrate their use into a standard lecture where they may be used as a demonstration unit or to facilitate a brief active learning exercise by placing several units in the room around which small groups of four to five students may gather. Beyond that of course they could also be used to facilitate cooperative learning by using the Jigsaw technique [4] where group members become experts in the use of a particular fluid mechanics or heat transfer unit through the formation of new expert or jigsaw teams each comprised of one member from each original group. After mastering unit concepts the original groups are reformed and each jigsaw expert facilitates a learning exercise so that everyone will learn a compete set of course concepts (i.e. completing the learning puzzle picture). Finally our DLM units could be used as an aid for problem based learning by having students examine the behavior of the system and then seek to find explanations for what they see – alternatively they could be given a homework assignment with equipment sizing and flow and temperature parameters achievable in the DLM.

Results

Since we know that having to provide power to an electric pump would be awkward, at best, in most classrooms and believing that hand pumps would probably provide a pulsating flow, we chose to design the DLMs with gravity feed. We also chose a one foot cube, with feed tanks built in and on top of the actual fluid or heat transfer module – this provides for convenient refilling and a safe and stable arrangement for locating the units on the top of lecture hall desks. Since most lecture hall and classroom desks are not level, we included adjustable leveling feet and a level indicator bubble (see Figure 2). Our DLM design calls for clear acrylic to allow the students to easily see what is going on (see Figures 3 and 4).

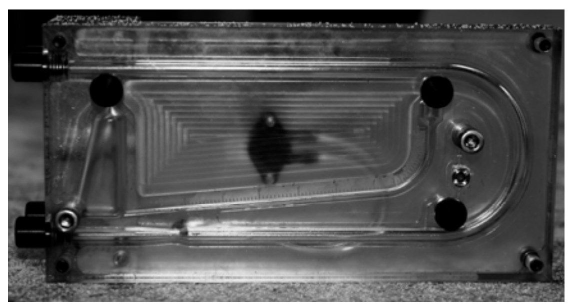
Figure 3: Venturi Cartridge with Dye Injection Port and Built in Manometer

This combination immediately causes design issues in the areas of pressure drop, turbulent flow, and capacity. If we make the tubing large, we will have a low pressure drop and gravity will be sufficient to feed the system. However this will lead to higher volumetric flow rates, which will empty the feed tanks faster. Larger tubing will also give a lower velocity at a given volumetric flow rate. This, of course, lowers the Reynolds number, making turbulent flow harder to achieve. Conversely, if for a given volumetric feed rate we make the tubing small, it will be easier to achieve turbulent flow, but the pressure drop will increase making it difficult for gravity to feed the system.

We overcame this obstacle through a few simple modifications to our initial design and criteria. First, we realized that if we place the 'waste' tank on the floor and prime the waste lines, we can essentially increase the height of the system by about two and a half feet. This provides more head to work with and allows us to overcome a higher pressure drop. We placed the various apparatuses in interchangeable cartridges which allow us to have each unit slightly larger and more visible. This also eases the space burden of using one apparatus for a multitude of fluid mechanics and heat transfer apparatuses.

Figure 4: Shell and Tube Heat Exchanger Cartridge

On the heat transfer side, temperature is a glaring constraint. We chose to design for operation with one gallon of hot and one gallon of cold tap water, as this could be reasonably found near most classrooms and lecture halls. Hot tap water runs about 120°F and cold tap water runs near 50°F. Is this enough of a temperature difference to get heat transfer on no more surface area than is available in such a small apparatus? If we realize that we aren't looking for industrially meaningful heat transfer, just a change of as few as 5°F, such that the concepts can be illustrated, then this is enough of a temperature difference for our purposes. Although if more heat transfer is desired, ice could be placed in the cold water reservoir. This would reduce the run time due to the volume occupied by the ice, but provide a larger temperature difference.

The last design issue is how to power the instrumentation. Our initial thought was to build inclined manometers into the unit everywhere we needed a pressure reading, and to use handheld thermocouple readers for all of the temperature measurements. Since we would have needed eleven total manometers, which would have consumed most of the surface of the DLM, we switched to differential pressure transducers and a built-in digital readout. For the alpha prototype we chose a commercial display that could be run off of a 12 volt sealed lead-acid battery and also read the thermocouples. This is probably the single highest cost item ($800) in the unit, and consumes a fairly large amount of space.

At the time of writing, the alpha prototype is nearly complete and has been shown to the class. Heat transfer cartridges have been given out one per student group for each group to develop a learning experience for the rest of the class. The students are giving positive feedback and one even reported that seeing the module corrected her misconception of the shape of a shell and tube heat exchanger.

Conclusions

By paying careful attention to the purpose of the DLMs, we can design an apparatus that will provide a meaningful learning experience for students. It is not necessary to have a large temperature change across a heat exchanger. What is needed is an apparatus that can demonstrate the differences between turbulent and laminar flow, and demonstrate the concepts of heat transfer in each flow regime and allow pressure drop measurements and calculations for all units so students can learn to model these effects.

Acknowledgements

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