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Transference of Hands-on Desktop Learning Pedagogy Across Institution and Program Types

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Kitana Kaiphanliam is a Senior Undergraduate student in the Chemical Engineering program at Washington State University (WSU), where she will also be continuing her education. She currently works with the Improving Undergraduate STEM Education (IUSE) group on a hands-on learning project funded by the National Science Foundation's Division of Undergraduate Education. Kitana is an active member of the American Institute of Chemical Engineers (AIChE) at WSU, and will serve as their Graduate Student Advisor for the 2018 academic year.

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Arshan Nazempour completed his PhD in Chemical Engineering at Washington State University and worked under Professor Van Wie's supervision on two projects, synergistic influences of oscillating pressure and growth factor on chondrogenesis in a novel centrifugal bioreactor and hands-on learning solution for students.

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Dr. Robert Richards received the Ph.D. in Engineering from the University of California, Irvine. He then worked in the Building and Fire Research Laboratory at NIST as a Post-Doctoral Researcher before joining the faculty of the School of Mechanical and Materials Engineering at Washington State University. His research is in thermodynamics and heat and mass transfer. Over the last five years he has become involved in developing and disseminating research based learning methods. He was a participant in the NSF Virtual Communities of Practice (VCP) program in Spring, 2013, learning research based methods to instruct thermodynamics. More recently he introduced the concept of fabricating very low cost thermal fluid experiments using 3-D printing and vacuum forming at the National Academy of Engineering's Frontiers of Engineering Education in October, 2013. He is presently a co PI on the NSF IUSE: Affordable Desktop Learning Modules to Facilitate Transformation in Undergraduate Engineering Classes, High School Recruitment and Retention.

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Dr. Olusola O. Adesope is an Associate Professor of Educational Psychology and a Boeing Distinguished Professor of STEM Education at Washington State University, Pullman. His research is at the intersection of educational psychology, learning sciences, and instructional design and technology. His recent research focuses on the cognitive and pedagogical underpinnings of learning with computer-based multimedia resources; knowledge representation through interactive concept maps; meta-analysis of empirical research, and investigation of instructional principles and assessments in STEM.

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Dr. Derek L. Englert, University of Kentucky
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Introduction

The use of alternative and complimentary learning methods to aid in student comprehension of engineering concepts has been explored for the past several decades. While think-pair-share is commonly used and has proven to be an effective learning method [1], hands-on learning methods have been gaining notoriety due to their potential for being more applicable to engineering students [2], as the majority of these students tend to be active or kinesthetic learners [3]. To support this mode of learning, Low Cost Desktop Learning Modules (LC-DLMs) were created at Washington State University (WSU). The LC-DLMs are hands-on apparatuses in which activities associated with them may be used to supplement lecture material and assist student learning of a variety of engineering concepts.

Although the LC-DLMs have great potential and have proven to work at WSU, without the ability to translate to other universities, it would not be an ideal learning method. Three steps are required to completely disseminate a project: awareness, understanding, and action [4]. Through the years of testing at WSU, the LC-DLMs have gained awareness and understanding within the engineering education community, but the next step requires propagation of this learning method to outside universities. Although the terms “propagation” and “dissemination” are commonly used interchangeably, they act as two separate steps that lead to the overarching goal of adoption; dissemination is the sharing of methods, while propagation is the success of such methods by outside universities [5].

The recent “How-to guide” already referenced [5] provides details about the issues facing would-be propagators of educational methods. Journal articles, conference presentations, online platforms, and instructional videos are a few methods that have been considered to ease the transition of a new implementation into the course curriculum of beta institutions. These methods alone, however, generally do not lead to propagation and sustained adoption—more engagement with adopters is often required. The most effective ways to overcome the barriers between dissemination and propagation and to engage adopters are through personal connections, teaching seminars, and building a community to answer questions and mentor new instructors.

As a result of a sabbatical leave taken by Prof. B. J. Van Wie, on-site mentoring, face-to-face discussions, targeted demonstrations, follow-up personal e-mails, all took place with the University of Kentucky at the main campus in Lexington (UK-Lex) and the branch campus in Paducah (UK-Pad). To determine the translatability of the LC-DLMs to other institutions, a set of modules were sent for implementation in two classes at UK-Lex and one class at UK-Pad. The LC-DLMs used for this study were a Venturi and Hydraulic Loss modules—both modules were tested in three Junior-level engineering classes. In this paper, details will be provided on the methods and assessment results of the implementation with emphasis on two of the classrooms in particular, as the third class will be included in a later study.

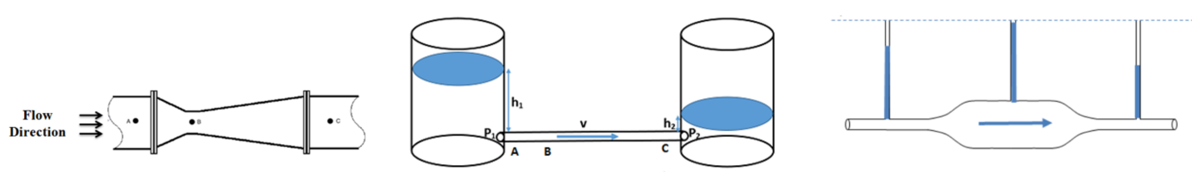
Classroom Implementation Experiment

For on-site mentoring Prof. Van Wie met with two implementing professors: Prof. S. Wilson (UK-Lex) in a Fall 2016 visit before initiating his Spring 2017 sabbatical and Prof. D. Englert (UK-Pad) during the sabbatical period. To begin, Prof. Van Wie set-up an LC-DLM with ancillary fluid reservoir, pump, tubing and connectors, while the new implementing professors set-up a companion system. They then went through student team-based worksheets to practice data collection and review the activity-guiding questions on the worksheet. Discussions also took place around pre- and posttest questions, how to coach team-learning activities, and troubleshooting the hardware.

After the on-site mentoring, Prof. S. Wilson held an in-class fluid mechanics LC-DLM practice implementation Fall 2016. Prof. Van Wie met with Prof. S. Wilson and Prof. I. Escobar during the Spring 2017 sabbatical and in a subsequent Summer 2017 visit to review how the Fall 2016 implementation went and how to improve the Fall 2017 implementations. Frequent e-mail exchanges took place between lead author, Ph.D. candidate Beheshtipour and the three UK professors to arrange logistics, update worksheets, and fine-tune the implementations and pre- and posttest strategies. Data assessment was done at WSU by co-authors Beheshtipour and Kaiphanliam.

For the study presented in this paper, the two classes analyzed include one class from the UK-Lex and one from the UK-Pad campuses; data from other classes are being analyzed in further detail and expected to be included in other presentation or publication forums. For the remainder of the study, the classes of interest will be referred to as Class 1 and Class 2. Class 1 had 40 students from UK-Lex, while Class 2 had 29 students from UK-Pad. Other than pre-test results, no controls were used to adjust for GPA of individual students nor for differences between the two classes.

The two classes were given an articulated pre-test to determine students' incoming knowledge of the Bernoulli equation and mass and energy balances. After taking the pre-test, the students continued with lecture as normal, which included topics from the LC-DLM. From there, the students filled out a worksheet while running various mini-experiments on the Hydraulic Loss LC-DLM. The two groups were then given a posttest on mass and energy balance material with respect to the Hydraulic Loss module. After completing the Hydraulic Loss material, the students then repeated the same process, but for the Venturi LC-DLM with a respective posttest for that module. Both the pre- and posttests consisted of a mix of multiple choice questions and justification sections.



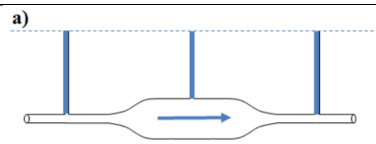
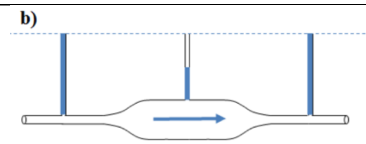
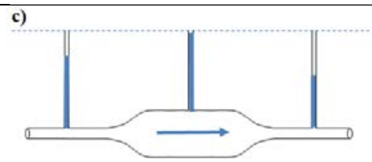
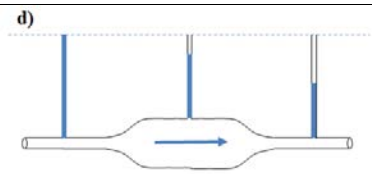
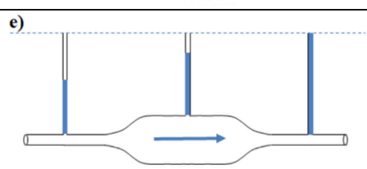
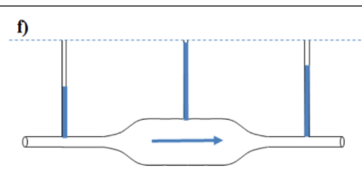
(1) (2) (3)

Figure 1. *A preview of the topics covered in the pre- and post- tests: (1) velocity and pressure profiles in a venturi, (2) velocity and pressure profile in a pipe, and (3) hydrostatic pressures through an expansion.*

The pre-test covered all topics shown in Figure 1, including: (1) velocity and pressure profiles in a venturi, (2) velocity and pressure profiles along a straight pipe, and (3) pressure profiles through a contraction and an expansion. While the posttests varied depending on the LC-DLM used—the questions used in the pre- and posttests, however, did not differ. The posttest corresponding with the Hydraulic Loss module covered topics (2) and (3), while the posttest corresponding with the Venturi module covered topics (1) and (3).

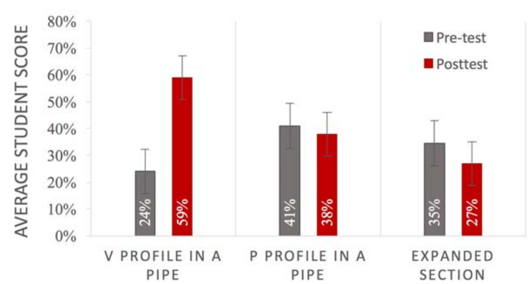
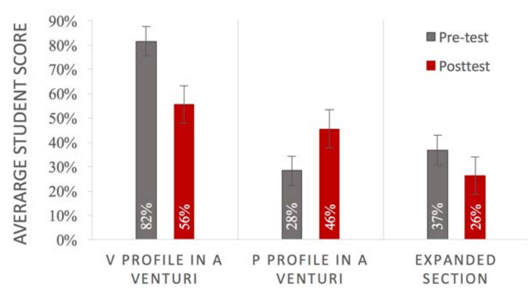
Rather than giving full points for only the correct answer and zero points for any other option, the multiple choice questions were graded on a scale to include complete or partial conceptual correctness. Partial credit was given to determine the level of how well the student understands the concept, rather than if the student understands the concept in its entirety. Below in *Table 1* is an example of the scale used.

Table 1. An Example of the Grading Scale Used for Pre- and Posttests.

Option	Score out of 100
	0
	0
	100
	20
	40
	80

Results and Discussion

Based on the graphs in *Table 2*, Class 1 showed an increase in performance across all three questions from the pre- to posttest after using the Hydraulic Loss module, while Class 2 showed a decrease in performance for both the "pressure profile through a pipe" and "hydrostatic pressure through an expanded section" questions. After using the Venturi module, however, both classes decreased in performance for the "velocity profile in a venturi" question.

<table>
<tr><th colspan="3">Table 2. LC-DLM Results of Two Classes from the University of Kentucky.</th></tr>
<tr><th></th><th>Class 1</th><th>Class 2</th></tr>
<tr><td>Hydraulic Loss</td><td>
</td><td>
</td></tr>
<tr><td>Venturi</td><td>
</td><td>
</td></tr>
</table>

To determine the significance of these results, a paired t-test was used to analyze the data. The statistical analysis only considers pre- to posttest data, which does not account for any other factors for each student. Of the pre- to posttest changes for the 12 questions asked in both classes, six were significant while one approached significance. *Table 3* displays the statistics for each class along with the significance value for each question in the pre- and posttests.

From the statistics of the class data, the only two questions that were significant for both classes at a 95% confidence level were the "velocity in a pipe" and "pressure in a venturi" questions. For the remaining "velocity in a venturi," "pressure in a pipe," and both "expanded section" questions, all but one were insignificant decreases in performance. One case where the decrease in performance was significant was for the "velocity in a venturi" question for Class 2. This may be due to students choosing the option where velocity change through a venturi is sharp and linear, rather than curved and exponential. These students most likely applied what they think they saw while using the LC-DLM instead of considering that the Bernoulli equation is used to perform an energy balance where kinetic energy involves a v^2 term where v itself is dependent inversely on the cross-sectional area represented by the square of the diameter.

Table 3. Statistics on Class Results from the University of Kentucky.

LC-DLM	Question	Class	Mean†	Std. Error	P-value	Significant?‡
Hydraulic Loss	Velocity in a pipe	1	-0.186	0.090	0.044	Yes
		2	-0.345	0.124	0.010	Yes
	Pressure in a pipe	1	-0.233	0.073	0.003	Yes
		2	0.034	0.116	0.769	No
	Expanded section	1	-0.014	0.071	0.846	No
		2	0.076	0.071	0.291	No
Venturi	Velocity in a venturi	1	0.073	0.045	0.113	No
		2	0.260	0.063	0.000	Yes
	Pressure in a venturi	1	-0.184	0.064	0.006	Yes
		2	-0.172	0.077	0.036	Yes
	Expanded section	1	-0.164	0.082	0.053	Near
		2	0.104	0.105	0.333	No

‡ *Significance assuming a confidence level of $p < 0.05$*

† *A negative value represents an increase in performance from pre- to posttest due to the posttest value (higher) being subtracted from the pre-test value (lower) in the calculation for mean*

A previous implementation was conducted by the lead institution using the Shell and Tube Heat Exchanger LC-DLM. Although the LC-DLM used was different than those tested in this study, the pre- to posttest results were significant 50% of the time at a 95% confidence level, which is similar to the results seen in this study. Six out of the 12 pre- to post improvements in this study were significant, while two out of the four cases at the lead institution were significant [6].

Many factors through the execution process may have had an effect on these results. Although the instructors went through a brief training on how to implement the LC-DLMs, this doesn't account for the different teaching-styles of each instructor. The results may have also been influenced by the order in which the LC-DLMs were presented—for example, the average score increased in Class 1 for the "hydrostatic pressure through an expanded section" question after using both the Hydraulic Loss and Venturi modules. This is reasonable since that question requires understanding of both hydraulic loss and pressure changes through a venturi. Another factor to consider is that the students were allowed to take the posttests outside of class; though the incentive to discuss with peers was diminished because full credit was given for just taking the quiz, this does not absolutely preclude peer discussions before answering.

Based on a comment made by one of the instructors that "the students worked better without [her] there because they do it on their own," students using the LC-DLMs have more motivation to become active learners because they are required to be alert while operating the system, prompted through worksheet exercises to discuss phenomena and thereby construct their own understanding of the system. Furthermore, the use of a physical system offers live observance of changes in the physical system such as the shift in heights of manometer fluid with flow.

Conclusions & Future Directions

Although there were many factors to consider that may have affected the results, the LC-DLM implementation showed similar statistics with improved student outcomes, at least for some concepts, at a university other than where the technology was developed, which suggests transferability of the LC-DLM pedagogy. The on-site mentoring and discussions along with online instructions, phone discussions were helpful for engaging the faculty in using the DLMs in their classes.

Previous studies at the founding university have shown significant improvements with the modules when compared to a control group. To further determine the transferability of the LC-DLMs, the classes used in this study will be compared to another class where half of the students acted as a control group. This data is currently being analyzed and will be formally presented at the 2018 American Society for Engineering Education (ASEE) meeting in Salt Lake City. In the same way that the LC-DLMs had a significant impact in performance relative to a control group at the founding university, it is expected that similar results will occur at the beta site institution.

Acknowledgements

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