AC 2009-2338: A MINIATURE OPEN CHANNEL-WEIR FOR THE STANDARD CLASSROOM: IMPLEMENTATION AND ASSESSMENT

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Miniature Open-Channel Weir for the Standard Classroom: Implementation and Assessment

Abstract

A miniature open-channel flow system with weirs was used to teach characteristics of open-channel flow, flow control and measurement in a Civil Engineering Water Resources Engineering class. One class was given hands-on active learning; the other class, as a control will receive traditional lecture in the following semester. Preliminary analysis of the results shows that concept inventory performance for students who received the hands-on active learning exercise is improved by 52.1 % over their pre-test. In addition, a flashlight survey discloses that 29.5% of students were very satisfied while 65.9% were satisfied with the hands-on active method compared to the traditional lecture method.

Introduction

According to the learning cone [1] shown in Fig. 1, students retain knowledge better by seeing than by only reading or hearing. Having that as a motivation, Van Wie and coworkers [2] have developed portable desktop learning modules (DLMs) for chemical engineering and have implemented nontraditional learning pedagogies: namely, cooperative, hands-on, active and problem-based learning. Cooperative learning has been implemented by forming small groups of students to work on worksheets, quizzes, homework and projects. Hands-on learning involves groups of students observing theoretical principles in action with the DLM hardware. Active learning is promoted by group exercises in the form of worksheets which require students to do derivations and calculations and to discuss implications. Problem-based learning involves open-ended group design projects.

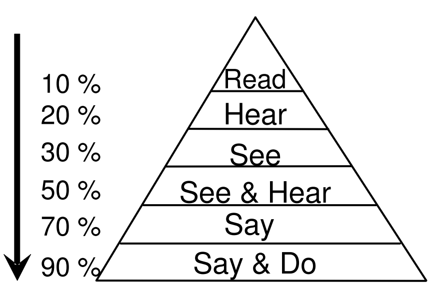


Figure1. Learning Retention

To our best knowledge, there is no study done on the use of open channel as a desktop learning module in the literature. Van Wie[2] and his group has been designing desktop modules and different cartridges like venturimeter, orifice meter, Reynolds's experiment, double pipe heat exchangers, shell and tube and extended area heat exchangers, packed bed in chemical engineering area. Now, goal of the research group is to extend those learning modules to new areas like civil/environmental engineering and biomedical engineering.

This research implements a newly designed civil engineering DLM cartridge in a Water Resources Engineering course. Specifically, Hands-on and Active Learning (HAL) pedagogies were applied along with the new DLM cartridge, covering the topic of open-channel flow with weirs.

Desktop Module with Open Channel and Weirs:

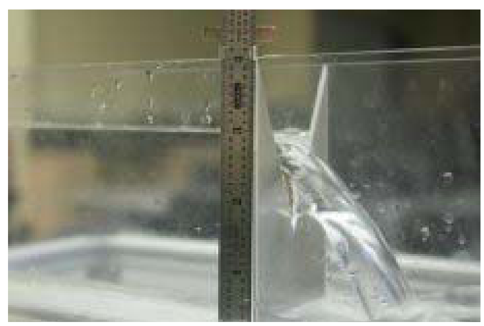
The Desktop Learning Modules (Fig. 2) are house-built and consist of an approximately one cubic foot base unit with interchangeable cartridges for doing different experiments. The differences from other bench top commercial modules are that they occupy much less space, one can run different type of experiments only changing the experimental cartridge using the same units and take it to a classroom without even having to use the power cord. The unit consists of two four-liter tanks, each with its own pump, and a lead-acid battery to supply power to the pumps as well as to instrumentation such as pressure transducers, thermocouples and a display unit. The batteries need to be charged after 2-3 hours of operation but they allow for continuous use during a two-hour course period. Flowrates are controlled by rotameters on the system control panel and provide flowrates in the range of 0 to 40 GPH.

An open channel (flume) was constructed out of Plexiglas with a width of 2 inches, height of 4 inches and length of 22 inches. It has two flow entrances supplied by the two DLM pumps. A sluice gate is placed 2 inches from the entrance. The channel sits on top of the DLM base unit and water continuously flows through the channel and back into the storage tanks. Triangular (45^o and 90^o) and rectangular weirs made of stainless steel were used to measure flowrates in the channel and an underflow weir was used to observe the hydraulic jump phenomenon (Fig. 3).

The experiments offered to students were to take height of water data just a couple of inches before the weirs in the open channel for each type of weir at two different unknown pump settings. Then they were asked to find the flow rate in the channel and compare among the weirs.

Figure 2. One cubic foot desktop learning module with open channel on top.

(a)



(b)

(c)

Figure 3. (a) Underflow weir and hydraulic jump (b) 45^{o} V-notch weir (c) rectangular weir.

Assessment Methods:

Concepts inventories were prepared according to the instructor's choice of conceptual questions. Two slightly different sets of questions were prepared, one for use as a pre-test and one as a post-instruction test (see Appendix A for selected conceptual questions). Before the subject on "open-channel flow" was taught in the class, students were given the pre-test. After that, student groups used the desktop module to perform experiments and fill out worksheets (see Appendix B for the given worksheet) which contained some conceptual questions, derivations, and calculations using the DLM experimental data. Then students were given the post-instruction test to assess improvement in conceptual understanding. The concept inventories had 12 multiple-choice questions that were designed to assess student understanding of the concepts of open-channel flow as taught in this course. The response choices for each question included the correct answer and distracters designed to capture common student misconceptions of the subject. Improvement of students' performances over pre-test was calculated by dividing the difference in post-test and pre- test by pre-test score.

Students were also given a well-designed flashlight survey (see Appendix C) to compare attitudes towards hands-on, active learning versus traditional lecture. The students were asked to say how much the new pedagogy, group work, and visualization of a real open-channel flow system enhanced their grasp of the concepts.

Results:

The results of the pre and post concept inventories showed a gain of 52.1% as calculated by dividing the difference in post-test and pre- test by pre-test score multiplied by 100.

Flashlight survey results (Fig.4) show that, out of 44 students, 29 students were satisfied, 13 of them were very satisfied, 1 unsatisfied and 1 very unsatisfied by the introduction of desktop modules along with the hands-on, active learning method.

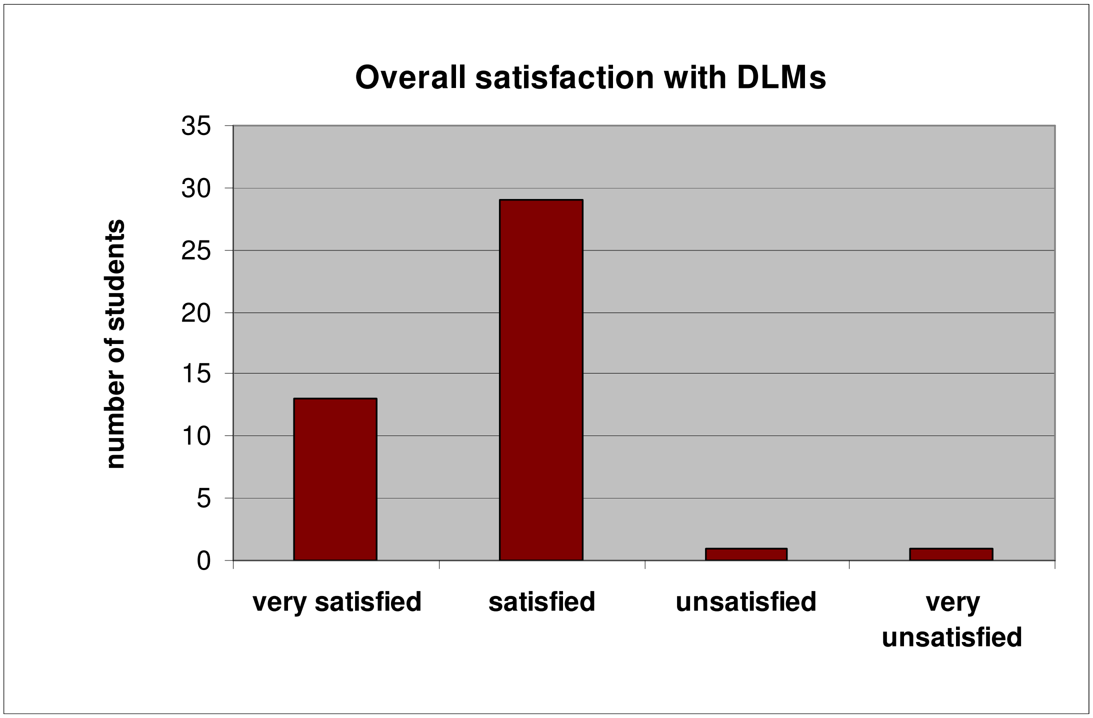


Figure 4. Flashlight survey results on how students like the hands-on active learning compared to traditional lecture.

Acknowledgements

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Bibliography:

1. NTL Institute for Applied Behavioral Science, 300 N. Lee Street, Suite 300, Alexandria, VA 22314. 1-800-777-5227
2. Golter, Van Wie, Scuderi, Henderson, Dueben, Brown, Thomson, "Combining Modern Learning Pedagogies in Fluid Mechanics and Heat Transfer", *Chemical Engineering Education*, **39**(1), 280 (2005)

Appendices

Appendix A. Example of selected concept inventory questions

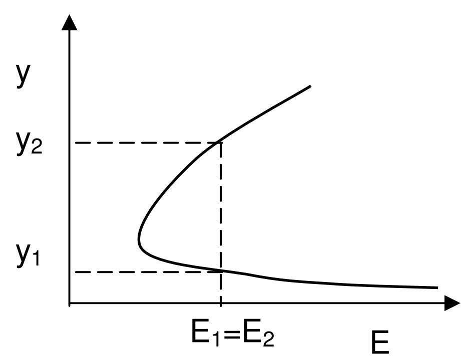
Question 1. Consider steady flow of water in an open channel of rectangular cross section. A hydraulic jump occurs if:

a) upstream velocity (inertial forces) is high enough to overcome gravity forces
b) gravity forces are high enough to overcome inertial forces
c) flow transitions from subcritical to supercritical
d) energy is the same at points 1 and 2

Question 6. The triangular weir (or the V-notched weir) has an advantage over other weir shapes because the V shape

a) creates a larger and measurable H at small Q
b) increases the pressure forces right on the weir
c) causes more head loss at the weir
d) creates a smaller and measurable H at small Q

Question 8. Consider the energy diagram below for a short section. How would you explain the phenomena where $E_1=E_2$? E_1 is energy at water depth y_1 and E_2 is at water depth y_2.



a) velocity head at 1 is much greater than velocity head at 2, and pressure head at 2 is much greater than pressure head at 1
b) velocity head at 2 is much greater than velocity head at 1, and pressure head at 1 is much greater than pressure head at 2
c) y_1 should be equal to y_2, because pressure at 1 is equal to pressure at 2, and velocity heads are equal
d) E_1 is not equal to E_2, because velocity head and pressure head at 1 are greater than velocity head and pressure head at 2

Appendix B. The worksheets given to the students.

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Worksheet #1: Hydraulic Jump

Name(s): ____

____

1. Explain the hydraulic jump using a sketch and a specific energy diagram. Label supercritical and subcritical flow and the corresponding Froude number relative to 1 (i.e., Fr < 1, Fr > 1, or Fr = 1).

2. What is the Froude number? How is it defined? What is its physical meaning and significance?

3. In terms of energy, what is the head loss, h_L associated with the hydraulic jump? You don't need to calculate, just show the equation.

4. Water discharging into a 10-m-wide rectangular horizontal channel from a sluice gate is observed to have undergone a hydraulic jump. The flow depth and velocity before the jump are 0.8 m and 7 m/s, respectively. The flow depth and velocity after the jump are 2.46 m and 2.28 m/s, respectively. Determine (a) the head loss, h_L (b) the wasted power production potential due to the hydraulic jump (c) how many light bulbs (each bulb is 60 w) could be lit with the wasted power.

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Worksheet #2: Weirs

Name(s): ____

1. Fill in the data sheet by using three sharp-crested weirs using
   a. pump A
   b. pump B

	Weir Head, H (cm)		
	2-inch rectangular	45-degree V-notch	90-degree V-notch
Pump A			
Pump B			

2. If pump A provides a flow rate of 79.04 mL/sec, calculate the weir discharge coefficient C_w for each type of weir.

3. Calculate the flow rate for each weir when pump B is on.

Appendix C. The Flashlight survey

WSU CE 351 Survey Fall 2008

1. Comparing the hands-on active group learning to the lecture format to what extent do you:		Much more	Somewhat more	The same	Somewhat less	Much less
a.	Spend more time on task for the hands-on aspect	☐	☐	☐	☐	☐
b.	Discuss course topics outside of class for the hands-on part	☐	☐	☐	☐	☐
c.	Learn in new ways for the hands-on part	☐	☐	☐	☐	☐
e.	Interchange ideas with other students for the hands-on part	☐	☐	☐	☐	☐
f.	Feel more isolated for the hands-on part	☐	☐	☐	☐	☐
g.	Discuss ideas concepts with the instructor for the hands-on part	☐	☐	☐	☐	☐
h.	Make use of your unique abilities and skills to aid understanding for the hands-on part	☐	☐	☐	☐	☐
i.	Feel challenged to create your own understanding hands-on part	☐	☐	☐	☐	☐
j.	Feel the hands-on part prepares you more for work in the field	☐	☐	☐	☐	☐

2. How strongly do you agree with the following statements about this course?		Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
a.	Hands on activities helped more than lectures to understand the course concepts	☐	☐	☐	☐	☐
b.	During the hands-on I was encouraged more to answer my own questions	☐	☐	☐	☐	☐
d.	The hands-on activities helped me realize connections between areas of knowledge that I hadn't appreciated before	☐	☐	☐	☐	☐
e	During the team exercises I learned to consider contrasting points of view	☐	☐	☐	☐	☐
f.	I improved at collaborating with peers during the team exercises	☐	☐	☐	☐	☐
g.	The hands-on activities pushed me to think	☐	☐	☐	☐	☐

3. Because of the hands-on group work how likely were you to:		Very Likely	Likely	Unsure	Unlikely	Very Unlikely
a.	Ask for clarification when you didn't understand something	☐	☐	☐	☐	☐
b.	Work on assignments with other students	☐	☐	☐	☐	☐
c.	Miss comments made during a discussion about ideas and concepts taught	☐	☐	☐	☐	☐
d.	Tell the instructor when you have a complaint or suggestion about the course	☐	☐	☐	☐	☐

4. During the group and hands-on learning:		Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
a.	I am better able to remember important facts	☐	☐	☐	☐	☐
b.	I have a more thorough understanding of the ideas and concepts taught	☐	☐	☐	☐	☐
c.	I am better able to visualize the ideas and concepts taught	☐	☐	☐	☐	☐

5. Indicate how strongly you agree or disagree with each of the following statements:		Strongly Agree	Agree	Unsure	Disagree	Strongly Disagree
a.	Because of the hands-on aspects I am more comfortable participating in discussions in this course, than I am in other courses	☐	☐	☐	☐	☐
b.	I feel comfortable telling the instructor when I disagree with something he said	☐	☐	☐	☐	☐
b.	The hands-on & group learning technique used in this course is overrated	☐	☐	☐	☐	☐

6. Overall how satisfied were you with the introduction of hands-on group learning in this course

☐ Very Satisfied

☐ Satisfied

- ☐ Unsatisfied
- ☐ Very Unsatisfied

Other Comments: