Work in Progress: Fostering Cognitive Engagement with Hands-on Learning Pedagogy

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Work-In-Progress (WIP): Fostering Cognitive Engagement with Hands-on Learning Pedagogy

Abstract

The purpose of this work-in-progress (WIP) paper is to report on an ongoing study that used Chi and Wylie (2014)'s Interactive, Constructive, Active, and Passive (ICAP) framework (I > C > A > P) to survey the degree to which LC-DLMs foster cognitive engagement as students learn about a venturi meter in a fluid mechanics and heat transfer course. Fredricks, Blumenfeld, and Paris (2004) define cognitive engagement as the effort students invest in understanding what they are learning. Indeed, cognitive engagement is critical for effective teaching and learning in engineering. Although there is research evidence showing that students learn better with hands-on approaches than traditional lectures [1, 2], little is known about student differential levels of cognitive engagement that underlie such improved learning. As part of a large program of federally-funded research, our research team has developed light-weight, portable, ultra-Low-Cost Desktop Learning Modules (LC-DLMs) that enable students to employ systems experientially to illustrate the physics that underlie transfer processes and provide students with visual cues to help develop robust understanding of the fundamentals of momentum, heat and mass transfer. Sixty-seven (67) participants used LC-DLMs to learn venturi concepts in an engineering course. Overall, preliminary results show that the majority of the participants reported that LC-DLMs helped foster active, constructive, and interactive forms of engagement far more than lectures did. For example, all but two of the participants agreed or strongly agreed that the use of LC-DLMs helped promote interactive forms of engagement such as discussion with peers, asking and answering questions and clarifying understanding with peers through robust discussions. Some open-ended items solicited information about the physical features of the LC-DLMs that were helpful in learning venturi concepts and ways the LC-DLMs hindered or enhanced their engagement and learning. Most of the participants reported that the visual cues afforded by LC-DLMs made the venturi concepts more relatable and helped them develop conceptual understanding better than if they had only been taught using lectures.

Keywords: motivation; desktop learning module; hands-on learning; active learning

Introduction

Many researchers have adopted a multifaceted nature of engagement that shows the complexity of describing how student engagement takes place. A student engagement framework that has been frequently used in the literature was advanced by Fredricks and colleagues [1], and includes three types: behavioral, emotional, and cognitive engagement. Cognitive engagement has been defined as the efforts students invest in understanding what they are learning [1]. These authors define behavioral engagement as including participation in academic and social or extracurricular activities. Such participation is considered very important for developing social networks that help prevent or limit dropping out. Finally, they define emotional engagement as including both feelings learners have about their learning experience, such as interest, frustration, or boredom, and their social connection with others [1]. Specifically, there is research evidence showing a positive relationship between the three types of engagement and different educational outcomes, including academic achievement [1, 2, 3], and student persistence in learning [3, 4]. Although there is research evidence showing that students learn better with hands-on approaches rather than traditional lectures, little is known about student differential levels of cognitive engagement that underlie such improved learning. The present study examines the effects of hands-on pedagogical approach in fostering different forms of cognitive engagement.

The ICAP Framework of Cognitive Engagement

Chi and colleagues define the ICAP framework as a taxonomy for differentiating four modes of cognitive engagement, based on the overt behaviors of students [5, 6]. Chi and Wylie [7] theorized that as students engage in class activities and assignments, their actions or thinking can be characterized into four levels: "…interactive, constructive, active, or passive" (ICAP, p. 220). Indeed, Chi and Wylie theorized student cognitive engagement inside the classroom using the ICAP framework, delineating the learning environments as decreasingly effective in the order shown (i.e., I > C > A > P). Appendix A shows brief description of the levels of engagement.

Objectives of the Study

The purpose of this work-in-progress is to report a project that used the Chi and Wylie's [7] Interactive, Constructive, Active, and Passive (ICAP) framework to survey the degree to which Low-Cost Desktop Learning Modules (LC-DLMs) helped foster different forms of cognitive engagement as students learned about a venturi meter in a fluid mechanics and heat transfer course.

Method

Participants

The participants for this study were 67 undergraduate students of chemical engineering at a large public university in the Pacific Northwest of the United States. Students were enrolled in junior level Fluid Mechanics and Heat Transfer course, the only fluid mechanics course that chemical engineering students in the university are required to take. All 67 students responded to the survey because it was part of class activity.

Materials

As part of a large program of research, we developed Low Cost Desktop Learning Modules (LC-DLMs) to facilitate active learning in engineering classrooms (see Figure 1). They are miniaturized versions of industry-type equipment that can be used to illustrate engineering concepts in the classroom. The module kits consist of a base setup with fluid reservoirs, tubing, valves, pumps, connected to rechargeable batteries, battery cases with on/off switches, stands for the LC-DLMs, and the LC-DLMs themselves which can be used interchangeably, e.g., venturi, orifice and double pipe and shell and tube heat exchanger cartridges, depending on the instructional need. Also connected to fluid mechanics LC-DLMs are static head tubes to register pressures, and digital thermometer probes to display temperatures.

Procedure

The classroom sections involved 50-minutes thrice-weekly instruction on concepts in fluid mechanics and heat transfer taught with the LC-DLMs. Data for this study were obtained from participants who worked with LC-DLMs in spring 2018. Four sets of concepts were taught (hydraulic loss, venturi meter, double-pipe heat exchanger, and shell-and-tube heat exchanger), each with a corresponding LC-DLMs, throughout the semester while other concepts were taught with regular lectures. The professor guided the class through worksheets that were designed to allow students to work cooperatively in interactive learning groups. Participants were then asked to complete an online survey administered over Qualtrics© at the end of the semester. The survey prompted participants to reflect on their LC- DLM instruction and report how well they believed being taught concepts with LC-DLM influenced their learning experience compared with other course concepts they learned with regular lectures in the same class. Participation in the experiment was voluntary. Due to space constraint and availability of data, we only provide results for the venturi meter for two reasons (1) all the participants responded to the survey during the week when they learned with venturi meter; and (2) findings from venturi meter are similar to findings from other topics. Hence, a decision was made to present data for the venturi meter.

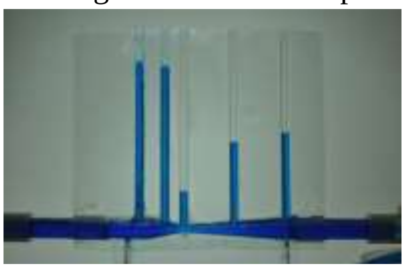

Figure 1. Venturi flow meter

Data Analysis & Results

Distributions were normal and within acceptable levels of skewness and kurtosis [10]. The reliability coefficients of sub-scales making up the survey are reported in Table 1 below. All the forms of engagement showed very good reliability coefficients except for the Active domain which is lower than 0.70 but still above 0.50.

Table 1.

Descriptive Statistics of the different forms of engagement (N = 67)

Form of Engagement	*Mean*	*SD*	*Cronbach's Alpha*
Interactive	3.91	0.53	0.70
Constructive	3.63	0.60	0.82
Active	3.90	0.47	0.57
Passive	2.58	0.85	0.81

Mean scores are out of a 5.0 with scores above 3.0 showing the benefits of LC-DLM lessons over lessons that were taught with lectures. Results from Table 1 show that LC-DLMs fostered better interactive, constructive and active engagement than lectures (mean scores > 3.0). Additional investigation shows that all but two of the participants agreed or strongly agreed that the use of LC-DLMs helped promote interactive forms of engagement such as discussion with peers, asking and answering questions and clarifying understanding with peers through robust discussions. A key feature of the venturi LC-DLM is the changing diameters. We were interested in how participants' ability to see the changing diameters in the venturi LC-DLMs helped them understand key concepts about velocity changes, energy transformations and pressure changes. Appendix B shows the descriptive statistics of participant responses on three items about the changing diameters. Results from Appendix B show that the changing diameters in the venturi LC-DLMs fostered robust understandings of velocity changes, energy transformations and pressure changes, with mean scores all > 4.0.

Some open-ended items resulted in solicitation of information about the physical features of the LC-DLMs that were helpful in engaging participants to learn venturi concepts and ways the LC-DLMs hindered or enhanced their engagement and learning. For the question "What physical features of the DLMs were helpful in engaging you to learn venturi concepts?", most of the participants reported that the visual cues afforded by LC-DLMs (particularly the ability to see the changing diameters in the venturi LC-DLM) made the venturi concepts more relatable and helped them develop conceptual understanding better than if they were had only been taught using lectures.

Discussion

This is an ongoing study that is part of a large federally-funded program of research that is rigorously examining the effects of LC-DLMs in fostering engineering students' learning, engagement and motivation. In this work in progress, we specifically examined the effects of LC-DLMs on fostering different forms of engagement. Findings show participants reported that LC-DLMs helped foster active, constructive, and interactive forms of engagement far more than lectures did. In line with extant literatures in cognitive engagement [1], it may be that the affordances of LC-DLMs especially the ability for students to manipulate the tool helped foster elaboration and self-regulation [8].

Through some of the open-ended items, we solicited information about the physical features of the LC-DLMs that were helpful in learning venturi concepts and ways the use of the LC-DLMs hindered or enhanced student engagement and learning. The majority of the participants reported that the visual cues afforded by LC-DLMs made the venturi concepts more relatable and helped them develop conceptual understanding better than if they had only been taught using lectures. This aligns with findings from Huk and colleagues [9] explicating the educational value of visual cues. In sum, this work in progress is an important step in researching different ways to foster student engagement in engineering education. Our research team is collecting more data so as to provide more robust analyses with a large sample size.

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Appendix A.
Brief description of the four levels of cognitive engagement

The Passive Mode

On the passive (P) level of engagement, Chi and Wylie [7] designated passive activities as those where students *receive* information with no expectation of interaction. Examples of passive forms of engagement include students listening to a lecture without doing anything else, reading a text passage without doing anything else or watching a video.

The Active Mode

The second mode of engagement in the ICAP hypothesis is the Active (A) form. Chi and Wylie [7] characterize an activity as "active" if students *manipulate* instructional materials or activities. Examples of active forms of engagement include students listening to a lecture and copying solution steps to a problem, underling or highlighting a text passage while reading or manipulating a tape by pausing, rewinding or fast forwarding a tape while watching a video. These behaviors are more active than the first stage, although students are still not engaged to the point of creating original information.

The Constructive Mode

The third mode of engagement in the ICAP framework is the constructive engagement (C). Learners who are constructively engaged tend to *generate* or "produce additional externalized outputs or products beyond what was provided in the learning materials" [7, p. 222]. For example, learners at this level of engagement may draw concept maps to represent what the instructor has presented orally or verbally, they may ask probing questions to understand materials at a deeper level, self-explain concepts to themselves or compare and contrast information that is being learned with prior knowledge.

The Interactive Mode

The final level of the ICAP engagement framework is the interactive engagement (I). In this mode of engagement [7], learners defend or argue a position in dyads or small groups, ask and answer questions with a partner or debate with a peer. Indeed, the distinguishing feature of this mode of engagement is the ability of learners to engage in productive *dialogue*. This allows learners to be active contributors to knowledge.

Appendix B.

Descriptive Statistics of the effects of changing diameters in the venturi LC-DLMs (N = 66)

Item	*Mean*	*SD*
The ability to see the changing diameters in the venturi DLM *helped me understand velocity changes*	4.21	0.65
The ability to see the changing diameters in the venturi DLM *helped me understand energy transformations*	4.00	0.64
The ability to see the changing diameters in the venturi DLM *helped me understand pressure changes in the venturi*	4.12	0.60