The Effects of Using Desktop Learning Modules on Engineering Students' Motivation: A Work in Progress

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Work in Progress: The Effects of Using Desktop Learning Modules on Engineering Students' Motivation

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Abstract

Various reports have been published during the past decade highlighting a wide range of problems with engineering curricula, especially the lecture-dominated form of transmitting core engineering concepts to students. Researchers have called for active learning approaches for teaching engineering courses. However, little is known about the effects of active learning approaches on students' motivation to learn engineering topics. Using data from 85 participants, the current study examined the effects of an active learning approach (using the Desktop Learning Modules - DLMs) on students' motivation and adoption of learning strategies in an engineering course compared with students who only had traditional lectures. Results from the analyses showed that participants who learned with DLMs reported statistically significant effects of DLMs for *elaboration* of core engineering ideas studied, and that DLMs fostered *peer learning* and *critical thinking* compared with lectures. No significant differences were found for intrinsic and extrinsic goal orientations, task value, self-efficacy for learning and performance as well as metacognitive self-regulation. The results are discussed with respect to their implications for instruction in engineering education.

Keywords: active learning; hands-on learning; motivation; cooperative learning

Introduction

Various reports published within the past decade highlight a wide range of problems with engineering curricula, especially the lecture-dominated form of transmitting core engineering concepts to students [1-5]. These reports also show- that students' motivation in learning engineering concepts continues to wane resulting in reduced interest in engineering careers and low student-retention in engineering programs. Researchers have proposed different approaches to tackling this problem [6-7]. Examples include research experiences for undergraduate students [6], cooperative learning [8], project-based learning [9], competency-based learning [10], service learning [19-21], experiential learning [22], and several others. Although several studies have been conducted to examine the effects of active learning approaches on student learning, little is known about how engineering students' motivation is influenced by the use of active learning

approaches. Indeed, this is an emerging area of work that has recently been given considerable attention through some proposals funded by the National Science Foundation.

The literature on active and student-centered learning approach suggests that hands-on classroom activities are more effective than lectures for teaching engineering concepts [11], especially because they promote behavioral and cognitive engagement, which are precursors to meaningful learning. As such, we envisage that using a hands-on equipment [desktop learning modules ([i]DLMs), 19-20], that we develop for learning engineering concepts would afford hands-on activities, and promote active and meaningful learning, in ways that the tradition lecture cannot afford. This paper provides highlights from a large program of research that seeks to address some of the challenges inherent in teaching engineering concepts solely through lectures. Specifically, we examine the use of desktop learning modules in fostering student learning and motivation compared with traditional lectures. More specifically, this research used the Motivated Strategies for Learning Questionnaire [8; MSLQ] in assessing engineering student motivation and the degree to which the DLMs can enhance engineering students' motivation and strategies for learning. In this study, motivation is considered as a multifaceted construct that includes goal orientations, self-efficacy, task value, anxiety, etc. These motivational variables are critical for understanding students' academic performance and choices students make in the learning process [12]. For instance, students with higher levels of self-efficacy tend to establish challenging goals and spend effort to accomplish them whereas students with lower levels of self-efficacy tend to give up easily in the face of difficulty and avoid being involved in challenging tasks.

Motivated Strategies for Learning Questionnaire (MSLQ)

Students' self-regulatory behavior has been assessed using many standardized questionnaires, including the MSLQ [8]. Although there are many standardized questionnaires used to assess student motivation to learn, the MSLQ is one of the more widely used in general education research. The MSLQ is a self-report instrument specifically designed to assess students' motivational orientations and their use of different learning strategies. The MSLQ was designed to focus on the course level, situated between the very general and global level of all learning situations and the impractical, difficult-to-measure level of transient situations within one course [9, 13, 23]. By focusing on the roles of both motivation and cognition during learning, the MSLQ reflects the research on self-regulated learning, which emphasizes the interface between motivation and cognition [14-15]. Prior research using the MSLQ has found relationships between constructs on its motivational subscales such as: intrinsic goals, extrinsic goals, task value, control of learning beliefs, self-efficacy, and test anxiety, and constructs on its use of learning strategies subscales such as: rehearsal, elaboration, organization, critical thinking, metacognitive self-regulation, time and study environment, and effort regulation [16 - 17] . As widespread as the use of MSLQ is in educational research, its use is very limited in engineering education research even though it has been recognized as a viable instrument to help explicate student motivation [10]. We used MSLQ in the current study to research the relationships between all the constructs delineated above to investigate how motivational and learning strategy use might influence the learning process in DLM facilitated classrooms.

Active Learning Using the Desktop Learning Modules (DLMs)

The DLMs used in the engineering classrooms were developed as part of a large program of research. They are intended to be miniaturized versions of industry-type equipment that can be used to illustrate engineering concepts in the classroom- fluid mechanics and heat transfer in this case. The module consists of a base unit with rechargeable batteries, fluid reservoirs, pumps and tubing, and receptacle ports to which different detachable equipment cartridges can be installed (e.g. venturi, orifice and packed/fluidized bed cartridges) depending on the instructional need. Also connected to the base units are digital displays to monitor readings (e.g. differential pressure and stream temperatures) and a rotameter to control readings.

Figure 1 below shows a typical DLM with heat exchanger cartridge installed. The module consists of two reservoirs (Tanks A & B), and a pump, rotameter, gate valve, and thermocouples for inlet and outlet ports to be selected for each reservoir. Power is supplied to the pumps and thermocouples via the rechargeable batteries attached.
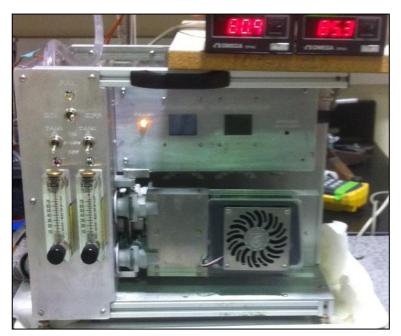

Figure 1. Front view of the Desktop Learning Module (DLM) with an extended area heat exchanger cartridge.

Objectives of the Study

Our objective is to examine how active learning approaches (in this case with the use of DLMs) influence students' motivation for learning engineering topics. Based on the socio-cognitive perspective of motivation and self-regulated learning, student motivation for learning is positively associated with their ability to self-regulate their learning abilities [18]. This view assumes that "motivation is dynamic and contextually bound and that learning strategies can be learned and brought under the control of the student" [12; p. 117]. First, we predict that the use

of DLMs will significantly improve students' motivation for learning and learning strategies compared to only listening to lectures. Specifically, we expected that active learning using DLMs will improve students' perception of task value, goal orientations and self-efficacy for learning and performance, which are important measures of motivation. Second, because measures of motivation are positively associated with learning strategies [18], we predicted that the use of DLMs will have more impact on the learning strategies of student in the DLM groups compared to students who only had lectures.

Method

Participants

The study reported in this paper was conducted in a semester-long course in a junior-level Mechanical Engineering class, ME301 Fundamentals of Thermodynamics, offered in fall 2014 at a large public university in the Pacific Northwest. This is the first fluid mechanics course that mechanical engineering students in the university are required to take. Data from two different sections of the fall 2014 course are reported in this paper. The first section of the course had 51 participants who used the DLMs to learn about fluid mechanics (treatment group) while 34 students in another section learned about fluid mechanics only through lectures (control group). Each class met three times a week for 50 minutes.

Materials

The DLMs used in this study were developed for fluid mechanics and heat transfer. The participants' self-reported motivation and learning was measured by four motivational subscales and four cognitive subscales selected from the MSLQ: intrinsic goal orientation (4 items), extrinsic goal orientation (4 items), task value (4 items), and self-efficacy for learning and performance (6 items). The four learning strategies subscales used in this study were elaboration (6 items), critical thinking (4 items), metacognitive self-regulation (4) and peer learning (3 items). Participants responded to each statement using a 7-point Likert scale (1 = not at all true of me, 7 = very true of me) in terms of their motivation and learning behavior in the course using the DLMs.

Procedure

The study was conducted throughout one semester. Both groups received lectures on the same topics in thermodynamics over the course of the semester. However, the experimental group was taught certain topics with the use of DLMs. The instructor facilitated each lesson around different concepts the DLMs were supposed to emulate, as participants worked in groups. . Data were collected at the end of the 15-week course to evaluate the type of impact the use of DLMs had on the experimental group. Participants in both groups were asked to self-report their motivation and learning using the MSLQ. The survey was administered with the Qualtrics© (Utah, U.S.A.) online survey tool.

Data Analysis & Results

Before data analyses, we examined the distribution for outliers and normality. In the preliminary analysis, we explored the frequency distribution of participants' responses to items on the survey about the reason for taking the class to examine if there were differential patterns in responses across the two groups. A visual inspection indicated that responses were homogenous for all participants except for items asking if the *"class-content seemed interesting"* and class *"is required of all students in the college."* Pearson's Chi-square test of independence was performed on these items, and an item the *number of hours student worked* to confirm if they needed to be included as covariates in the primary analysis (model) – statistically significant difference between the lecture and DLM groups on these three items could indicate that the items might be interacting with other constructs of motivation and learning strategies measured in the study. The test indicated there were no significant differences between the DLM and Lecture groups on these items (*p = .60, .38* and *.22* respectively). We also conducted analysis of internal consistency of subscales on the surveys to assess the reliability of the subscales. Internal consistency is a reliability measure that simply estimates how correlated different items that are supposed to be measuring the same construct are [21]. An instrument with Cronbach alpha of 0.7 and above is generally considered having a good reliability, while alphas below 0.5 are unacceptable. Overall Cronbach's alpha for all items of the survey was .79. Computed Cronbach's alpha for each subscale is reported in Table 1. In the primary analysis, we conducted a one-way multivariate analysis of variance (MANOVA) to examine differences between the two groups on all the constructs measured.

Table 1. Reliability of Subscales

Sub-Scales	Mean	SD	Cronbach's α
Intrinsic Goal Orientation Rehearsal	5.35	0.83	.59
Extrinsic Goal Orientation	5.54	1.06	.67
Task Value	5.39	1.12	.82
Self-Efficacy for Learning & Performance	5.25	1.18	.89
Elaboration	5.15	0.98	.71
Critical Thinking	4.99	1.00	.72
Metacognitive Self-Regulation	4.65	0.87	.45
Peer Learning	4.83	1.29	.74

Mean of items on measured Likert value (1 -7)

Descriptive Statistics from Survey Data

Table 2 shows the means and standard deviations for the four motivational and four learning strategies constructs measured by the survey. High mean on the subscales used is indicative of

construct desirability. Using Pillai's trace (used in place of Wilks's λ because of large disparity in sample size between the groups), the MANOVA analysis found statistically significant differences in group scores on the strategies for learning sub-scales between the DLM and Lecture groups, $V = 0.338$ $F(8, 76) = 4.859$, $p < .0001$; partial $\eta2 = .338$. Mean scores for the both DLM and Lectures groups are considerably high for the motivational sub-scales, while the DLM group was higher than the Lecture group on the strategies of learning sub-scales.

Table 2. Descriptive Statistics

| *Measures* | **DLM Group** | | | **Lecture Group** | | | *Effect Size* | *p* |
	Mean	*SD*	*n*	*Mean*	*SD*	*n*	*d*	
Extrinsic Goal Orientation	5.58	0.88	51	5.48	1.30	34	0.08	0.69
Intrinsic Goal Orientation	5.46	0.85	51	5.19	0.80	34	0.03	0.14
Task Value	5.33	1.26	51	5.48	0.88	34	-0.01	0.56
Self-Efficacy for Learning and Performance	5.34	1.31	51	5.13	0.94	34	0.18	0.43
Elaboration	5.45	0.81	51	4.70	1.06	34	0.82	0.00*
Peer Learning	5.12	0.99	51	4.38	1.55	34	0.59	0.01*
Critical Thinking	5.31	0.90	51	4.51	0.97	34	0.86	0.00*
Meta-cognitive Self-Regulation	4.75	0.84	51	4.50	0.91	34	0.28	0.20

Mean of items on measured Likert value (1 -7)

* p < .05

We did not find any statistically significant differences between the DLM and Lecture groups on *Intrinsic goal orientation* ($F(1, 83) = 2.24$, $p = .14$), *Extrinsic goal orientation* ($F(1, 83) = .16$, $p = .69$) and *Self-efficacy for learning and performance* ($F(1, 83) = .63$, $p = .43$) sub-scales, thus suggesting that both groups were not significantly different in their motivations and self-efficacy. Although we expected DLM use to promote task value, results did not show any significant difference among the groups ($F(1, 83) = .35$, $p = .56$). On the other hand, students who used the DLMs reported improved learning strategies specifically on three measures: *Elaboration* ($F(1, 83) = 13.58$, $p < .001$, Cohen's $d = .82$), *Peer Learning* ($F(1, 83) = 7.21$, $p < .001$, Cohen's $d = .59$) and *Critical Thinking* ($F(1, 83) = 15.11$, $p < .001$, Cohen's $d = .86$) as predicted. These were all statistically significant showing an advantage of using the DLMs. No statistically significant differences were found for intrinsic and extrinsic goal orientations, task value, self-efficacy for learning and performance as well as metacognitive self-regulation ($p > .05$), although we observed a pattern with the DLM group having higher ratings than the Lecture group on most of these sub-scales.

Discussion

This study is part of a large federally-funded program of research that is examining the effects of using an active learning approach (DLMs) in fostering engineering students' self-reported motivation and learning strategies. Considering the role that motivation plays in the choice of learning strategies that student adapt and how these influence learning, this work-in-progress (study) fills an important gap in engineering education literature. Results showed that participants who learned with DLMs reported statistically significant effects of DLMs for *elaboration* of core engineering ideas studied, and that DLMs fostered *peer learning* and *critical thinking* compared with lectures. These results, albeit preliminary, suggest that the use of active learning approaches like the DLMs might be associated with increased use of elaboration strategies when learning engineering concepts. Elaboration strategies enable students to build internal connections between concepts being learned [8] and have been found to be positively associated with critical thinking skills [22]. This could be an important advantage of using the DLMs as one primary goal of engineering education is to present information to students in such a way that they can elaborate on and think critically about the information [3-5].

Participants also reported that the use of DLMs afforded them the opportunity to learn in a group. Although group learning needs to be properly structured to leverage its inherent benefits, this result is also very important. There is plentiful evidence that peer learning is a powerful learning approach [23]. These results are promising and should be further explored in future studies.

No significant differences were found for intrinsic and extrinsic goal orientations, task value, self-efficacy for learning and performance as well as metacognitive self-regulation, although we observed a pattern with the DLM group having higher ratings than the Lecture group on most of these measures. Goal orientation of participant might not have been impacted very much because of limited exposure to DLM sessions and student's prior motivation to high grades at completion of the class. A within study design investigating motivational changes over time would be useful in future explorations. It is not surprising that we did not find a significant difference in task value between groups considering our findings about goal orientation. Indeed, task value has been found to highly correlate with intrinsic motivation and self-efficacy for learning and performance [22]. Although we found no significant difference between groups on meta-cognitive self-regulation, results showed that the DLM group had a high score ($M = 4.75$) on that construct than the lecture group did ($M = 4.75$). Again, this is not surprising considering the poor reliability of the instrument on that measure (Cronbach's $\alpha = .45$). Future studies may further examine the effects of using DLMs on these motivational constructs and investigate the degree to which these factors predict student academic performance.

In sum, this work has the potential to open up frontiers of new knowledge about engineering student motivation with hands-on active learning approaches, like the DLMs. Future work may strategically explore the degree to which student motivation with the DLMs will predict recruitment and retention of students into engineering disciplines.

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