AC 2008-1196: EFFECTS OF SUPPLEMENTAL LEARNING OPPORTUNITIES DESIGNED TO ENGAGE DIFFERENT LEARNING STYLES

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Effects of Supplemental Learning Opportunities Designed to Engage Different Learning Styles

Abstract

We provided a series of one-hour supplemental learning opportunities (SLOs) outside of, but coordinated with, a sophomore-level engineering problem-solving course. The SLOs were designed to engage different aspects of active/real-world learning style preferences by adopting one of two approaches: 1) a structured and engaging classroom lecture environment with on-paper, problem-solving exercises, or 2) a hands-on, kinesthetically-active laboratory environment with integrated on-paper, problem-solving exercises. Pre- and post-SLO assessments revealed that students learned from both types of SLOs. Analysis of course exam grades revealed that students who attended one type of SLO did not consistently outperform students who attended the other type of SLO. Students whose preferences for sensory learning (as indicated by their scores on the Index of Learning Styles) were most strongly matched by the style of their SLO group (i.e., strongest sensory preferences attending kinesthetically active SLOs, and least sensory preferences attending classroom active SLOs) performed better on course exams than students with moderate sensory learning preferences attending either SLO group, and better than students whose preferences for sensory learning were least matched by the style of their SLO group. In some cases, the observed performance differences were statistically significant, although the mean grade point averages of students in the strongest, moderate, and least-matched groups were not statistically significant. Further analysis should help reveal to what degree student performance was related to learning style and SLO style match as opposed to other factors.

Introduction

The idea of using varied teaching styles in order to engage multiple learning styles in order to improve student learning is firmly grounded in theory[1, 2], and has caused us to consider carefully how we teach ES201 ("Conservation and Accounting Principles"), the foundational engineering course at Rose-Hulman Institute of Technology. This course teaches a systems, modeling, and accounting approach to engineering problem-solving, and so emphasizes both mathematical skills and physical insight. Because the course has no hands-on laboratory component, we wondered if there were ways to help our students better gain the physical insights embedded in the course learning objectives. We also wondered if we were adequately engaging the learning styles of students who learn best by actively doing real-world things.

The literature generally supports the idea that using various forms of active learning will increase student engagement and promote learning (for an overview, see reference 3, for a representative study, see references 4 and 5). Just as there are many instructional approaches that can be considered "active learning" (see reference 3), there are many inventories of learning styles that address various aspects of the broad term "active learning." For example, the VARK guide to learning styles[6, 7] describes a broad "Kinesthetic" learning style as the style of someone who prefers to learn from experience or practice; someone who focuses on real-world things. The Index of Learning Styles (ILS)[8, 9] system separately considers preference for "Active" learning, or learning by actively doing things (as opposed to "Reflective" learning, in which someone prefers to learn through quiet reflection), and the preference for "Sensory" learning, in which someone prefers to focus on and recalls information gained from their senses through real experiences (as opposed to "Intuitive" learning, in which someone prefers to focus on and recall theories, concepts and ideas that are not necessarily grounded in real experience). Individuals with Kinesthetic, Active, and Sensory learning styles are, in theory, poorly served by traditional classroom lecture environments. Instructional strategies that incorporate various forms of active learning may help individuals with these learning style preferences.

We therefore provided a series of supplemental learning opportunities (SLOs) outside of (but coordinated with) the ES201 class to selected students as described in the Methods section below, to engage different aspects of active/real-world learning preferences. We are seeking evidence (assessment results, exam scores, course grades) of improvement in engineering problem-solving skills attributable to either or both of these two active learning SLO approaches: 1) a well-structured and engaging classroom lecture environment with on-paper, problem-solving active learning exercises, and 2) a hands-on, kinesthetically-active laboratory environment, emphasizing concept understanding and integrating on-paper, problem-solving exercises.

Methods

All students enrolled in the Fall 2007 offering of ES201 at Rose-Hulman Institute of Technology[10] were invited via email to apply to participate in this research project. Students gave informed consent for participation (Institutional Review Board approval #RHS0068) and completed the Index of Learning Styles[9] (ILS; Copyright © 1991, 1994 by North Carolina State University; authored by Richard M. Felder and Barbara A. Soloman) and the VARK questionnaire[7] (VARK copyright version 7.0 (2006) held by Neil D. Fleming, Christchurch, New Zealand and Charles C. Bonwell, Green Mountain Falls, Colorado 80819 U.S.A.) on a protected internal web page. Each student's score in the ILS Active domain, in the ILS Sensor domain, and in the VARK Kinesthetic domain was used, along with each student's cumulative grade point average, gender, primary academic major, and ES201 course instructor, to assemble two experimental groups of thirty students. Students who volunteered to participate in the study but who were not selected for an experimental group received a thank-you note and a bag of candy in their campus mailbox.

One group of students attended "classroom active" SLOs, or SLOs taught in a structured classroom environment using active learning techniques. The professor leading this session routinely called on students by name to answer questions, and students in this session completed on-paper problem-solving exercises. Students in the classroom active SLOs were, therefore, active participants in a classroom environment. The other group of students attended "kinesthetic active" SLOs, or SLOs taught as hands-on laboratory exercises with short demonstrations and lecture explanations. The two professors who led this SLO group interacted with students as they worked in teams to complete activities and on-paper problem solving exercises. Students in the kinesthetic active SLOs were therefore active participants in a learning environment which required them to be physically active, primarily doing things with their hands, and secondarily solving problems on paper. All three professors who taught the SLOs routinely teach the ES201 course, and receive excellent student evaluations of teaching for their offerings of ES201.

Five one-hour SLOs of each type were held during the 10-week Fall 2007/2008 quarter: the first two SLOs occurred before the first ES201 course exam, the next two SLOs occurred before the second course exam, and the last SLO occurred before the third exam. Students who attended all five SLOs were compensated $100 for their time; students who attended four SLOs received $65, and students who attended three or fewer SLOs received no monetary compensation. Both types of SLOs were held on Tuesday evenings from 6:00 - 7:00 p.m.; the classroom active SLO group met in a traditional classroom setting (students sitting in rows, facing the instructor) and the kinesthetic active SLO group met in a teaching laboratory (students facing each other around tables, moving to use equipment and to occasionally face the instructors). The kinesthetic active SLOs activities are described in detail elsewhere[11].

All SLO instructors worked from the same general learning objectives and coordinated the SLO activities and example problems so that both groups of students were exposed to similar terminology. For example, when the kinesthetic active SLO group used skateboards in a hands-on exercise illustrating kinetic friction, the classroom active SLO group solved a problem on paper that involved skateboards and kinetic friction. Care was taken to choose examples and terminology that would be accessible to students regardless of gender, ethnicity, and academic major. For example, stickers of young white male ‘skater dudes’ on skateboards used in the kinesthetic active section were covered over with Rose-Hulman stickers. Common household appliances (e.g., toasters, hair dryers) were used as examples, rather than industrial equipment, military fighter jets, etc.

Students in both SLO groups completed a short assessment quiz/survey (for some sessions, pre- and post-session assessments were administered) after each SLO. Students in both SLO groups completed the same assessments. The SLO instructors did not see the assessments prior to the sessions. Another professor (who also routinely teaches the ES201 course) met with the SLO instructors to confirm their learning objectives and activities, and created and scored the assessments.

Data from students who completed fewer than four SLOs were not used for this report.
For analysis purposes, SLO assessment results were grouped by: SLO type; degree of preference for kinesthetic learning (assessed using the VARK instrument; degree of preference for active learning (assessed using the ILS); degree of preference for sensory learning (assessed using the ILS). The specific numerical values used to create these groups, which were chosen to ensure that at least five students would be in any given analysis group, are shown in Table 1.

Table 1. Assessment scores used to group SLO assessment data for analysis.

	Learning Style		
	Kinesthetic	Active	Sensory
Assessment Instrument and Domain	VARK, Kinesthetic	ILS, Active	ILS, Sensory
Scores for Degree of Preference: ***Strongest***	5 or more	8 or more	8 or more
Least	2 or less	4 or less	5 or less
Moderate	all other scores	all other scores	all other scores

Scores on each of the ES201 course exams were collected for all students who were enrolled in the Fall 2007 offering of ES201, regardless of whether they participated in the experimental

SLOs or not, and transcripts of all of these students will be collected after the completion of the 2007/2008 academic year (IRB approval #RHS0069). This paper will focus on initial analyses which were conducted using data from the course exams, primarily the first exam, and which were intended to identify areas of interest for subsequent investigations using the full data set. For these initial analyses, a control group of size comparable to the SLO groups was created by randomly selecting five students each (none of whom participated in the SLOs) from ES201 sections taught by six different instructors. To account for potential differences in the two versions of the first course exam that were given (a morning and an afternoon version), individual exam scores were transformed into z scores, using the mean and standard deviation of either the morning or the afternoon exam scores as appropriate.

Results and Discussion

Thirty students were originally selected to participate in each SLO group, and twenty-five students in each SLO group attended four or more SLO sessions. Demographic characteristics of these students are given in Table 2, which shows that the SLO groups were well-matched.

Table 2. Demographics of SLO groups. Specific course instructors are represented by letters for anonymity.

	Kinesthetic Active	Classroom Active		Kinesthetic Active	Classroom Active
Number of Students	25	25	Percent Female	40%	44%
Grade Point Average:			Primary Majors:		
Mean	2.93	3.05	*Biomedical Engineering*	6	8
Median	3.09	3.03	*Computer Engineering*	2	2
Maximum	4.00	3.98	*Electrical Engineering*	6	3
Minimum	2.08	2.09	*Engineering Physics*	1	1
Course Instructors:			*Mechanical Engineering*	10	11
A	5	4	Learning Styles:		
B	4	3	*Moderate-Strong Kinesthetic*	19	17
C	3	0	*Moderate-Strong Active*	20	19
D	3	2	*Moderate-Strong Sensing*	19	17
E	3	4			
F	2	2			
G	3	4			
H	2	6			

Differences in performance (across SLO groups) on individual SLO assessment items were detectable when the individual items were strongly consistent with the nature/activities of one or the other SLO session. These results indicate the importance of matching learning goals, assessment strategies, and learning practice. However, neither SLO group consistently outperformed the other group, and overall assessment scores were generally similar across both sections. Assessments that were administered both before and after SLO sessions showed improved post-session scores, indicating that students in both types of SLOs learned from these sessions.

Matching learning style preference and SLO style seemed to be most important when matching preference for sensory learning, rather than matching preferences for active or kinesthetic learning. In the kinesthetic active SLO, students rated with the strongest and moderate preferences for sensory learning outperformed students with the least preferences for sensory learning on five of six assessments. In the classroom active SLO, the moderate and least sensory learners outperformed strong sensory learners in all six assessments. However, these performance differences were statistically significant ($p < 0.025$, Kruskal-Wallis test) for only one SLO assessment. Ratings of preference for sensory learning were not correlated with overall grade point average, gender, ES201 course instructor, or primary academic major. Students with preferences for active learning seemed to be well-served by both SLO types. Detailed analyses and discussion of the SLO assessment results are reported elsewhere[12], and so are omitted here.

On the first ES201 exam, students in the classroom active SLO group outperformed students in either the kinesthetic active SLO group or the randomly-selected control group (Figure 1); these differences were not statistically significant. These differences were not apparent on the second and third course exams, for which the performance of students across all groups were essentially the same. No group significantly outperformed any other group on the final exam (Figure 2). The majority of the points on all course exams and the final exam were devoted to quantitative engineering problem-solving, just as was emphasized in the classroom active SLO group.

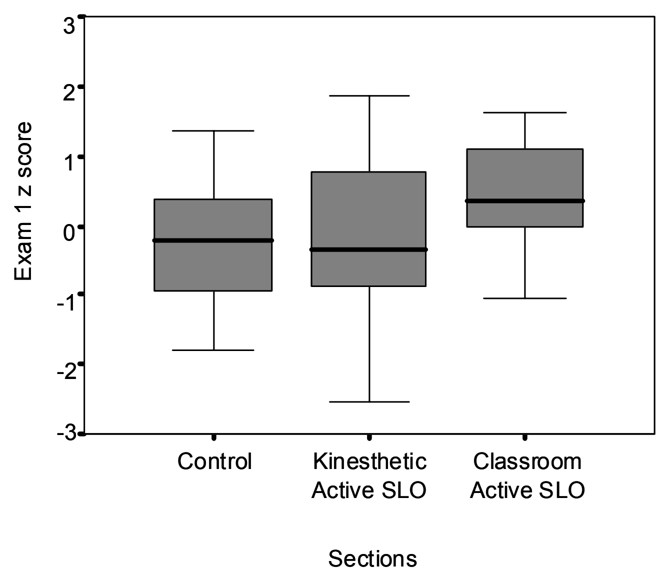

Figure 1. Performance of SLO groups on first course exam. $n = 30$ (control); $n = 25$ (each SLO group).

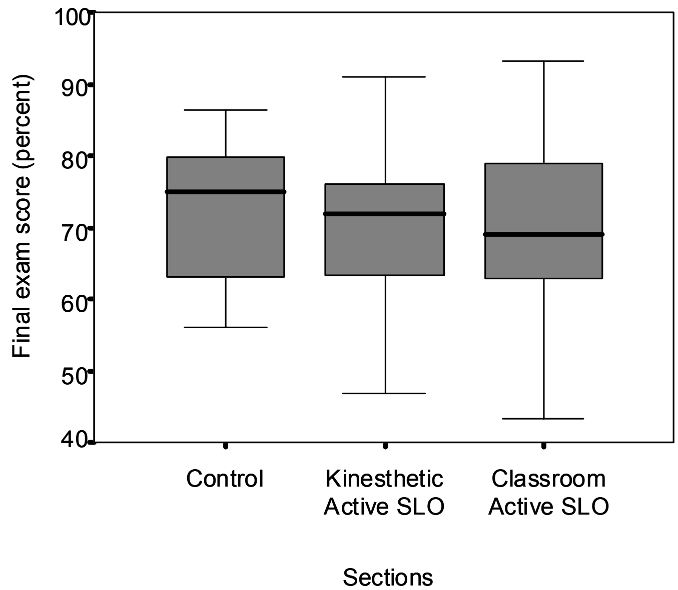

Figure 2. Performance of SLO groups on course final exam. $n = 25$ (control); $n = 23$ (kinesthetic active SLO group); $n = 25$ (classroom active SLO group).

Within students who attended four or more SLO sessions, scores on the first course exam were weakly correlated with overall grade point average (Spearman's rho = 0.404, $p < 0.01$), as might be expected. Student scores on the first course exam were not related to student scores on the first two SLO assessments. Since these assessments were not useful predictors of student performance on the first course exam, the utility of such assessments may be simply in providing feedback to SLO instructors, and in assessing very specific skills across SLO groups. No significant differences in performance on the first course exam were detectable when SLO-attending students were grouped by ES201 course instructor. Omitting students majoring in Engineering Physics (since $n = 2$), no significant differences in performance on the first course exam were detectable when SLO-attending students were grouped by primary academic major. Although the mean cumulative grade point averages of SLO-attending female and male students were essentially the same, female students performed slightly, but not significantly, worse than male students on the first course exam (Table 3).

Table 3. Grade point averages and first course exam performance of male and female students. Data are means ± standard deviations; $n = 21$ (females), $n = 29$ (males).

	Cumulative grade point average	Exam 1 z score
Females	3.06 ± 0.54	- 0.14 ± 1.19
Males	3.04 ± 0.56	0.10 ± 1.09

Within SLO-attending students, no significant differences in exam scores were detected between students with the strongest, moderate, and least preferences for kinesthetic learning, or between students with the strongest, moderate, and least preferences for sensory learning. Within students who attended four or more SLO sessions, students with moderate preferences for active learning significantly outperformed ($p < 0.4$, Mann-Whitney test) students with the strongest preference for active learning (Figure 3). It is possible that students with moderate preferences for active learning were able to benefit from both types of SLOs (since both required active learning, one in a hands-on sense and one in a "minds-on" sense), and were additionally better able to learn from the traditional classroom environment than students with strong preferences for active learning. The results shown in Figure 3 are related to the results shown in Figure 1. The kinesthetic active SLO group contained more students with the strongest preferences for active learning (10, versus 6 in the classroom active group) and fewer students with moderate preferences for active learning (10, versus 13 in the classroom active group). Further analysis is needed in order to determine whether the classroom active SLO benefited student learning in a way that was detectable on the first course exam, or whether some aspect of a moderate preference for active learning benefited student learning in a way that was detectable on the first course exam.

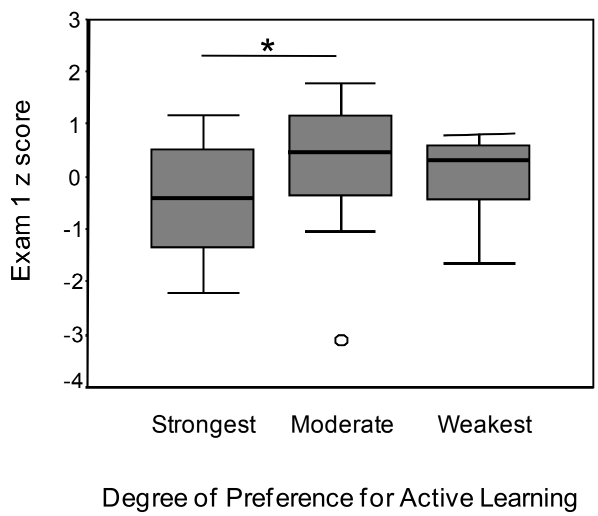

Figure 3. Performance on first course exam as a function of strength of preference for active learning. °: statistical outlier. *$p < 0.04$, Mann-Whitney test; $n = 16$ (Strongest preference), $n = 23$ (Moderate preference), $n = 11$ (Weakest preference).

Students whose preferences for sensory learning were matched by the style of their SLO group (i.e., students with the strongest preferences for sensory learning attending the kinesthetic active SLO; students with the weakest preferences for sensory learning attending the classroom active SLO) performed better on the first course exam than students with moderate preference for sensory learning attending either SLO group, and better than students whose preferences for sensory learning were mismatched by the style of their SLO group (Figure 4). These performance differences were not statistically significant. The trend displayed in Figure 4 also occurred in the data from the second and third course exams, as well as the final exam, on which students whose preferences for sensory learning matched their SLO style significantly ($p < 0.01$, Mann-Whitney test) outperformed students whose sensory learning preferences did not match their SLO style (Figure 5).

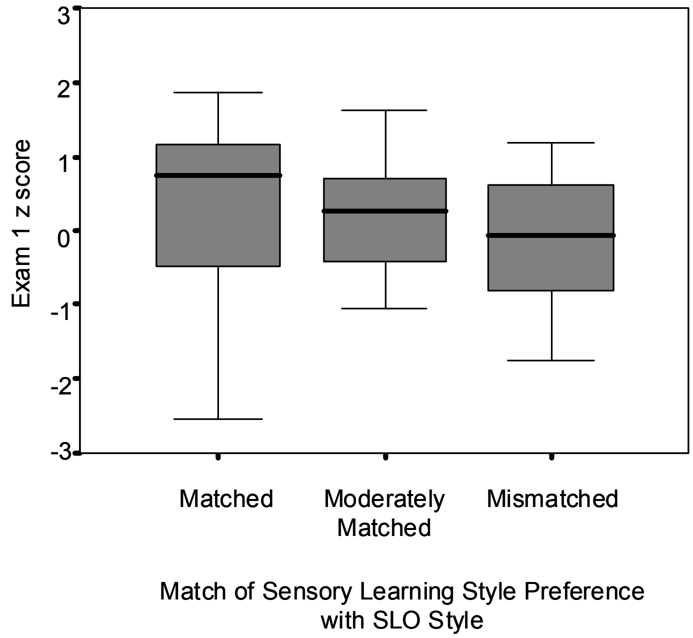

Figure 4. Performance on first course exam grouped by degree of match between preference for sensory learning and SLO style. $n = 20$, "Matched" (strongest sensory preference and kinesthetic active SLO, or least sensory preference and classroom active SLO); $n = 13$, "Moderately Matched" (moderate sensory preference and either SLO); $n = 17$, "Mismatched" (least sensory preference and kinesthetic active SLO, or strongest sensory preference and classroom active SLO).

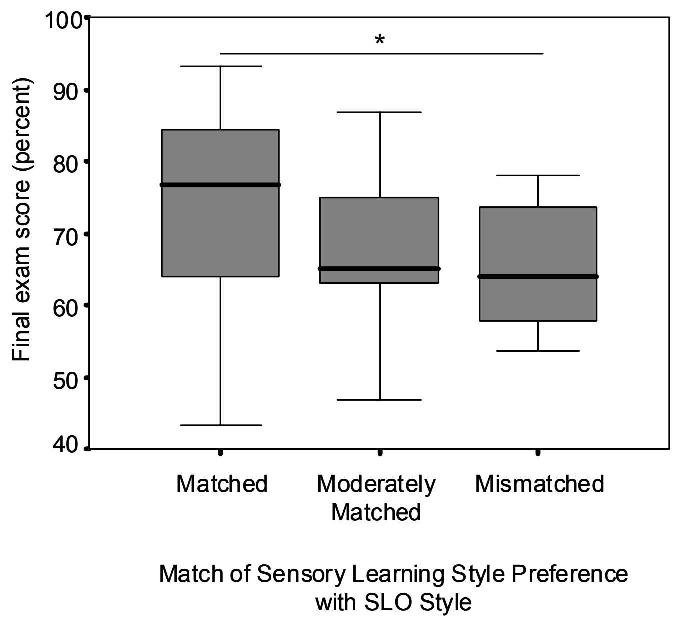

Figure 5. Performance on course final exam grouped by degree of match between preference for sensory learning and SLO style. *$p < 0.01$, Mann-Whitney test; $n = 18$, "Matched" (strongest sensory preference and kinesthetic active SLO, or least sensory preference and classroom active SLO); $n = 13$, "Moderately Matched" (moderate sensory preference and either SLO); $n = 17$, "Mismatched" (least sensory preference and kinesthetic active SLO, or strongest sensory preference and classroom active SLO).

Clearly, a number of factors beyond the matching of learning style preference and SLO type could have influenced the trend shown in Figures 4 and 5 (personality issues, study habits, etc.). For example, the mean GPA of students in the "Matched" group was slightly, but not significantly, higher than the mean GPA of students in the "Moderately Matched" or "Mismatched" group (3.19 versus 2.92 and 2.98, respectively). One might anticipate that students with higher overall grades would have better study habits and would therefore be expected to perform better on any given final exam. Future study utilizing closer matching of mean (and maximum/minimum) GPAs across the groups represented in Figures 4 and 5 should help separate potential effects of overall academic skills versus effects of targeted supplemental learning opportunities.

Conclusions

A number of caveats should be acknowledged when considering the results of this study. The population size of this study was small, and this study examined only one offering of only one course. The SLO activities and examples were created specifically for this study; because the kinesthetic active SLOs were a major departure from standard ES201 teaching practices, they and the SLO assessments may need refinement. The primary, original purpose of both the VARK and the ILS instruments is to help people identify study strategies likely to be effective for their individual learning styles. This study did not examine the helpfulness of different study strategies, but instead sought evidence of the helpfulness of teaching strategies – a logical and related, but secondary application of these instruments. Overall, however, evidence indicates that students successfully learned engineering problem-solving skills from SLOs structured as either a classroom active learning environment or as a kinesthetic active learning environment. It may be possible that some aspect of having a moderate (rather than strong) preference for active learning may benefit student learning in a way that is detectable in exam scores. Scores on all three course exams and on the course final exam demonstrated the same trend in which the degree of match between sensory learning preference and SLO style was related to exam performance. Further analysis is required to determine how much of this trend is related to learning style and SLO style match, and how much of this trend is related to other factors. As this project continues, we will continue to seek evidence of possible effects of supplemental learning opportunities that engage different student learning styles.

Acknowledgments

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