AC 2008-1404: STUDENT STUDY HABITS AND THEIR EFFECTIVENESS IN AN INTEGRATED STATICS AND DYNAMICS CLASS

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Student Study Habits and their Effectiveness in an Integrated Statics and Dynamics Class

Abstract

Integrated Statics and Dynamics is a required five-credit course that was offered for Mechanical Engineering students at Clemson University for the first time in Fall 2006. The large-enrollment course was taught using innovative active learning techniques and new course materials. To aid in the development of the course, 211 students were asked to self-report their study habits in an 8 question survey. A cluster analysis was used to identify three study habit profiles. Knowing how students allocate their time and the effectiveness of their strategies can promote more effective guidance for students who are struggling to learn the material while managing their time, and could drive course design with proper emphasis on each aspect of coursework.

I. Introduction and Background

In Fall 2006, an active-learning approach modeled after Beichner and colleagues' SCALE-UP method[1] was implemented at our institution to teach sophomore Mechanical Engineering students statics and dynamics in one integrated course. A cluster analysis of survey data allowed us to identify three patterns of study among the students; minimalist, help seeker, and SI dependent. The goal of this exploratory research is to identify study habit profiles in order to support course development and create plausible hypotheses for further research into pedagogical innovations.

<u>Course Description</u>

Integrated Statics and Dynamics is a required five-credit course required for Mechanical Engineering students at Clemson University. The large-enrollment course is taught using innovative active learning techniques[1,2] and new course materials[3]. The class meets for nearly six hours a week in a studio-style classroom with 7-foot-diameter round tables seating up to nine students. Lecture time has been transformed into studio time that allows students to work on learning exercises together in class while the instructor and several learning assistants are present to guide them. Statics is taught as a special case of dynamics. Within the first week, students are analyzing the dynamics of lifting.

Because Statics and Dynamics courses historically have high DFW rates (percentage of students receiving a grade of D or F or withdrawing from the course), the Academic Success Center provides Supplemental Instruction (SI) for these classes. A traditional class would have one undergraduate SI leader who would attend all classes and then facilitate study sessions several nights a week. Often theses sessions consist of the SI leader helping the students work through their homework. Because Integrated Statics and Dynamics is a large enrollment class that meets more frequently than traditional classes, the SI system had to be modified to ease the load of the SI leaders. Multiple SI leaders served as learning assistants in each class, and a joint session was held for all three sections several nights a week. This resulted in smaller time commitments for the SI leaders, but very large SI sessions.

Cluster Analysis

Cluster analysis is the process of uncovering natural groupings in data[4] by clustering objects (students in this case) according to attributes (the students' study habits in this case). Each survey item is essentially a dimension in space and a student's responses to the survey questions are her coordinates. These coordinates can be used to calculate the Euclidian distances between students. Although many variations are possible, there are two major types of clustering; hierarchical and partitioning. A typical agglomerative hierarchical clustering algorithm computes the distance between every pair of objects and then groups the two closest. This process is repeated until all the objects are grouped together. The result is a multi-level hierarchy of groups. K-means clustering is a common partitioning method. The objects are randomly partitioned into K clusters and the centroid or average of each cluster is computed. Each point is then reassigned to the cluster with the closest centroid. The centroids are recomputed and the process is repeated.

II. Methods

An integrated Statics and Dynamics course was developed, and is a requirement for students majoring in Mechanical Engineering. There were three sections of the course each semester with enrollments ranging from 33 to 66 students per section. In the Fall semesters of 2006 and 2007, all students in the course were given a voluntary survey consisting of 8 questions during the last week of class. The surveys were administered by a teaching assistant while the instructor was not in the room. Students were asked only to write their student number on the survey. Two hundred and eleven students completed the survey; 169 students selected at least one of the multiple choice answers for each of the questions. Write-in answers were also accepted, but they were not used in this analysis. All methods were approved by the Institutional Review Board; confidentiality of student identities and survey responses was maintained throughout the study.

Coding

Quantitative analysis of the survey responses varied depending on the format of the question. The first survey question was regarding homework, with 6 close-ended and one open-ended response choices:

1) I did the homework for this class (circle all that apply)
   a) by myself
   b) with help from my team or table
   c) with help from classmates not at my table
   d) at SI
   e) with help from the instructor
   f) during class
   g) other:______________________

Since the students were asked to circle all that apply, each choice (a-f) was scored separately with a 1 if it was circled and a 0 if it was not.

The remaining questions were scored by ranking the choices. This was done for clustering purposes so that the value for someone who "always or almost always" does the homework is closer to someone who "usually" does the homework than to someone who only "occasionally" does the homework. For simple interpretation, the highest values are associated with those habits traditionally considered the most prudent. For example, in question 2 shown below, choice a) always or almost always was assigned 4 points while answer d) never or almost never was assigned 1 point.

2) I did the homework
   a) always or almost always
   b) usually
   c) occasionally
   d) never or almost never
   e) other: ______________________

The remaining questions were scored in a similar manner. The questions and point values are given in the appendix. The survey given to the students did not include point values. Question 5 regarding journal questions was not used for clustering the data because of ambiguous wording, and because completion of the journal questions was required for the 2006 class but optional for the 2007 class.

The dependent variables used in the study were incoming GPR, course grade, and grade differential, as well as pre-scores, post-scores, raw gains, and normalized gains on the Statics Concept Inventory[5] (SCI) and the Dynamics Concept Inventory[6] (DCI). A grade differential was calculated as the difference between the course grade and the previous semester GPR. This normalized differences between incoming GPR for different clusters. Raw gains are calculated as post-score minus pre-score. Normalized gains are calculated by dividing the raw gain by the maximum possible gain (points possible minus pre-score).

Cluster Analysis

Twelve dimensions were used for the cluster analysis. Six were the binary items from question 1, and six were ordinal scores from questions 2, 3, 4, 6, 7, and 8. Since the scales varied the scores were standardized to have a mean of zero and a standard deviation of 1. Both hierarchical and K-means methods were used to cluster the students using MATLAB[7]. Since K-means groupings can vary due to random starting points, 100 replicates were used to find the best solution for 2,3,4,5, 6, and 12 clusters. However, the chosen solution was consistently found with as few as 10 replicates.

Based on average silhouette values, the 3-cluster K-means grouping was selected (average silhouette value 0.3365). Cluster 2 of the chosen decomposition was very consistent. It appeared in hierarchical groupings as well as K-means groupings of various sizes. Analysis of variance (alpha=0.05) was used to determine whether at least one of the groups was different for each independent and dependent measure. Ten of the 12 dimensions used for clustering showed significant differences.

III. Results

Clusters

Table 1 gives the mean values of responses to the survey questions for each group. Brief descriptions of each groups study habits are below. Due to the binary nature of question 1, the averages for items 1a through 1f also represents the proportion of students who reported each behavior.

Table 1: Average survey response values by cluster (followed by standard deviation). Means with common super scripts are not significantly different based on ANOVA and Fisher's Least Significant Difference Test (alpha = 0.05)

Cluster	1a. Did HW alone**	1b. Did HW with help from team or table**	1c. Did HW with help from other classmates**	1d. Did HW at SI**	1e. Did HW with help from the instructor**	1f. Did HW during class**	2. Homework Frequency**	3. Reading Frequency**	4. Reading Depth	6. SI Attendance**	7. Time spent on course**	8. Attention in class
1.Minimalist	0.73^{a} (0.45)	0.42^{a} (0.50)	0.21^{a} (0.41)	0.06^{a} (0.24)	0.00^{a} (0.00)	0.08^{a} (0.28)	2.98^{a} (0.87)	2.96^{ab} (1.38)	3.25 (1.21)	1.83^{a} (1.06)	3.25^{a} (1.33)	3.13 (0.76)
2.Help Seekers	0.76^{a} (0.44)	0.82^{b} (0.39)	0.76^{b} (0.44)	0.88^{b} (0.33)	1.00^{b} (0.00)	0.29^{b} (0.47)	3.76^{b} (0.56)	3.53^{a} (1.01)	3.88 (1.17)	3.47^{b} (1.18)	4.65^{b} (1.11)	3.35 (0.70)
3.SI Dependent	0.45^{b} (0.50)	0.54^{a} (0.50)	0.70^{b} (0.46)	0.95^{b} (0.21)	0.00^{a} (0.00)	0.10^{a} (0.30)	3.83^{b} (0.38)	2.64^{b} (1.29)	3.41 (1.20)	4.08^{c} (1.08)	4.47^{b} (1.40)	3.22 (0.71)

** At least one group is significantly different based on ANOVA (alpha=0.05)

Cluster 1 (48 students): Minimalists

Most students in this group did not take advantage of Supplemental Instruction (SI). They also reported spending the least amount of time outside of class, doing the least amount of homework, and were the least likely to seek help from their classmates.

Cluster 2 (17 students): Help Seekers

Everyone in this group reported seeking help from the instructor on homework. No one in the other groups reported seeing the instructor for homework help. This group used every resource available to them. They sought help from peers and SI, and also worked on their own. They reported the most frequent reading and the most hours spent studying outside of class.

Cluster 3 (104 students): SI Dependents

Members of this group were the least likely to do the homework on their own. They reported the highest attendance at SI sessions and 95% reported doing homework at SI. They also reported doing the most homework, but the least reading.

Performance

Table 2 shows each group performance in the class and on the concept inventories. Significant differences were noted in six of the eleven categories. The three groups had similar incoming GPA's (semester GPR from previous semester) and SCI pre-scores. The Minimalists had the highest DCI pre-score, followed by the Help Seekers. The SI Dependent group scored the lowest on the DCI pre-test.

Table 2: Average performance by cluster (followed by standard deviation).

Cluster	Incoming GPR (4 point scale)	Course Grade (4 point scale)	Grade Differential**	SCI Pre-Score (out of 27)	SCI Post-Score** (out of 27)	SCI Gain*	SCI Normalized Gain**	DCI Pre-Score** (out of 29)	DCI Post-Score** (out of 29)	DCI Gain	DCI Normalized Gain
1.Minimalist	3.06 (0.86)	2.23 (1.37)	-0.78[a] (1.15)	7.58 (3.61)	13.68[a] (4.46)	6.55 (4.76)	32%[ab] (24%)	10.39[a] (3.19)	13.52[a] (4.35)	3.16 (3.59)	17% (20%)
2. Help Seekers	2.95 (0.86)	2.88 (1.17)	0.05[b] (0.91)	6.50 (2.07)	13.40[ab] (6.14)	7.80 (6.63)	38%[a] (33%)	9.56[ab] (2.68)	12.73[ab] (4.93)	3.20 (3.82)	17% (21%)
3. SI Dependent	3.01 (0.75)	2.28 (1.01)	-0.76[a] (0.92)	6.43 (3.40)	11.36[b] (4.06)	4.85 (4.56)	22%[b] (22%)	8.63[b] (2.93)	11.47[b] (3.65)	2.83 (3.48)	13% (19%)

** At least one group is significantly different based on ANOVA (alpha=0.05)
* At least one group is significantly different based on ANOVA (alpha=0.10)

Grades

An analysis of variance did not reveal significant differences between groups in average grade in the class. However, the difference in grade differential was very significant (even at alpha=0.01). The grade differential was calculated for each student by subtracting their previous semester GPR from their final grade in the class. For example, the Help Seekers had an average grade differential of 0.05. This positive value indicates that they performed just slightly better in Integrated Statics and Dynamics than they did in their previous classes. The other groups had differentials of -0.78 and -0.76, indicating that they performed ¾ of a grade point below their own average. Negative values are not out of the ordinary since Statics and Dynamics is generally considered one of the most difficult courses in the Mechanical Engineering curriculum.

Concept Inventories

The SI Dependent group had significantly lower raw and normalized gains on the SCI and lower post-scores on both inventories. Although the Minimalists had slightly (but not significantly) higher SCI pre-scores, the Help Seekers caught up with them on the SCI post-test while the SI Dependent group lagged behind. The minimalists started and ended highest on the DCI, followed by the Help Seekers. There were no significant differences between groups on DCI raw or normalized gains.

IV. Discussion and Implications for Instructional Approach

The three groups identified in the present study appear to parallel the behavior and performance of the groups identified in more controlled study of example elaboration by Stark, et al[8]. The authors gave students worked examples to study and counted the types of elaborations they made. The students were then tested for near and far transfer, and were clustered based on the frequency of each type of elaboration. The three profiles in that study were:

- ***Passive-superficial elaboration:*** These learners showed low overall elaboration activity. They showed the weakest performance on the transfer tasks.
- ***Deep cognitive elaboration:*** This group showed above average cognitive elaboration, such as considering principles and concepts, explaining goals and operators, and noticing coherence between examples. They were significantly more successful on far transfer tasks than the passive-superficial group, but not significantly so on near transfer tasks.
- ***Active-meta-cognitive elaboration:*** The key feature of this group is their distinctly above average use of both positive and negative self-monitoring elaboration. These included any statement of understanding or lack of understanding. The group also demonstrated a lot of cognitive and superficial elaboration as well. This group outperformed the passive superficial group on both near ($p=0.1$) and far transfer ($p=0.05$).

In our study, homework problems are similar to worked examples. The exams, which make up 80% of the final grade, tend to look like homework problems; therefore final grades may be used as a rough indicator of near transfer. The concept inventories represent far transfer tests since they require a more conceptual understanding.

- ***The Help Seekers*** reflect the active meta-cognitive group. They are aware of their misunderstandings and seek to resolve them. Mastery appears to be their goal.
- ***The SI Dependent group*** is much like the passive superficial group. They are going through the motions. They come to class, they turn in the homework, and they go to SI sessions. The SI program can have a very positive influence on students who want to learn the material, but it seems that in this instance many students were attending SI sessions with the goal of getting the right answers. This group very rarely worked by themselves, so they probably were not even aware that they could not do the work on their own. They have seen enough problems worked to develop a formulaic knowledge, but they lack conceptual understanding.
- ***The Minimalists*** represent the deep cognitive elaboration group. They are not as self-aware as the active-meta-cognitive group, but they are using more effective methods than the passive-superficial group. Since they work alone they are forced to consider questions like “What is the next step?” and “What equations or principles apply here?”

because no one is there to show them. It is not clear whether these students work alone because they choose to or because they are shy. When they did seek help, it was mostly from students who sit at their table, which might indicate that they just did not know many other people in their class.

In terms of how these students worked through problems, there are distinct differences between these three groups. All three groups are working through the same examples, but the SI Dependent group might think that writing it down is the same as learning it. They are able to perform as well as the Minimalists on the tests because they have developed formulaic knowledge, but the concept inventory shows that they do not really understand the principles. The Minimalist group, on the other hand, is forced to think about the problems more because they are working alone. There is no one to just tell them the next step; they must seek answers in the course materials. They spent less time out of class than the SI Dependent group, but had higher gains on the SCI.

Another interesting note is that although it did not appear to have an effect in the active meta-cognitive learners, Stark et al. found that elaboration training was useful in bringing learners up to the deep cognitive elaboration level from the passive-superficial. This may support adopting a cognitive apprenticeship approach to help these students master the material, where steps in problem-solving are illustrated, and students are encouraged to understand not only what steps to take, but why. Thinking Aloud Pair Problem Solving (TAPPS)[9] may also be an effective approach for teaching students how to elaborate effectively.

Clearly we must find ways to emphasize to students the importance of really working through a problem and checking their understanding of each step and of the big picture. One way to do this is through decreasing the percentage of grade points allotted to homework. In the classes surveyed, the homework was worth 6-8%, an amount intended to be large enough that students would take it seriously, but small enough that they would not be severely penalized for "learning experiences." However, many of them still seem to be obsessed with getting the right answer and uninterested in learning from it.

Another option is to limit which problems are discussed at SI sessions. Many of the students will probably continue to work in groups, but maybe there will be more discussion and a less formulaic approach, since no one will spell out the solution for them.

One limitation of this study is that study habit profiles only describe behaviors and not the motivation behind the behaviors. There is likely to be more than one motivation that leads to the same behaviors. For example, the study habits exhibited by the Minimalist group might describe two types of students. One would be those who work alone because they want to avoid appearing to their peers like they are not succeeding or even perhaps because they think they are above their peers in their thinking. The other would be those who are so unaware and unmotivated that they do not do real work of any kind except come to class and take the tests and hope for the best. Their outcomes will be quite different, and this is reflected by the high standard deviations within the dependent variables for this group. Future studies will include a motivational component to examine the relationship between motivation and behavior.

V. Conclusions and Future Work

Study habits of students in an integrated Statics and Dynamics course were assessed through a voluntary survey in order to determine which practices are the most helpful to the students. These data indicated that there are three distinct behavior patterns for these students, which lead to different levels of conceptual understanding of the material. The largest group has the most troubling study habits and the worst conceptual outcomes. These students reported doing the homework very regularly and attending Supplemental Instruction sessions almost religiously, but seem to get little out of it. Less than half reported doing the homework on their own. The smallest group took advantage of every resource available to them, including the instructor. On average, this group was able to maintain their GPR. The third group scored an average of ¾ of a letter grade worse than their incoming GPR, but did quite well on the concept inventories. More information is needed to really understand the decisions of this group. It could be that they do not need to spend a lot of time outside of class to grasp the material, or it could be they just choose not to and are unaware of or unconcerned about their progress in the course. Because both these types of students would exhibit similar behaviors, this analysis is not sufficient to separate them. Future studies will be expanded to discern students' motivations behind these study habits.

VI. References

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VII. Appendix

Study Habits Survey

This survey is completely voluntary. The information you provide will be used to identify factors that contribute to success in this course. Your instructor will not see the results of this survey until after final grades have been submitted.

1) I did the homework for this class (circle all that apply)
   a) by myself (0/1)
   b) with help from my team or table (0/1)
   c) with help from classmates not at my table (0/1)
   d) at SI (0/1)
   e) with help from the instructor (0/1)
   f) during class (0/1)
   g) other: ____

2) I did the homework
   a) always or almost always (4)
   b) usually (3)
   c) occasionally (2)
   d) never or almost never (1)
   e) other: ____

3) I did the reading for this class
   a) always or almost always (5)
   b) usually (4)
   c) occasionally (3)
   d) only when I thought there might be a quiz (2)
   e) never or almost never (1)
   f) other: ____

4) I typically read
   a) critically, making sure I understood each section (5)
   b) carefully, but didn't stop to think about what I was reading (4)
   c) quickly, skimming for important terms/equations (3)
   d) during class (2)
   e) not at all (1)
   f) other: ____

5) I did the journal questions (not used for cluster analysis)
   a) the night before they were due (2)
   b) as I read the chapter (6)
   c) after I read the chapter (5)
   d) after class (4)
   e) during class (3)
   f) I didn't read the chapter, I just guessed at the journal questions (1)
   g) Never or almost never (0)
   h) other: ____

6) I attended SI
   a) as often as possible (_____ times a week) (5)
   b) when there was homework due (4)
   c) when I needed help on the homework (3)
   d) right before the test (2)
   e) never (1)
   f) other: ____

7) I typically spent _____ hours a week on this class (not including class time)
   a) 0-2 (1)
   b) 2-4 (2)
   c) 4-6 (3)
   d) 6-8 (4)
   e) 8-10 (5)
   f) 10-12 (6)
   g) more than 12 (7)

8) I paid attention in class
   a) always or almost always (4)
   b) usually (3)
   c) occasionally (2)
   d) never or almost never (1)
   e) other: ____

Thank you for your participation.