International Journal for the Scholarship of Teaching and Learning

Volume 1 | Number 2 Article 19

7-2007

Assessing the Gains from Concept Mapping in Introductory Statistics

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In an effort to improve active learning in introductory statistics, we introduce the use of concept mapping techniques as part of the course. While previous papers have touted the use of this and other interactive teaching methods in statistics education, we add to this literature by providing additional assessment of its efficacy. This comes through an experimental design that involves a single instructor teaching two sections of the same statistics course over the same semester. Both cover the same material in the same way with the exception that concept mapping is used in one section, but not the other. Assessment of learning outcomes is done through the use of pre-tests and post-tests of understanding of statistical concepts. We also track changes in student's study habits over the semester through additional surveys. We find only weak evidence that concept mapping is effective in aiding student learning of statistics.

Keywords

Active learning in statistics, Concept mapping techniques Concept maps

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In an effort to improve active learning in introductory statistics, we introduce the use of concept mapping techniques as part of the course. While previous papers have touted the use of this and other interactive teaching methods in statistics education, we add to this literature by providing additional assessment of its efficacy. This comes through an experimental design that involves a single instructor teaching two sections of the same statistics course over the same semester. Both cover the same material in the same way with the exception that concept mapping is used in one section, but not the other. Assessment of learning outcomes is done through the use of pre-tests and post-tests of understanding of statistical concepts. We also track changes in student's study habits over the semester through additional surveys. We find only weak evidence that concept mapping is effective in aiding student learning of statistics.

Introduction

Across the Academy we have heard the call to move away from the "chalk and talk" approach to teaching and adopt a pedagogy that engages students more in the learning process. We have attended workshops on collaborative learning and been introduced to activities such as classroom experiments and one-minute papers. We have read the journal articles describing teaching innovations and have been told that these activities enhance student engagement and increase student satisfaction with our courses. Yet relatively few of these papers evaluate the effect of these activities on objective measures of student learning. Indeed, Holleran, Taylor, and Santopietro *(2006)* report the results of their examination of the contents of the *Journal of Economic Education* and the *Journal of Economics and Finance Education* for the period of 2001-2006. They note that of nearly two dozen articles describing a specific active-learning technique none reported any empirical evidence of the effect of that activity on student learning.

One goal of this paper is to address this concern by assessing empirically the effect of introducing a particular teaching innovation into the classroom. Specifically we describe the use of Concept Maps in an introductory statistics course and report the results of testing the marginal effect of this exercise on various measures of student performance and study-related behavior. This process of introducing, assessing and, where

https://doi.org/10.20429/ijsotl.2007.010219

appropriate, revising teaching and learning activities is part of what can be considered classroom research.

Kochis (2006) defines classroom research as "the systematic investigation of the effects of our teaching on student learning for the purpose of improving instruction". These investigations produce feedback about student learning to instructors that is typically used to inform teaching decisions made by instructors in their classrooms. One aspect of classroom research is the investigation of patterns of learning in a particular course - what are the barriers to learning, what teaching strategies can improve performance, how effective are the new strategies employed. This paper attempts to answer such questions in the context of a required introductory statistics course taken by all business and economics students at the University of Minnesota Duluth.

delMars, Garfield and Chance (1999) developed a model of classroom research for statistics education structured on the basis of four questions:

- What is the problem?
- What technique can be used to address the learning problem?
- What type of evidence can be gathered to show whether the implementation is effective?
- What should be done next, based on what was learned?

These questions outline both the approach taken in this study and the presentation of results. In the first section we discuss the problem encountered by our students, particularly their failure to understand the connection between key concepts in statistics. Following that we describe the introduction of concept mapping as a technique to address this learning problem. Next we describe our assessment of the effectiveness of concept maps on student outcomes and finally we make suggestions about how we might refine the activity in the future.

What is the Problem?

A common theme that runs through the statistics education literature is that most students in introductory statistics courses lack an understanding of the relationship among important concepts in statistics (e.g., Garfield, 1994; Schau and Mattern, 1997; delMas, Garfield, and Chance, 1999). Yet a vital dimension of the statistical expertise needed statistical reasoning and problem solving is the "presence of an understanding of the key elements of statistics and their relationships" (Turns *et al*, 2000).

As instructors we view the introductory statistics course as a consistent story of related concepts as we move from description statistics through probability to statistical inference. Unfortunately students often miss the big picture and see statistics as a series of disconnected topics. Students may be able to calculate a standard deviation and a standard error but often they do not understand how these concepts are related (both in terms of similarities and differences). As a result, students often confuse the concepts using one when they should have used the other. We particularly see the consequences of

https://doi.org/10.20429/ijsotl.2007.010219

this lack of understanding in the area of statistical inference as students fail to make the connections between fundamental concepts, such as sample, population, sampling distributions, and sampling variability.

Because of this isolated understanding of concepts, students remain novices in their statistical thinking (Schau and Matten, 1997). Students tend to memorize, for example, the steps of estimation and hypothesis testing without truly understanding the process. As we introduce different situations (difference between means, difference between proportions, hypothesis testing in regression, etc.) students become overwhelmed thinking of each of these as separate topics rather than a part of an integrated whole. This failure to develop a deep understanding of the integration of concepts affects their clarity of learning and retention of knowledge. Ausubel (1968) advanced a theory which contrasted meaningful learning from rote learning. One characteristic of rote learning is the lack of a deliberate effort to relate new knowledge to prior learning. This is contrasted with the affective commitment to relate new knowledge to prior learning which occurs in meaningful learning. It would appear that many of our statistics students are engaged in rote learning rather than the meaningful learning needed for effective statistical reasoning and problem solving in the introductory course as well as retention of knowledge necessary for success in future courses in the business and economics curricula and their eventual careers.

To initially identify the problem students in one section were having with the course we administered the GAMES© Survey Instrument developed by Marilla Svinicki (2004). The survey items consist of components of effective study behavior - goal-oriented study (G), active studying (A), meaningful and memorable studying (M), explaining the material in order to learn it (E), and self-monitoring (S). According to Svinicki (p. 131) students who engaged in the learning behaviors reflected by this model will learn at a deeper level. However, students self-reported that, when studying, they seldom "make connections between what I am studying and past classes or units" or "create outlines, concept maps, or organizational charts of how the ideas fit together." The results of the survey led us to specifically introduce concepts mapping as a class exercise to encourage students to make connections among the key concepts of statistical inference.

What Technique Can Be Used to Address the Learning Problem?

Concept maps are an increasingly popular technique used to support "meaningful learning." According to Ausubel (1968) "the most important single factor influencing learning is what the learner already knows." Based on Ausubel's principles of meaningful learning in which there must be a deliberate effort to relate new knowledge to prior learning, Novak and Gowin (1984) developed concept maps for use in science education. Concept mapping involves the visual representation of how concepts within a domain are interrelated. A concept map consists of a hierarchal structure of cells or nodes that represent concepts or ideas and labeled cross-links representing the relations between concepts. These cross-links between concepts can be non-, uni-, or bi-directional. The links connect not only adjacent concepts but concepts in different domains of the concept map as well. It is this feature that distinguishes concept maps from other organizers such as outlines and mind maps. The resulting network of concepts can be an aid to learning by explicitly integrating new and old knowledge and assist students in understanding the relationships between statistical concepts such as populations, samples, sampling

https://doi.org/10.20429/ijsotl.2007.010219

distributions and statistical inference.

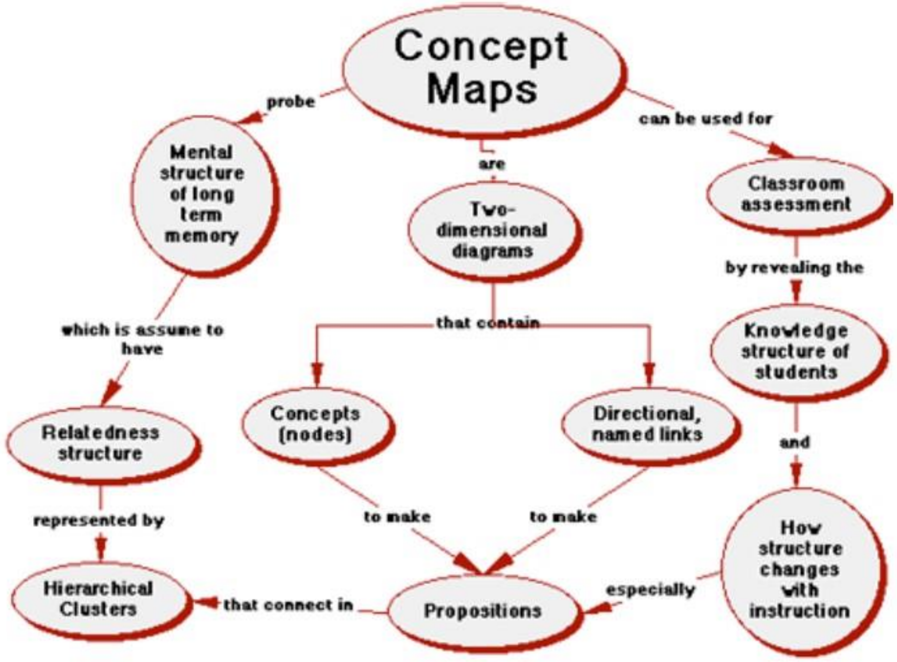

Figure 1: Concept Map Of Concept Maps

Source: Zeilik (1999)

Introductory statistics is an ideal course for implementing such a learning tool. The course typically is designed to develop groundwork for inferential statistics right from the start with each concept covered building upon previous concepts. The successful student must relate new knowledge to prior learning. Additionally, relational thinking, seeing the interconnectedness among concepts such as populations and samples or variability and sampling error, is necessary for truly and deeply understanding the material.

In addition to creating explicit links between concepts leading to meaningful learning, the process of concept mapping in class may have other benefits as well. Educational and cognitive theorists have posited that an active, hands-on approach to course material leads to higher-order learning; thus the mapping process is a learning experience in and of itself. Concept mapping is often introduced as a small group activity (e.g., Brown, 2003; Prezler, 2004; Calderon-Steck, 2006). The benefits of cooperative/collaborative learning have been well documented across academic disciplines (e.g., Giraud (statistics), 1997; Maier and Keenan (economics), 1994). Several studies have evaluated the usefulness of concept maps across three groups, a control group, individual mappers and group mappers (Brown, 2003; Calderon-Steck, 2006; Chiou, 2006) finding that group mappers outperformed those who did no mapping or who did mapping as individuals. Thus, it is difficult to disentangle the independent effect of the concept mapping from the effects of cooperative learning.

John Budd (2003) describes an in-class exercise in which small groups of students create a Mind Map, which are similar to Concept Maps, for a specific topic. In addition to the benefits of a collaborative learning technique such as this, he notes that an exercise such as this can re-energize a course. Just the process of having students work with colored markers and large sheets of paper increases the energy level of the class and introduces an opportunity for creative expression not found at other times during the course. That change of pace can increase student motivation resulting in the outcome, as reported in a number of studies, that students think that concept mapping is a useful exercise.

Implementation

The primary goal in introducing concept maps to students in introductory statistics is twofold. The course-specific goal is increasing conceptual understanding of statistical inference by explicitly linking course content on an on-going basis throughout the course. Additionally, we seek to improve student's study habits by providing an active learning tool that should be useful in many learning environments. One aim of the current study is to provide evidence as to whether or not these goals are met through the introduction of concept mapping into the learning process. The first step in doing this, then, is to design an experiment in which these desired outcomes can be measured.

Design of Experiment

With the same instructor teaching two sections of the same course, it was possible to introduce the use of concept maps into one and then treat the other section as a control group with which to compare outcomes. Having the same instructor for both groups allowed instruction in both sections to cover the same material in the same way, removing the potential for instructor bias in the outcomes, although there are likely additional sources of bias in such an experiment.

The course in which the experiment took place was a standard introductory business statistics course, required for majors in business and economics. Typical content coverage includes organizing data into tables and charts, numerical descriptive/summary statistics, probability, probability distributions, sampling distributions, statistical inference, including estimation and hypothesis testing, simple regression and correlation analysis. The teaching approach was a mix of lecture, examples and worked problems, along with hands-on practice with data analysis using Microsoft Excel. Standard assessment tools were utilized in determining course grades, including homework, quizzes, two midterm exams, and a final exam. The first midterm covered material through topics dealing with summarizing data using tables and charts, descriptive statistics, and also the basics of probability. The second midterm covered material through probability distributions, sampling distributions, and confidence interval estimates for means and proportions.

Total class size for each section was 46 students, although not all students completed all of the surveys and assessment tools we refer to here. For the control group there were 35 participants and for the mapping group, 38 students completed all survey and assessment materials. These are thus the sample sizes for all that follows. The control group, as determined by coin flip, met at 9:30 AM and the group implementing concept maps met at 2:00 PM, with each section meeting twice weekly for one hour and fifteen minutes. Of the participating students in each section, about 2/3 were sophomores and 1/3 juniors, with one freshman in the control group. Additionally, the control group was split nearly evenly between males and females, while the mapping section was 60% male. Both groups contained students who reported some previous exposure to statistics, either through

https://doi.org/10.20429/ijsotl.2007.010219

another course in statistics or as part of a math course. The control group had a greater proportion of students with no previous exposure, at 60% versus 43% for the mapping group.

For the concept mapping section, development of concept maps was done at two points in the semester, in the class session just prior to each of the midterm exams. Implementation proceeded as follows.

Concept Map Exercise 1

Prior to the class session in which the first concept maps were developed students were given a short introduction to concept maps and instruction on their construction and use. This included reference to online resources at www.studygs.net/mapping for more information and examples. Following this short introduction to concept maps, students were informed that the next class period would be spent working in groups to develop such maps as a means of reviewing for the upcoming exam. Students were asked to bring in individual lists of terms and ideas from which they could draw in putting together their maps. The word around which the lists, and therefore the concept maps, were to be built was "population", representing the central unifying theme – study of a population characteristic of interest. The lists were meant to help students begin to start thinking about the connections between the topics thus far and prepare for discussion and collaboration with others in developing the concepts maps.

On the day of implementation students were assigned to groups of 5 or 6. Each group was given scratch paper for developing rough drafts, colored markers, and a poster sized sheet of paper for the final product. Group members used their lists to develop a group concept map linking material covered up to that point and using the term "Population" as the central theme. This took place in three phases: first, groups were given about twenty-five minutes to brainstorm and come up with initial drafts of concept maps; next groups were asked to assign members to visit with other groups to observe their approaches and get ideas for improvement; finally, after 10 minutes of "mingling", the groups came back together to complete their group maps. In the last few minutes of class each of the eight groups presented their map to the class.

Concept Map Exercise 2

The second concept mapping exercise took place about a month after the first and, as a continuation of the initial concept mapping experience, was intended to expand upon the previously constructed maps. Again the unifying theme was the study of a population, only this time we added topics and ideas from probability and probability distributions, with the intended focus being on how sampling distributions fit in with everything else covered in the course up to that point. As in the previous exercise, students were instructed to bring in a list of terms and ideas, focusing on material covered since the first mapping exercise.

On the day of the exercise, the following took place:

- In an effort to assess the usefulness of concept mapping in aiding student understanding, a short quiz was given at the beginning of the class period, with a follow-up quiz given after the exercise.

https://doi.org/10.20429/ijsotl.2007.010219

- The maps from the previous exercise were posted in the front of the classroom so students could draw from other's ideas.

- Students were assigned to eight **new** groups of 5 or 6 students. Groups were asked to start from scratch, utilizing the old maps and also the student's individual lists to develop concept maps linking all of the material covered in the course to that point.

- The class was given 15 minutes for each group to come up with a first draft and then again allowed to mingle with other groups to see their approaches.
- After 10 minutes of mingling, the groups came back together and spent 10 minutes completing their maps.

- During the post-quiz the completed maps were posted in front of the room and students were asked to vote on the best mapping. Groups were barred from voting on their own. Extra credit points were given to the two groups with the most votes.

Evidence of Effectiveness?

To evaluate whether or not the objectives of the experiment have been met, comparisons are made between the section that produced concept maps and the control group who did not. Both goals stated above were assessed through the use of pre- and post-tests and surveys.

Assessment of learning outcomes was done through the use of the Statistics Concept Inventory (SCI) (see the SCI website at https://engineering.purdue.edu/SCI/index.htm for details on this instrument and its use). This 38 question testing instrument is designed to measure the impact of alternative teaching and learning strategies on the understanding of core concepts typically covered in an introductory statistics course. This is done through comparison of results obtained by administering the test at the beginning of the course, prior to any instruction, and then again at the end of the course. Both the mapping group and the control group took the tests on the same days.

Potential impact on student study habits and learning strategies over the semester was also tracked. This was done through the use of the GAMES Survey Instrument developed in Svinicki (2004). This survey, intended to reveal student learning styles and study methods, also was administered both at the beginning and at the end of the course in order to track how those may change over the semester. This part of the assessment is not course or content specific, but merely an attempt to see if students report changes in learning behavior over the semester and attempt to determine if exposure to concept mapping has any influence on this.

In addition to the above, standard assessment tools -- exams, quizzes, and homework -- were used and scores on these were the primary determinant of student's course grades. In analyzing learning outcomes we use several bases for comparison, including pre and post results for the SCI, percentage point improvement on the SCI, normalized gain on the SCI, and overall course grade. Normalized gain is measured as

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$$Gain = \frac{PostSCI\text{ - }PreSCI}{MaxSCI\text{ - }PreSCI},$$

where *MaxSCI* = 38, the maximum possible correct. *Gain* is thus a measure of the proportion of the shortfall in points between the score on the pre-test SCI and the maximum possible score that is made up on the post-test (see Hake(2001) and references therein for a more complete discussion of this measure). Table 1 reports the means and standard deviations of the results from each of these measures for each group in the

study. The average gain reported in the table is the average of the individual gains from each section. Alternatively, the normalized gain can be calculated based on the class average as a whole. This method generates a gain of 9.8% for the control group and 7.2% for the concept mapping group. Although slightly larger in magnitude, the results are not qualitatively different.

Table 1. Means and standard deviations of scores

		Section		
		Control N = 35	CM N = 38	Total N = 73
PREPct	**Mean**	39.5%	39.3%	39.4%
	s.d.	9.7%	12.3%	11.1%
PostPct	**Mean**	45.4%	43.6%	44.5%
	s.d.	10.8%	12.2%	11.5%
SCI_Improve	**Mean**	5.9%	4.4%	5.1%
	s.d.	10.1%	12.8%	11.5%
SCI_Gain	**Mean**	9.0%	5.2%	7.0%
	s.d.	17.1%	19.8%	18.5%
Course_Grade	**Mean**	82.0%	84.7%	83.4%
	s.d.	11.2%	8.3%	9.8%

Table 1 indicates that outcomes on the pre-test SCI were very close between the two sections, indicating a similar average starting point for both groups. We also see that outcomes were close, on average, for the remaining instruments as well, with average improvement and gain by the control group slightly greater on the SCI than that for the concept mapping group. Table 2 reports *t*-test results at the 5% level of significance for equality of means between the two sections for each of the outcomes reported in Table 1. These were done under the pre-tested assumption of equivalence in variances across groups. In no case can we reject the null hypothesis that average class performance is the same across the two groups. Unfortunately, this provides no evidence that use of concept maps made any difference in performance on post-tests or course grades.

Table 2. *t*-test results for difference in means

https://doi.org/10.20429/ijsotl.2007.010219

	PREPct	PostPct	SCI_Improve	SCI_Gain	Course_Grade
Mean Difference	0.21%	1.78%	1.58%	3.73%	-2.70%
Std. Error Difference	2.61%	2.71%	2.72%	4.35%	2.30%
t	0.0790	0.6590	0.5800	0.8580	-1.1770
df	71	71	71	71	71
Sig. (2-tailed)	0.937	0.512	0.564	0.394	0.243
95% CI for Difference:					
Lower	-5.01%	-3.62%	-3.84%	-4.94%	-7.28%
Upper	5.42%	7.19%	7.00%	12.41%	1.88%

Using additional data on student characteristics that was collected with the SCI (summarized in Table 3), we can control for the effects of gender, class standing, and whether or not students have had previous exposure to statistics, say in high school or in a math class at some point. Table 4 reports univariate ANOVA analysis of the results for pre-test SCI scores, post-test SCI scores, improvement on the SCI, normalized gain, and final course grades. Along with class section, the new variables are included as factors in a multifactor univariate ANOVA model. In addition to allowing us to assess possible interactions of these additional factors with class section we may also gain insight into potential effects on performance outcomes across these subcategories as well. In addition to p-values for the significance of each factor or interaction effect in the model, Table 4 reports the *partial eta squared* statistic, an indicator of effect size of each on variability in the dependent variable. Finally, the R^2 and adjusted R^2 measures of fit for each model are reported.

Table 3. Additional factors

Between-Subjects Factors		N
Section	Control	35
	CM	38
Gender	Male	41
	Female	32
Standing	Sophomore	52
	Junior	20
	Freshman	1
StatEx	None	39
	Some Previous Experience	34

Even allowing for the possibility of interaction effects, section now only directly has a statistically significant impact on overall course grade, with the concept mapping group averaging 84.7% for the course and the control group averaging 82.0%. There is also a significant interaction effect with class standing on course grade, with sophomores in the control section outperforming juniors to a much greater degree than in the concept mapping section. The effect size of the interaction term is larger than that for section

https://doi.org/10.20429/ijsotl.2007.010219

itself, so it is likely that this is the driving force behind section being significant at all. Thus even here there is little convincing evidence that the concept mapping exercises had an effect on course grade. All other interaction terms involving section were insignificant. Class standing and previous statistics experience, which seems to have hurt rather than helped, were both significant and individually had much larger effect sizes on course grade than did class section. These variables, along with gender, all have significant interaction effects on course grade as well.

https://doi.org/10.20429/ijsotl.2007.010219

Table 4. Univariate ANOVA Results

Dependent Variable:	PREPct R^2 = .325 (Adj. R^2 = .132)		PostPct R^2 = .381 (Adj. R^2 = .204)		SCI_Improve R^2 = .254 (Adj. R^2 = .041)		SCI_Gain R^2 = .293 (Adj. R^2 = .092)		Course_Grade R^2 = .456 (Adj. R^2 = .300)	
Source	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared
Corrected Model	0.077	0.325	0.018	0.381	0.303	0.254	0.151	0.293	0.001	0.456
Intercept	0.000	0.849	0.000	0.883	0.016	0.099	0.031	0.080	0.000	0.977
Section	0.959	0.000	0.318	0.018	0.340	0.016	0.346	0.016	0.023	0.088
Gender	0.344	0.016	0.001	0.176	0.027	0.085	0.025	0.087	0.045	0.070
Standing	0.076	0.088	0.006	0.166	0.083	0.085	0.050	0.101	0.000	0.270
StatEx	0.834	0.001	0.245	0.024	0.213	0.028	0.103	0.047	0.002	0.152
Section * Gender	0.959	0.000	0.171	0.033	0.229	0.026	0.096	0.049	0.663	0.003
Section * Standing	0.195	0.030	0.333	0.017	0.041	0.072	0.025	0.086	0.012	0.106
Gender * Standing	0.827	0.001	0.022	0.090	0.023	0.089	0.015	0.100	0.077	0.055
Section * Gender * Standing	0.057	0.063	0.024	0.087	0.740	0.002	0.628	0.004	0.213	0.028
Section * StatEx	0.279	0.021	0.558	0.006	0.647	0.004	0.503	0.008	0.818	0.001
Gender * StatEx	0.045	0.070	0.759	0.002	0.035	0.077	0.024	0.088	0.071	0.057
Section * Gender * StatEx	0.280	0.021	0.743	0.002	0.490	0.009	0.337	0.016	0.215	0.027
Standing * StatEx	0.025	0.087	0.120	0.043	0.505	0.008	0.521	0.007	0.002	0.165
Section * Standing * StatEx	0.966	0.000	0.308	0.019	0.374	0.014	0.181	0.032	0.846	0.001
Gender * Standing * StatEx	0.801	0.001	0.760	0.002	0.612	0.005	0.350	0.016	0.616	0.005
Section * Gender * Standing * StatEx	0.159	0.035	0.751	0.002	0.315	0.018	0.292	0.020	0.682	0.003

Shaded cells indicate significance of factors or interactions at a 10% level or less.

The only other statistically significant impacts from section appear to be in interaction with other variables. For the pre-test SCI score, section interacts with class standing and gender to produce a relatively small and likely inconsequential effect, given the R^2 of the model. Section interacts with class standing to have a small significant effect on absolute improvement in SCI scores between the pre- and post-tests, with sophomores in the control section again significantly outperforming juniors, with 7.6 and 0.9 percentage point gains, respectively. Finally, the normalized gain on the SCI had significant interaction effects between section and gender and section and standing. In both cases inspection of cross tabulations indicates this is due to significant differences within the control section, rather than the mapping section. Males in the control section averaged a normalized gain of 12.1 percent and females 4.3 percent, whereas in the concept mapping section the gains were 6.1 percent and 4.3 percent, respectively. At any rate, the effect sizes of these interactions are again quite small, especially given the explanatory power of the overall models.

https://doi.org/10.20429/ijsotl.2007.010219

Unfortunately, the results thus far offer little evidence that concept mapping had any impact on course outcomes or on student's conceptual understanding of statistics, as measured by the SCI. There may be a number of explanations for this, not the least of which is the small sample size upon which we are basing our conclusions. Additionally, any gains in understanding that may be realizable from the incorporation of concept maps into such a course may not be well measured by either the SCI or standard course assessment tools, as attempted here. This bears further consideration in future experiments of this sort.

GAMES Self-Reported Outcomes

Although the results pertaining to course specific learning outcomes were somewhat disappointing, it is possible that the introduction of a learning tool such as concept maps can have an impact on how students approach learning. The GAMES survey, described above, was administered in order to help assess whether or not this was the case. For each learning strategy listed on the survey form, students provide a ranking on a scale from one to five on their use of that particular strategy, with 1 indicating the strategy is never used, 2 rarely used, 3 sometimes, 4 often, and 5 indicating the technique is always used.

Table 4 contains the questions from the GAMES survey and reports the proportion of each class section reporting an increase in the use of each particular learning strategy over the course of the semester. Here we employ two alternative definitions of what an increase in usage may pertain to. We define an increase of Type A as representing greater usage of a skill on the post-survey than reported on the pre-survey for that item, so this measure counts *any* upward movement in reported usage as an increase. A Type B increase, on the other hand, is measured as a movement from a report of either "Never" or "Seldom" on the pre-survey to any of the higher three rankings on the post-survey, representing an adoption of the method by a student who reported little, if any, use of it prior to the course. Any differences between sections that are statistically significant at the 10% level are indicated by an asterisk in the CM column. We do note that in a number of cases there were no changes in a student's use of a particular strategy and some even reported declines in usage of some strategies from what was initially reported. The shaded questions in the table are those which refer specifically to the use of concept maps or of making explicit connections between topics, which is a primary characteristic of concept maps.

The results in Table 4 indicate that the concept mapping group reported greater proportionate increases in learning strategy usage over the semester than did their counterparts in the control group for slightly more than half of the surveyed strategies (56%). They also report a greater adoption rate for previously unused/seldom used learning strategies for 65% of the techniques covered. Of course the reported differences in proportion are statistically significant for only a handful of the survey questions, due to the small sample sizes.

Table 4. Proportion of class reporting an increase in the use of each learning strategy

Type of increase (see text for definitions) :	**Type A**		**Type B**	
Section:	**Control**	**CM**	**Control**	**CM**
Goal-oriented study				
1. Analyze what I have to do before beginning to study.	28.6%	26.3%	5.7%	7.9%
2. Set a specific content learning goal before beginning to study.	34.3%	44.7%	14.3%	23.7%
3. Set a specific work effort (time or amount) before beginning to study.	31.4%	26.3%	17.1%	18.4%
4. Figure out why I am learning the material I'm about to study.	45.7%	42.1%	14.3%	23.7%
5. Be sure to understand what is expected of me in terms of learning and assignments.	25.7%	21.1%	0.0%	5.3%
Active Study				
6. Make notes in the margins of the text when I read.	28.6%	42.1%	17.1%	21.1%
7. Ask myself questions before, during, and after studying.	40.0%	42.1%	20.0%	13.2%
8. Pause periodically to summarize or paraphrase what I've just studied.	28.6%	34.2%	11.4%	5.3%
9. Create outlines, concept maps, or organizational charts of how the ideas fit together.	31.4%	50.0% *	14.3%	28.9% *
10. Look for connections between what I'm studying right now and what I've studied in the past or heard in class.	31.4%	34.2%	8.6%	18.4%
11. Write down questions I want to ask the instructor.	34.3%	50.0% *	17.1%	28.9%
12. Reorganize and fill in the notes I took in class.	34.3%	31.6%	14.3%	13.2%
13. Work through any problems that are illustrated in the text or in my class notes.	28.6%	36.8%	17.1%	18.4%
14. Create vocabulary lists with definitions and my own examples.	20.0%	28.9%	8.6%	7.9%
15. Take breaks periodically to keep from getting too tired.	17.1%	10.5%	0.0%	0.0%
Meaningful and memorable				
16. Make up my own examples for concepts I am learning.	20.0%	18.4%	11.4%	10.5%
17. Put things in my own words.	8.6%	21.1% *	0.0%	5.3%
18. Make vivid images of concepts and relationships among them.	31.4%	13.2% *	8.6%	5.3%
19. Make connections between what I am studying and past classes or units.	28.6%	18.4%	8.6%	5.3%
20. Be sure I understand any example the instructor gave me.	31.4%	31.6%	8.6%	10.5%
21. Create concept maps and diagrams that show relationships among concepts.	34.3%	39.5%	17.1%	28.9%
22. Ask the instructor for more concrete examples and picture them in my mind.	22.9%	36.8% *	11.4%	23.7% *
23. Look for practical applications and real life settings for the things I'm learning.	14.3%	15.8%	8.6%	10.5%
Explain to understand				
24. After studying, meet with a partner to trade questions and explanations.	34.3%	52.6% *	14.3%	31.6% *
25. Write out my own descriptions of the main concepts.	28.6%	23.7%	11.4%	15.8%
26. Discuss the course content with anyone willing to listen.	17.1%	34.2% *	8.6%	23.7% *
27. Answer questions in class.	34.3%	26.3%	22.9%	21.1%
28. Make a class presentation.	25.7%	18.4%	8.6%	10.5%
29. Help another student who is behind in progress.	22.9%	34.2%	11.4%	10.5%
Self-monitor				
30. Make sure I can answer my own questions during studying.	34.3%	26.3%	11.4%	5.3%
31. Work with another student to quiz each other on main ideas.	25.7%	34.2%	11.4%	13.2%
32. Keep track of things I don't understand and note when they finally become clear and what made that happen.	31.4%	26.3%	17.1%	10.5%
33. Have a range of strategies for learning so that if one isn't working I can try another.	34.3%	42.1%	20.0%	28.9%
34. Remain aware of mood and energy levels during study and respond appropriately if either gets problematic.	37.1%	36.8%	14.3%	10.5%

*indicates difference is significant at 10% level

https://doi.org/10.20429/ijsotl.2007.010219

Of the categories in the survey, the concept mapping group shows greatest relative gains of type A in the "Active Study" and "Meaningful and Memorable" categories. Within Active Study, questions 9 and 10 directly pertain to learning strategies that may be related to the use of concept mapping. For both of these strategies the mapping group reported a greater percentage increase in use than did the control group. However, only for question 9, which mentions concept maps explicitly, is the difference statistically significant. Within the Meaningful and Memorable category two questions pertaining directly to concept mapping's potential strengths, questions 18 and 19, go the other direction, with the control group exhibiting a proportionately greater increase in the use of these strategies, with the difference in question 18 being statistically significant. Question 21, again directly mentioning concept maps, shows only slightly greater increases over the control group for those actually experiencing their use in the course, despite the results for question 9, which is very similar. Using this measure, there is only mixed evidence of any positive impact on learning behavior and study methods from the introduction of concept maps. Of the two statistically significant questions that pertain directly to concept mapping, the evidence is contradictory.

For the Type B increases, which essentially measure new adoption of the learning strategy in question, there were even fewer statistically significant differences in relative take up rates between the two groups. Of these, question 9 in the Active Study category indicates the concept mapping group had double the adoption rate for this strategy than that of the control group. Question 21 also indicates a large, but statistically insignificant difference here. This may seem an obvious result of the introduction of these methods in that section, but the second mapping exercise took place about a month previous to the post-survey, with no mention of it in between. This leads us to believe that student reporting of concept maps being adopted as a learning strategy is genuine. If that is the case, and students did add this learning tool to their repertoire, then that can only be considered a success.

Another use for the data gleaned from the GAMES surveys is to see if increased use or adoption of the learning strategies addressed on it had any impact on the learning outcomes reported above. We investigate this for those questions, highlighted in table 4, that pertain most to the use of concept mapping, the main aim of this study. Table 5 and Table 6 report the results of multifactor univariate ANOVA for the impacts on improvement in SCI scores, the normalized gain in SCI scores, and overall course grades from gains of type A and type B in the highlighted survey questions. For this analysis the data was pooled across sections and the analysis done separately for each GAMES category, due to overlap in the questions being asked.

https://doi.org/10.20429/ijsotl.2007.010219

Table 5. Impact of Type A increases in GAMES strategies on learning outcomes

Dependent Variable:	SCI_ImprovePCT		SCI_Gain		Course_Grade	
Source	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**
Corrected Model	0.383	0.043	0.520	0.032	0.023	0.128
Intercept	0.000	0.198	0.001	0.148	0.000	0.985
TypeA_9	0.562	0.005	0.635	0.003	0.006	0.104
TypeA_10	0.141	0.031	0.152	0.029	0.044	0.058
TypeA_9 * TypeA_10	0.337	0.013	0.646	0.003	0.152	0.030
	R Squared = .043 (Adj R Squared = .001)		R Squared = .032 (Adj R Squared = -.010)		R Squared = .128 (Adj R Squared = .090)	

Dependent Variable:	SCI_ImprovePCT		SCI_Gain		Course_Grade	
Source	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**
Corrected Model	0.229	0.129	0.294	0.118	0.031	0.204
Intercept	0.030	0.071	0.084	0.045	0.000	0.978
TypeA_18	0.051	0.057	0.076	0.048	0.549	0.006
TypeA_19	0.764	0.001	0.900	0.000	0.273	0.018
TypeA_21	0.228	0.022	0.225	0.023	0.092	0.043
TypeA_18 * TypeA_19	0.379	0.012	0.576	0.005	0.758	0.001
TypeA_18 * TypeA_21	0.379	0.012	0.368	0.012	0.384	0.012
TypeA_19 * TypeA_21	0.986	0.000	0.929	0.000	0.004	0.118
TypeA_18 * TypeA_19 * TypeA_21	0.288	0.017	0.263	0.019	0.694	0.002
	R Squared = .129 (Adj R Squared = .036)		R Squared = .118 (Adj R Squared = .023)		R Squared = .204 (Adj R Squared = .119)	

Shaded cells indicate significance at a 10% level

Table 5 indicates there is weak evidence that greater usage of strategies 9 and 10 on the GAMES survey had an impact on overall course grades, but no evidence that these mattered for performance on the SCI. Questions 10 and 19 are nearly identical, yet in the lower panel of the table question 19 only has an impact in combination with the use of concept maps, as indicated by question 21. Questions 9 and 21 also are very close, and both provide weak evidence that greater use of concept maps or similar tools impacted course grades. The only evidence of effect on the SCI is for improvement of the use of

https://doi.org/10.20429/ijsotl.2007.010219

visualizing concepts and relationships from question 18. Here again the evidence is weak at best.

Table 6. Impact of Type B increases in GAMES strategies on learning outcomes

Dependent Variable:	SCI_ImprovePCT		SCI_Gain		Course_Grade	
Source	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared
Corrected Model	0.110	0.083	0.175	0.069	0.407	0.041
Intercept	0.003	0.124	0.011	0.089	0.000	0.966
TypeB_9	0.470	0.008	0.484	0.007	0.286	0.016
TypeB_10	0.718	0.002	0.859	0.000	0.312	0.015
TypeB_9 * TypeB_10	0.056	0.052	0.071	0.046	0.589	0.004
	R Squared = .083 (Adj R Squared = .043)		R Squared = .069 (Adj R Squared = .028)		R Squared = .041 (Adj R Squared = -.001)	

Dependent Variable:	SCI_ImprovePCT		SCI_Gain		Course_Grade	
Source	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared	Sig.	Partial Eta Squared
Corrected Model	0.107	0.124	0.127	0.118	0.152	0.111
Intercept	0.414	0.010	0.454	0.008	0.000	0.921
TypeB_18	0.743	0.002	0.986	0.000	0.264	0.019
TypeB_19	0.379	0.012	0.399	0.011	0.772	0.001
TypeB_21	0.015	0.084	0.011	0.092	0.277	0.018
TypeB_18 * TypeB_19	.	0.000	.	0.000	.	0.000
TypeB_18 * TypeB_21	0.117	0.036	0.109	0.038	0.800	0.001
TypeB_19 * TypeB_21	0.028	0.070	0.034	0.066	0.032	0.067
TypeB_18 * TypeB_19 * TypeB_21	.	0.000	.	0.000	.	0.000
	R Squared = .124 (Adj R Squared = .058)		R Squared = .118 (Adj R Squared = .052)		R Squared = .111 (Adj R Squared = .045)	

Shaded cells indicate significance at a 10% level

Table 6 does provide some evidence that the adoption of the selected learning strategies had some impact on SCI performance. The combination of making connections between topics and formalizing those connections in some way, as indicated in questions 9 and 10 on the survey, does show a slight statistically significant impact on improvement on the SCI over the semester, as measured by the normalized gain and the percentage point change in scores. Question 21 addresses the use of concept maps specifically and the

https://doi.org/10.20429/ijsotl.2007.010219

evidence her shows that adoption of this learning tool also had a small but significant effect on the SCI measures.

All in all there is not a lot of evidence here suggesting that there was a great benefit from the use of concept maps for either the students that participated in the exercises or for all of the students that reported greater usage or adoption of this type of tool on the GAMES survey. While this is a disappointing result, the presence of even weak evidence of effect suggests it is worthwhile to continue to investigate these questions and collect additional data in the hopes of strengthening the results.

What Should Be Done Next Based On What We Learned?

Heinze, Fry and Novak (1990) noted that the introduction of concept maps should not be considered a "quick fix." Concept mapping does appear to move students toward meaningful learning but this movement may be slow. This may be due to the fact that it takes time for students to learn the process of concept mapping and realize its potential (Wandersee, 1990). Or, as suggested by Santhanam, et. al. (1998) students, especially underclassmen, view rote memorization as the optimum approach to study. These habits that have served the students well throughout high school may be difficult to break. Although in our case it appears that the concept mapping did change study behaviors as reflected by the GAMES© survey, it is probably the case that the mapping was done too infrequently to have a significant impact on performance.

One issue raised in the literature has been does it matter who prepares the map and how. On the one hand concept maps can be constructed by the teacher, by students in groups or by individual students. Students can fill in the details of a map that has been partially constructed by the instructor or can develop a map from scratch. Wandersee (1990) argued that the educational benefit accrues chiefly to the mapper. As noted earlier according to previous studies mapping done collaboratively enhances performance more than that done by individuals. However, given the independent effects of collaboration on performance we cannot be sure how much of the improvement should be attributed to concept mapping. If Wandersee is correct, there is an argument to be made for individual students to construct their own maps. One strategy that might be considered is for each student to prepare a concept map rather than simply a list of concepts prior to the exercise and then have students work from those maps to construct one group map. In this way we can retain the benefits of collaboration while increasing individual accountability.

Finally, no attempt was made to grade the concept map itself. Several scoring rubrics can be found in the literature with the common feature of scoring on the basis of complexity and validity. For instance, scores are based on the number of concepts and correctness of relationships indicated by the cross links. Making the concept mapping a graded exercise likely would increase student motivation.

Conclusion

The goal of this exercise was to determine the effectiveness of a particular learned focused activity. While much previous work suggests that such activities are useful in enhancing student learning, there is typically little empirical support offered. In this paper we find

https://doi.org/10.20429/ijsotl.2007.010219

little evidence to support concept mapping as an effective tool given the measurement tools employed. One possible explanation for this involves the types of outcomes measured, which included pre- and post-tests and course grades. These gross measures of performance may not be sensitive enough to the type of learning that concept mapping enhances, i.e. the relationships between the concepts covered in the course that may not be directly addressed on a multiple choice exam. It may also be the case that the design and frequency of the activity was insufficient to measurably alter learning outcomes in the course. However, the self-reported results from students on the GAMES survey suggested some potential for improvement in study habits as a result of introducing students to concept mapping.

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