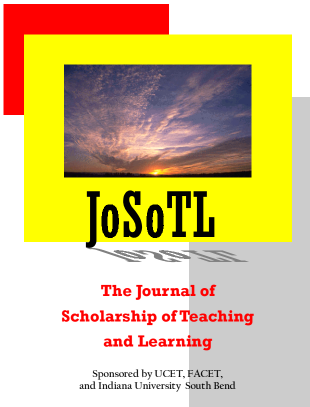

The Journal of Scholarship of Teaching and Learning (JoSoTL)

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Developing Our Community

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In recent years, interest in the Scholarship of Teaching and Learning has grown significantly. We at JoSoTL are proud that we have been able to help further the sense of scholarly community provided by journals in this field. Journals offer a means to "make public" the activities of our colleagues as we pursue our common topic. Articles published in JoSoTL provide points of discussion, and "progress reports," as we work to understand the art and science of teaching and learning.

As a web-based journal, JoSoTL also enhances aspects of the scholarly community. We can provide our publication without charging subscriptions (thanks to the kind support of Indiana University South Bend, and the University Center for Excellence in Teaching – UCET). We receive submissions and comments from authors and readers located around the world. Monetary barriers caused by subscription rates (and submission fees at some journals) can affect the reach of publications adversely, and we are thankful that we have been able to avoid these barriers to developing our community.

Regardless of the advancements in electronic communication, there remain occasions where meeting "face-to-face" is advantageous. One field that I study is the use of technology in business decision-making – Management Information Systems. Researchers in that field acknowledge that there are times when decision-makers still prefer to be in the same room, physically together, to discuss factors in specific decision situations.

Educators also recognize the value of convening for teaching and learning. For instance, many schools of business offer certain degree programs through "distance education" systems. There are a number of schools offering graduate degree programs using these technologies. However, in almost every case, students are still required to travel to the home campus for at least one week of "face-to-face" work with their colleagues and instructors. There is an implicit understanding that it remains important for us to "get to know" each other in this familiar format before we attempt to collaborate using other communications platforms.

So too, I believe, we as scholars need to come together to advance our work. That is why we attend professional meetings. Here at IUSB, UCET annually sponsors the Midwest Conference on the Scholarship of Teaching and Learning. The fourth annual conference is scheduled for April 11, 2003, and Barbara Cambridge of AAHE will be the keynote speaker (for more information, see http://www.iusb.edu/~ucet, and click the "Scholarship of Teaching" link).

We at JoSoTL recognize the synergies we can develop through better partnership with the SoTL Conference here on our own campus. Many of the people involved in JoSoTL are also active in the SoTL Conference. Both of these projects have reached a certain level of maturity, and it is time to explore ways to advance our common cause: supporting our shared community of scholars. In future issues of JoSoTL, you will see more information about the conference. We will consider how we might help make public work presented at the conference. And we will encourage you, our readers, to become involved in the conference.

How to most effectively bring these two modes of community support (web-based journal and professional conference) is certainly open to interpretation. Web technology is still a very young medium, and no one has perfected a sound means for its optimal application. Here at JoSoTL, we strive to improve all aspects of our journal: both the editorial process and the delivery of the journal through our web site. Please offer your suggestions for improvement via email to gkern@iusb.edu, or josotl@iusb.edu. We welcome and appreciate all of your comments. Together, we can help to form a stimulating, vibrant community of scholars as we pursue our common interests in the Scholarship of Teaching and Learning.

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Development of a Simple Mathematical Predictor of Student Performance in General Chemistry

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Abstract

Colorado College uses a sequential course structure exclusively in its calendar that is similar to those used in summer programs at other institutions. In this approach, a student takes, and a faculty member teaches, only one four-hour course each month. This format enhances longitudinal studies of the factors that affect student grade performance and retention. In this study, standard predictors of success, such as ACT and SAT scores, are compared with a simple mathematical background knowledge probe. Other factors that may impact student performance such as economic background, gender, learning style, and time between courses are also discussed.

Introduction

One of the major problems facing faculty who teach science courses that have a significant reliance on a mathematical foundation is determining whether individual students entering the class have the appropriate preparation in this ancillary area. Compounding the difficulty of determining and then enforcing pre-requisites are other factors that can enter the picture, such as math anxiety as a separable issue from math or science competence.[1] A simple background probe that can be administered in a few minutes and which is relatively free of confounding bias is needed to provide important feedback at the outset of the course. Such an instrument would allow the teacher to do some last minute fine-tuning of the course level as well as offering the opportunity for scheduling of individualized remedial help.

Background

The past decade has seen a fierce national debate over the validity of using standardized exams such as the SAT in college admission decisions, especially as affirmative action has come under attack.[2] Newsweeklies expound upon these tests and their role in our society, and it seems likely the Supreme Court will soon have to sit on their constitutionality.[3,4]

In addition to being used for admissions and financial aid, these tests are also sometimes used to replace college-wide requirements and for placement in courses.[5] Some years ago, Pickering did an interesting long-term study using the SAT math score to identify students *a priori* who were expected to do poorly in General Chemistry. In a controlled experiment, he offered an intensive supplementary course in problem solving to a subset of the students with SAT math scores below 610. The modest improvement in grade noted (0.41 on a 4.0 scale for n = 43) versus the control group and the effect on their subsequent General and Organic Chemistry grades (0.17 and –0.08, respectively) for the same students raises questions about the long-term efficacy of such efforts.[6,7]

Despite the disheartening results in Pickering's study, science teachers continue to try to identify which students are likely to need help as early as possible. This seems especially important with the intensive course structure known as the "block plan" in which students take (and instructors teach) one course at a time for about a month. This structure is used at many

[1] Hembree, R., The nature, effects, and relief of mathematics anxiety, *Journal of Research in Mathematics Education,* **21**, 33-46 (1990).

[2] Mealer, B., Moves against affirmative action fuel opposition to standardized admissions tests, *Chronicle of Higher Eduction*, **48**(8) A40-A41 (Oct. 17, 1997).

[3] Cloud, J., What does SAT stand for? *Time*, **150**(20) 54-55 (Nov. 10, 1997).

[4] Lehman, N., Behind the SAT, *Newsweek*, **134**(10) 52-57 (Sep. 6, 1999).

[5] Coley, N., Prediction of Success in General Chemistry in a Community College, *Journal of Chemical Education*, **50**(9) 613-615 (1973).

[6] Pickering, M., Helping the High Risk Freshman Chemist, *Journal of Chemical Education*, **52**(8) 512-514 (1975).

[7] Pickering, M., The High Risk Freshman Chemist Revisited, *Journal of Chemical Education*, **54**(7) 433-434 (1977).

institutions for summer session courses, but it is used for the entire calendar of courses at Colorado College. One of the advantages of the block plan is that it fairly readily allows students to switch courses on the first day of class without increasing their years of matriculation if they can quickly determine what course is best for them. Even if a placement quiz or "knowledge probe" at the start of a course is not used to determine who may need extra help, it can provide students with additional information about whether they are in the appropriate course for their background and interest level.

Another use of such knowledge probes is to help in selecting groups for cooperative learning strategies. Because students exhibit a variety of learning styles,[8] it is useful to identify those that are stronger or weaker in the traditional algorithmic approaches. Depending on the tasks set by the instructor, it may then be desirable to form groups that are diverse in their abilities, or, if it makes sense is to spend more time with those groups needing additional help, it may be desirable to form groups with similar backgrounds.

At Colorado College, courses are limited to 25 students and there are up to eight different faculty teaching General Chemistry in any given year. Approximately 200 students take the introductory chemistry course each year, or about a third of each graduating class. No differentiation is made between students majoring in chemistry or any other field. General Chemistry I and II are offered almost every block, or nine and eight times per year, respectively. The courses are equivalent to the first and second semester of General Chemistry taught elsewhere, and each block is three and a half weeks long (followed by a half week break for grading and setting up the next course).

The unique nature of the block plan provides a "laboratory" for testing new ideas in education. With different teachers and so many students from varied backgrounds involved in the introductory courses, it is possible to obtain data on a host of variables with minimal confounding.

Because SAT and ACT scores are not routinely available to chemistry faculty at Colorado College for reasons of privacy, different "quizzes" have been devised that can be taken in a few minutes on the first day of class. The quizzes are taken without calculators, and they are designed to ask a few questions that are a little outside of the routine "algorithmic" approaches students learn, especially those that rely on a calculator. The results of these quizzes are shared with the students immediately so that they will be able to determine for themselves whether they need to arrange for additional tutoring or whether they should postpone the course until they are better prepared. Often the quizzes are simply exchanged with a neighbor and the scoring is covered in a couple minutes as a method of nearly instant feedback. In those instances, the quizzes may not even be collected, so the instructor may get no direct feedback on a given student's needs, and the student is given full responsibility for their own decisions regarding what to do with the results.

The purpose of this paper is to report on the efficacy of two of these quizzes, comparing them with other predictors and factors affecting long term "success". Success in this case is

[8] Felder, R. M., Matters of Style, *ASEE Prism*, **6**(4) 18-23 (1996).

measured by grades in subsequent chemistry courses, but other measures, such as retention and the number of subsequent courses taken are also considered. Personal reflections on what sorts of knowledge probes need to be developed in order to continue to improve through this classroom action research process are included in the ensuing discussion.

Experimental

Five General Chemistry II courses (n = 132 students) spread over five years (1995 to 2000) were randomly selected from those courses in which a two-question math quiz had been administered. Five additional courses (n = 117 students) were selected from those in which a seven-question quiz (Appendix 1) had been given. Three of these were General Chemistry I courses and two were General Chemistry II courses. The first two questions of the seven-question quiz are the same as those used on the two-question quiz. These courses involved two different teachers with varying degrees of cooperative learning strategies incorporated in their courses.

Additional retrospective information was obtained from student transcripts, such as the SAT and ACT scores for math and verbal reasoning, total financial aid, work-study grants, and grades in prior and subsequent chemistry courses. Information was also collected on how long students waited between courses, who taught each course, the format used in the course, length of time between courses, self-reported ethnic background, and the gender of the student. This information was correlated using multiple linear regression and ANOVA between the predictors and factors. Minitab version 12 was used throughout the analysis.

In one of the courses (a typical course of 25 students in spring of 2000), data was collected in class on the learning preferences of the students using the index of learning styles developed by Felder and Soloman.[9] The students self-scored this instrument, and made use of the suggested published strategies as they saw fit. Throughout the course, the instructor made the point of sharing with the students the various assessment tools being used and what was learned from them. Because the students saw themselves as involved in an experiment in this class, they seemed more involved in how the course was taught and in thinking about how to optimize their learning right from the start of the course. In the following year (spring of 2001), the same instructor in a matched class of students in terms of class size, content, text, diversity, and timing, repeated the experiment but without informing the students about the educational research aspects and assessments tools being used until the end of the course. Such classroom action research with individual courses is common, and these experiments add to the enthusiasm that both the instructors and the students feel in these courses.

Results

At Colorado College, students wait an average of 4.7 months between General Chemistry I and II, although they are advised to take them within the same semester. The average waiting period lengthens to 7.4 months between

[9] Soloman, B. A., and Felder, R. M., Index of Learning Styles, North Carolina State University, www2.ncsu.edu/unity/lockers/users/f/felder/public/ILSpage.html (2000).

General Chemistry II and Organic Chemistry I. Between the Organic Chemistry I and II, this period shortens to 2.6 months. Chemistry majors tend to take their courses somewhat closer together than this, and the Organic I and II progression reflects this as only Biochemistry and Chemistry majors (and those planning to attend medical school) are required to take the Organic Chemistry II. On the other hand, Geology majors (who are required only to take General Chemistry I) often wait three years between the first and second course. Only those Geology majors planning to continue into graduate school in the field return to take General Chemistry II.

Despite these widely varying times between courses, there is little evidence that students' *grades* were impacted by either putting off their chemistry courses or by taking them back-to-back. This may possibly be because most students who go on continue to mature in a parallel science and they bring that mental maturity with them. Alternatively, this may indicate that the learning strategies and motivation that the majority of students bring to their courses is more important to their overall success than the content we manage to impart in our chemistry courses, despite how sequential we think they are. (Students who skip a course or take them out of sequence *do* suffer, however, so there is something they are mastering even if we can't find an adequate test for it.) Whatever the reason, the gaps between courses are not drastically different from that experienced by students in a semester system, where the average time between material in successive semesters is 4.5 months (mid-fall to mid-spring) and 7 months (mid spring to mid fall).

The profile of the students entering General Chemistry II is typical of the student body as a whole, with 60% on financial aid and two-thirds of these on work-study. About 55% are female, 16% are a self-identified ethnic minority (about half are Hispanic), and the median SAT Math and English scores are 630 and 620 respectively. The average grade obtained in the first course is a 3.0 on a 4.0 scale. This drops slightly to a 2.9 in General Chemistry II and a little further to a 2.7 in Organic Chemistry I. The average returns to a 2.9 in Organic Chemistry II as primarily majors in chemistry, biochemistry, neuroscience, and pre-medical students take it.

Based on Soloman and Felder's four-dimensional Index of Learning Styles,[10] a given class will be moderately (but significantly) more visual than verbal and somewhat (but significantly) more active than reflective in their learning style preferences. The class will also be slightly (but not significantly) more sequential than global, and nearly equally balanced on the sensing versus intuitive dimension. Although the averages fall near the middle of the scale, at least a third of the students will have a strong preference for at least one learning style. Out of 25 students, each of the different dimensions were represented by at least two students with a strong preference for that style except the reflective and verbal dimensions, and even these had more than one student with a moderate preference in that direction. This profile matches the expected general science student population at Colorado College, which attracts outdoor-oriented, athletic students who like a balance of creative

[10] Soloman, B. A., and Felder, R. M., ibid, (2000).

outlets to go with the intensive study of the block plan.

These profiles indicate that using a variety of approaches on every major topic should be expected to be necessary in order to reach all of the students. At the end of the course in which the students were actively informed of the results of the various assessment tools, student evaluations indicated that they appreciated the efforts made to respond to their different styles of learning, and most students were more proactive than similar classes in trying to make the best use of the resources geared to their preferences. The following year's class (22 students), which had a slightly (but insignificantly) higher SAT-M score of 643.5 ± 40.3, 64% female, 14% minority (compared to 631.1 ± 53.2, 68% female, 16% minority), had a more typical (lower) level of engagement and interest in the class. The final standardized exams from the American Chemical Society, which are designed to have normal distributions around 50%, were also nearly equivalent (64.1% versus 62.0% for the second class compared to the first class, matching the ratio of the SAT-M scores). Although these results indicate the classroom involvement in the learning style research project had little or no impact on the student learning or grades achieved, the anecdotal evidence of retention and interest beyond the class is very much different: from the first class with the slightly lower SAT-M scores, five students (three women and two men) immediately selected the author as their academic advisor and two of these indicated an interest in majoring in chemistry, while only one from the second class did so in the in the two months following each course.

A multiple linear regression analysis of the various predictors (Table 1) shows that the two-question math quiz, graded 0 to 3 in half-units, is a better predictor of the grade a student will obtain in General Chemistry II than either the SAT or ACT math sub-tests. (Deviation from a normally distributed variable for the three predictors and the dependent "grade" is not significant despite their discrete functions.) General Chemistry II is one in which math ability plays a major role, as this is the course that deals with thermodynamics, acid-base equilibria, and kinetics. The ACT's better performance compared to the SAT may be due to a variety of factors. For example, the cram courses now available for improving a student's SAT test scores may be clouding the test's predictive power. Also, the ACT (in this study) seems to be taken by a larger percentage of students with a more diverse background of abilities and economic advantages compared to the SAT.

Table 1: National Test and Math Quiz Predictors of General Chemistry II Grades

Regression:

Predictor	Coef	StDev	T	P	ANOVA (F)
Constant	0.052	1.131	0.05	0.963	
Math-quiz	0.2549	0.1193	2.14	0.038	10.25
SAT-M	0.00027	0.0022	0.13	0.899	1.89
ACT-M	0.07982	0.0472	1.69	0.098	2.86

R = 0.504 R (adj. for d.f.) = 0.451 n = 48 (due to few students taking both tests)
Overall Regression: P = 0.005 (MANOVA F has 1 d.f./44 d.f.)

A regression of each predictor alone gives adjusted correlation coefficients of 0.381 (n=131), 0.257 (n=111), and 0.539 (n=65) for the Math pre-quiz, SAT-M, and the ACT-M tests respectively. As was noted above, the ACT test's apparently better performance is a result of the unique subset of students sampled, and Table 1 represents a better indicator of the relative merits of each test applied to the same subset of students despite the fact they are not truly independent variables.

Table 2: Math Quiz and Categorical Predictors of General Chemistry II Grades

Regression:

Predictor	Coef	StDev	T	P	ANOVA (F)
Constant	2.2372	0.3125	7.16	0.000	
Math-Quiz	0.30384	0.07654	3.97	0.000	22.94
Fin. Aid	-0.2869	0.1881	-1.53	0.130	2.92
Class	0.07920	0.09878	0.80	0.424	0.03
Instructor	0.0430	0.1448	0.30	0.767	0.22
Gender	0.04722	0.07062	0.67	0.505	0.68
Major	0.3691	0.1166	3.17	0.002	8.59
Ethnicity	-0.21308	0.09525	-2.24	0.027	5.00

R = 0.452 R (adj. for d.f.) = 0.397 (n = 129) Overall regression: P = 0.000
(MANOVA F has 1 d.f./121 d.f.; Durbin-Watson stat. = 2.01; Lack of fit P > 0.1)

In Table 2, the two-question math quiz is coupled with a number of categorical variables and one continuous variable (financial aid, expressed as a fraction of the full cost of attending). The class variable has four levels (1 – 4), and the other variables have all been reduced to two levels (-1, 1). The underlying assumptions of the regression model are violated by departures from normality for these predictors, but the results are still useful for making some qualitative observations.

The results of this regression and MANOVA suggest that the class (first, second, third, or fourth year student), instructor, and gender of the student have little or no impact on the grade achieved in these courses. The major of the student (one of the chemistry options versus non-chemistry majors), the ethnic background of the student (Caucasian versus all others), and the financial need of the student are more important. As might be expected, chemistry majors tend to achieve higher grades, although at this stage of their careers only a small fraction have declared their major. Thus, cause and effect are still undifferentiated.

There is also a correlation of financial need and ethnic background, as students from more diverse backgrounds tend to have higher financial need at Colorado College. The financial need is usually (but far from always) coupled with more time spent on work-study, and this is time that may interfere with time spent on the course. Based on anecdotal student information, another contributor to the financial need effect that is largely independent of the student's ethnic background is that students who have a large loan often are under pressure from their families to transfer to a less expensive institution. This effect is most pronounced in the blocks taught at the end of the year as students begin to mentally disengage from the course and the institution.

While a complete analysis of the results of the seven-question pre-quiz will not be presented here because of the similarity of its results to the two-question pre-quiz, it should be noted that the seven-question pre-quiz doubles the range of possible scores (0 to 7 instead of 0 to 3). This improves its value for individual person diagnostics. It also adds a component that tests for recollection of chemical content from previous courses. As a result, it does a slightly better job of predicting the grade a student is likely to achieve. Although the results presented in this paper have focused on General Chemistry II, both the two-question and the seven-question quizzes have been administered in General Chemistry I with very similar results.

Even though memory of prior course content was not a variable emphasized in this study, comparison of the two-question prediction to the full seven-question prediction indicates that chemistry content memory is not as important as facility with math in predicting a subsequent course grade. The memory portion was also more subject to loss as the time interval between courses increased. There is little evidence that general chemistry is strictly sequential, as various textbooks order the material differently. Instead it seems there are a variety of valid starting points and the more grasp the student has of the global picture, the more easily new material can be placed in a meaningful context. Thus, the grade obtained in subsequent courses seems to be more closely connected to some longer lasting skills or a more global knowledge than it is to any specific content recollection. However, at Colorado College, content tests such as the American Chemical Society General Chemistry tests do correlate strongly with the course grade ($p = 0.000$) when they are administered at the end of the course, as does the GRE-subject test in chemistry ($p = 0.011$), which is taken by many of the majors at the end of their undergraduate career. The average grade on this latter test is comparable to the national scores for students from other schools, indicating that the block plan does allow an accumulation of content that can be measured to some extent.

Reflections and Future Directions

The efficacy of this simple knowledge probe for detecting those students who have math difficulties relevant to the course has been born out over the years. The positive impact of taking the time to involve the students in understanding their own learning processes is equally apparent, although more work is needed to find ways to make such involvement more time efficient in order to avoid additional loads on the faculty. Much less clear is what intervention measures to take with those students who have math difficulties in order to affect a long-term gain in chemistry. At a minimum, a good math review at the outset, additional tutoring outside of class, or a remedial math course is required. For some students this will prove to be adequate, but for a large percentage, something more is needed.

In a recent paper, Ashcraft and Kirk have provided some valuable insights into how math (or other anxieties) affect other performance.[11] By proving math anxiety is separable from math incompetence (and that they are independently treatable), they point the way to other testing that can indicate where students may obtain the help needed to overcome these two common hurdles. Not surprisingly, students with math anxiety often develop lower math aptitudes as they progress through their education, and as a society we must recognize (and treat) this problem in the same way we are beginning to recognize handicaps such as dyslexia.

The demonstration of the impact of math anxiety on the speed of mental processing for students who are competent in math despite having such anxiety indicates that giving these students longer to respond will allow them to reveal their actual level of competency on the subject matter of interest. Ashcraft and Kirk argue that problems that involve some form of math beyond the level of multiplication or addition tables, and which call upon other forms of memory at the same time, compete for "space" in the smaller "working memory" available to these students compared to others. An analogy might be comparing two computers, one with a smaller or "busier" CPU (due to interference from the anxiety) than the other. Both can solve the same complex problems, but because more shuffling of the data is needed in the smaller/busier CPU machine, longer time must be spent to achieve the same end result. Except for the time factor, both will achieve the same final goal. If one machine lacks the proper programs (math competence), it will not be able to solve the problem until such programming is provided, at which time it may be faster or slower depending upon multiple factors, including the "working memory" it has.

This anxiety preoccupation in the "CPU of the mind" also is relevant when the material is presented in the class if a mathematical presentation is involved. "Taking it in" will take longer for these students just as purely written (textual) presentations will take a dyslexic student longer to process correctly. The inherent abilities except for this time factor are in no way diminished. This suggests again that multiple modes of presentation are needed in order to reach the diverse population of students that we will encounter in our classes, especially if we are to help all of them achieve their full potential for contributing to society.

What does this suggest should be done in the way of modifying the knowledge

[11] Ashcraft, M. H., and Kirk, E. P., The Relationships Among Working Memory, Math Anxiety, and Performance, *Journal of Experimental Psychology: General*, **130**(2), 224-237 (2001).

probe described here? First, at least some measure of the level of math anxiety should be obtained so that the student may be steered to the appropriate source of help. Math anxiety is highly correlated with chemistry anxiety in general,[12] underscoring the need to determine the influence of this factor on student performance at an early stage. Two simple probes that may be of use for this include asking the students to report the number of high school math courses they have taken and to rank their own anxiety on a scale of 1 to 5. Both of these showed significant correlation ($p = 0.05$) with a much longer test of math anxiety that Ashcraft and Kirk employed, and this author intends to include at least these two in the next version of the background knowledge probe. As Claude Fuess once said, "I was still learning when I taught my last class."[13]

A slightly longer math test taken without calculators that includes a more active, non-mathematical, non-verbal visual test component (such as rotating or constructing actual stick and ball models of stereo isomers)[14] might also be useful for predicting academic success in Introductory Chemistry courses. This would offer a better range of responses so individuals can be more accurately diagnosed as well as keeping its predictive power for the group. It might also better test for the multiple intelligences that are correlated with the necessary skills to do well in Chemistry. The question of how sequential general chemistry really is, especially in the context of developing critical thinking skills, is still open for debate. Clearly, it would be very useful to proceed to background knowledge probes that can be administered on the first day that will determine what level of development students have achieved in the area of critical thinking skills, and then to select questions that help lead the students to move to the next level. Some work is beginning to be done in this area,[15] but a great deal of foundation still needs to be developed for a large percentage of students, including simply moving them beyond a state of anxiety.

Whether the instructor includes additional questions that probe other learning styles and intelligences, a short math quiz that does not allow the use of a calculator "crutch" taken at the start of the course seems to be a better predictor than the national ACT-M or SAT-M test. The short quiz described here with its immediate availability of results for either the students or the instructors (or both) provides a viable alternative to the much-maligned national tests.

[12] Eddy, R. M., Chemophobia in the College Classroom: Extent, Sources, and Student Characteristics, *Journal of Chemical Education*, **77**(4), 514-517 (2000).

[13] Claude M. Fuess, After 40 years at Phillips Academy, *Independent Schoolmaster*, Atlantic Monthly Press 52, http://www.bartleby.com/63/30/2530.html.

[14] Habraken, C. L., Perceptions of Chemistry: Why is the Common Perception of Chemistry, the Most Visual of sciences, So Distorted?, *Journal of Science Education and Technology*, **5**(3), 193-201 (1996).

[15] Kogut, L. S., Critical Thinking in General Chemistry, *Journal of Chemical Education*, **73**(3), 218-221 (1996).

The Journal of Scholarship of Teaching and Learning (JoSoTL)

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The Scholarship of Teaching and Learning:

Facilitating Adult Learning

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Abstract

In the Scholarship of Teaching and Learning (SOTL) project I developed, I chose to investigate how constructivist teaching strategies influence the learning processes of adult students in higher education. I chose to teach two groups of students to use a constructivist strategy called concept mapping. They used this strategy during the courses I taught in the first semester of this study. Then, I followed these students during semester two to see if they continued to use concept maps and to find out how the use of maps impacted their learning. To accomplish this, I checked the students' first map and final map from semester one, and their maps, if any, from semester two. In addition, we interviewed the students at the end of semester one, and again at the end of semester two, to find out how the use of mapping affected student thinking and learning. Results indicate that 65% of students continued to use maps in the second semester and all students reported changes in their thinking.

Framing the Question

The question of how adults learn has always held a deep fascination for me. I believe this is because I started my professional career as a nurse and my first exposure to formal teaching was as a staff development instructor in an acute care setting. In that setting, I was always intrigued by the fact that staff development programs for adults produced such varied and unpredictable results. Some adults used the information presented and some did not. The raised two questions for me, "How do these adults learn within the context of their practice?" and, "What can I do to facilitate that type of learning?" As I moved on in my career, I decided that I wanted to understand this learning question in a much deeper sense and, thus, chose to pursue doctoral work in adult and continuing education. Ultimately, I accepted a faculty position in that discipline.

However, before that time my teaching experience included working with adult students in community college and university settings. Often, I saw these adults enter higher education relying solely on learning strategies that had worked for them in the past. Most often these strategies were rote learning, including memorization, recall of information and passive learning. I began to think about how I could not only teach the content in my courses, but how I could also help adults to understand their own learning processes. From my work as an adult educator, I knew that adults had experiences that were rich resources for learning and, yet, I often saw adults avoid using that experience in a higher education setting.

At about that same time, I came across the work of Stephen Brookfield. Brookfield (1995) advocates the position that if we are to become critically reflective teachers, we need to examine how we as teachers learn from our students, from our autobiography, from theory, and from our colleagues. I decided to take Brookfield's work seriously and began to think about my own experience as a learner, or my own autobiography. When I looked back at my own learning, I recognized that it was in my doctoral program at Cornell University that I began to understand my own learning. In that program, I was fortunate to be able to work with Dr. Joseph Novak (1984, 1998), and to learn more about constructivist learning and the use of concept mapping. As I began doing concept maps, I recognized that I did not understand how to link concepts. Additionally, I had not learned how to search out interconnections across bodies of knowledge, nor had I learned how to develop a shared meaning with the instructor. Using concept maps helped me to understand how I learned. As I developed this understanding, I started to use concept mapping in the courses I was teaching and each time I used it, I saw significant changes in how students learned. I also saw resistance from students and from other faculty in the use of this particular strategy. I would get questions from both students and faculty such as: "Why are you doing this?" "Does doing concept maps really make a difference?" Since I was teaching in a college of nursing at that time, a few colleagues and I, who were interested in mapping decided to study the learning outcomes for nursing students using maps (Daley, 1996; Daley, et al, 1999). In this work, we did see changes in learning and were able to document some information on how mapping influenced the learning process.

The issue for me then took on another aspect. Did students, once they left the courses that I taught using mapping, continue to use that strategy? I was curious about long-term student changes where mapping was not required. To me this question is very important because if the purpose of the mapping is to help students understand their own learning and to foster a "learning how to learn" (Novak, 1984) approach, then it seemed really important to know if they continued using this strategy. Also it seemed important to know if mapping was incorporated into their learning and thinking activities irrespective of its use in specific courses.

At about the time I was pondering this question, the University of Wisconsin – Milwaukee, under the direction of Tony Ciccone with the Center for Instructional and Professional Development (CIPD), began participating in the Scholarship of Teaching and Learning Program with the Carnegie Foundation for the Advancement of Teaching. CIPD sponsored a Center Scholars program and provided funding for me to investigate how adult students learn with concept maps. The funding allowed me to follow students for a year and see what impact the maps had on their learning.

Context of the Work: Adult and Continuing Education Graduate Program

I currently teach in an adult and continuing education graduate program. The students in our program are all Masters or Doctoral students who come to us from a variety of disciplines. Many of our students are trainers in business and industry, staff developers in health care, faculty in vocational technical institutions or teachers of adults in community-based agencies. Our students, all adult learners themselves, are on average 35-40 years old.

I chose to use two different courses in this project. The first is a Masters Degree course which is the initial course our students take when they enter our program. Since these students are very new to graduate education, they are often concerned that they do not have the ability to succeed in graduate school, and are often unsure of the requirements. Many have been out of school for a number of years and feel their academic skills are a bit rusty. The second course in this project is an elective in our program attracting predominately doctoral students. The second course was also taught completely on-line, with only one face-to-face orientation meeting.

In each course, I taught students to use concept maps by first having them read literature on concept mapping. Then we discussed mapping, either face-to-face or on-line, and they practiced developing maps by mapping out an article from their reading. In the first course, students did concept maps on their reading as a way to frame a paper on their development as adults, and in classroom exercises as a way to link conceptual material from the course to their own experiences. In the second, the on-line course, students did concept maps of case studies and used the maps to link the case study to their reading. Additionally, they mapped out and compared and contrasted two books. Finally, students in the second course created concept maps of their readings.

The face-to-face course met once a week during the evening. In this course, students developed maps any way they wanted. Some chose to hand write the maps, some did them on a computer program called Inspiration (http://www.inspiration.com), and some used other programs such as Microsoft Word or PowerPoint. The on-line course was structured in seven modules, including readings, learning activities, individual or group project work and on-line discussion time. In this course, students created their concept maps in Cmap, a server-based program created at the University of Western Florida (http://cmap.coginst.uwf.edu/) and installed on the UWM School of Education server. Students learned to access the Cmap program and then to develop maps on the server. In this way, students in this course could view their colleagues' work.

The purpose of this study was not necessarily to look at the impact of technology on the mapping process. However, because one course was face-to-face and one was on-line, the project did end up acquiring a technology facet. Still my major interest is how mapping shapes learning, whether face-to-face or on-line.

Finally, I used quantitative and qualitative research methods since both research methods are valued within the field of adult and continuing education. Moreover, since the purpose of this study was two-fold, first to see changes in concept maps, and second, to understand the student experience of learning with maps, it seemed to me that a mixed-method approach was needed.

Gathering Evidence

The major question that I wanted to investigate in this study was how concept mapping impacts adult student learning over time. To do this, I chose first to request that students participate with me in this venture. All the students enrolled in both courses agreed to have their course work analyzed and used in this study. While some students requested that certain pieces of their work not be used, as they saw them as very personal accounts of their growth and development as adults, most students were very agreeable about being interviewed and having their work analyzed.

In the Fall 2000, I collected the first and final concept maps created by 21 randomly selected students from these two courses. Then in December 2000, my assistant interviewed these 21 students. At first, I wanted to talk with students about how the mapping influenced them. However, I came to realize that if I did the interviews the students might tell me what they thought I wanted to hear. To avoid this potential bias a doctoral student in adult education, completed the interviews. We structured the interview guide so that she asked the following questions: 1. What was it like to use concept maps as a learning strategy? 2. What did you learn while doing concept maps? 3. Where else have you used the maps since the completion of your course (if at all)? 4. How was doing the maps the same or different than other learning strategies you have used previously? 5. What did you like most/or like least about using concept maps? 6. What changes, if any, did you see in your thinking ability since using concept maps? 7. What was the most significant learning you remember from this course? 8. If you were going to describe concept mapping to another graduate student, what would you say? 9. How do you see using/or not using this learning strategy in the future? At the end of the first semester, we scored the first and final maps, then analyzed the qualitative data collected by developing categories and coding the data.

In May 2001, we again contacted each of the 21 students and completed a second interview. If these students had constructed a concept map in the second semester, we then asked them to send us a copy of that map. Once again, we scored the maps (see Novak and Gowin, 1984 for scoring formula) and analyzed the interviews through a system of categories and codes. This is the dimension of the study which is most unique since, to my knowledge, there has been little work done following students over a period of time to see if and how their learning strategies change after learning concept mapping.

Emergent Findings and Broader Significance

So what has this work demonstrated about student learning? During the first semester there was a statistically significant change in student concept map scores from the first to the final map. The mean score on the first set of maps was 44.81 and the mean score on the final maps at the end of the semester was 121.43, for a difference of 76.62. This change in mean scores indicates that students learned to subsume lower order concepts under higher order concepts, to progressive differentiate concepts and to synthesize concepts on their maps. These findings indicate students learned to link, develop interconnections, analyze and synthesize course information with their experiences. What was really exciting to me, however, was that 65% of the students continued to use maps into their second semesters. For those students who did use the maps, the mean score on the maps from the second semester was 120.22. This seems to indicate a significant change from the end of the first semester in the quality and development of maps in those students who continued concept mapping. Two things are of particular interest; first, many students continued to do maps, and, second, that the mean score was virtually the same. I anticipated that the means would decrease to some degree compared to the end of the first semester.

When analyzing the interview findings, we were able to categorize student responses in three basic categories that indicated how they learned and used cognitive mapping. These categories were: Developing Cognitive Maps, Learning with Cognitive Maps and Follow-up. An example of a cognitive map is presented in Figure 1.

Developing Cognitive Maps

What students indicated was that their learning was facilitated when they understood how to develop maps. This involved understanding their own initial reactions, which were often negative, and being able to articulate how that reaction changed over time. Additionally, students indicated that they needed to be able to describe mapping to others and discuss what they liked and disliked about it and where they were having difficulty in creating maps. Finally, students expressed the view that their comfort and familiarity with computer software often impacted how they felt about mapping and how much they were able to learn from mapping.

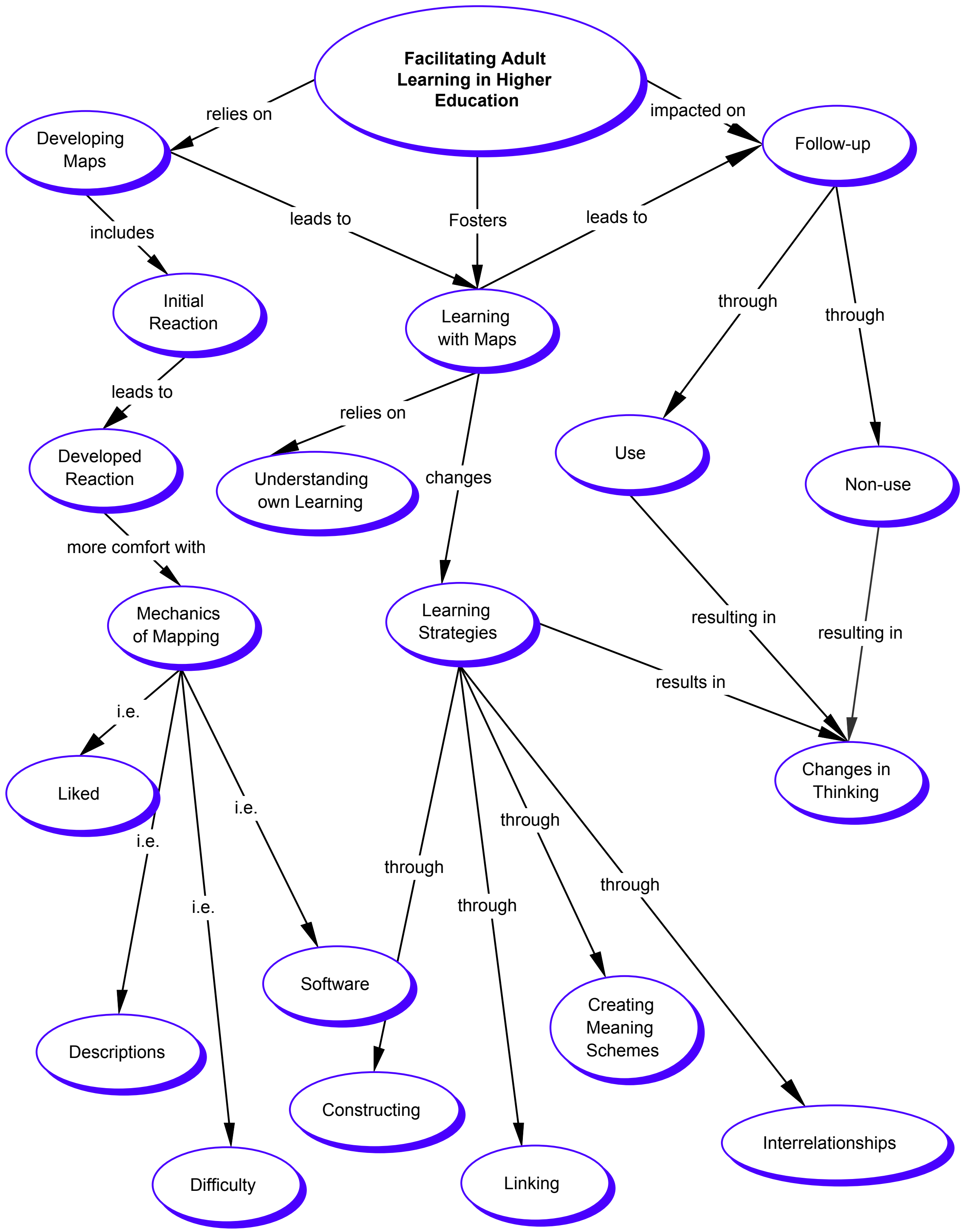

Figure 1: Facilitating Adult Learning in Higher Education Learning with Cognitive Maps

Students also indicated that mapping helped them to understand their own learning. It was through understanding their own learning that students began to use maps to develop the learning strategies of linking concepts, developing interrelationships, creating meaning schemes, and constructing knowledge. We could see from student responses in the interviews that linking was the first step in developing these new learning strategies. Students learned to link concepts in ways that made sense to them and connected with their previous experiences. They also learned to search out relationships among concepts. They told us that they learned how they were creating meaning schemes and constructing their own knowledge base through this process.

It was very exciting to hear student say things such as:

> *You read it first and then you pull out the basic concept, the major concepts that are within that framework and you draw connections between those concepts, and you are going to see connections and you are going to see distinctions that were not apparent to you before you sat down and actually did that. That is how you construct your new knowledge*

or,

> Concept mapping is a way to take the idea, apply it, and get a deeper meaning out of it at the very end. It is not just a matter of learning a concept, learning about theory, defining a word and spitting back a definition. It is actually applying it to what you know so that it makes more sense in the actual world.

or,

> *I would say things like the purpose of concept maps is to help us explore the meanings, the inner-relationships, that we are making as we developing our understanding of the concepts. So that it is a meaning/making process. That is what really grabs me, anyway*.

and, finally,

> *It made you look at whatever it was you were doing in its entirety. It made you look at it as a whole. And then started breaking it down by concepts and then you would rebuild it by linking stuff and I guess that is how I constructed new knowledge or how I found myself looking at things differently. You feel the knowledge building. You just feel yourself seeing things differently than before you started doing that.*

There were some students in the study who had difficulty creating maps and using mapping as a strategy. The difficulties seemed to be related to the time required. Often students would indicate that this type of learning activity required more time than they were prepared to, or wanted to, give to the particular assignment. Other students admitted that the difficulty they had with maps had more to do with changing how they learned. Students stated that the maps required them to think differently and some students just did not like that. As this student indicates:

> *But, I guess what I hated the most was that I had to change my thinking mode. It is before, like, well, I am just reading this information, and I am picking out what I see is in the writing or what the writer is trying to present. I guess I just didn't like the idea of changing old habits and doing things differently.*

Follow-up

In interviewing the students on follow-up we found that 65% did continue to use mapping as a learning strategy, but even those who did not use cognitive maps in future learning reported that their thinking had changed. Students were able to describe how, when they approached learning a new topic, they started to think conceptually, searching out interrelationships and looking for ways to connect the information with their experiences. What I found very interesting was that students were able to describe changes in their thinking even if they no longer sat down and formally developed maps.

In this project, students who continued to use mapping reported that they did so for a number of reasons. They seemed to use maps to understand course material in subsequent graduate courses. They also relied on maps as a way to understand particularly difficulty material. Many participants reported that when they felt "in trouble" in a course or that they "did not get it," they would try mapping out the material as a way to develop their understanding. Additionally, learners tended to use maps to frame projects for subsequent courses or work-related projects. One participant described how he had a big project to do at work and as a way to help his team understand the scope of the project, he mapped it out and shared the map with them. Another student described how she used a concept map in a subsequent class to demonstrate decision-making.

The students who did not use mapping indicated that they chose not to because it was not required, took too much time or they did not have access to concept mapping software. This last statement was a surprise to me. In teaching the classes, I thought I had been clear that the maps could be constructed in most any way the students chose. However, since the software does facilitate the actual mechanics of mapping it seemed that for those who did not create the maps, the lack of access to software most likely compounded the time problem.

Another interesting aspect of this study was that it included both an on-line and a face-to-face component. It did not appear that there was any difference in the quality of maps created by the students in the on-line and face-to-face courses. However, in the on-line course, there was a higher percentage of students who continued to do maps at the one-year follow-up. My sense is that this finding emerged because there were mostly doctoral students in the on-line class and those students saw the maps as tools to assist them in the conceptualization of their dissertations, as a way to synthesize literature reviews and as a way to conceptually link research and theory courses. I did not get the sense that the on-line component of the course facilitated map development, but rather that the students' need to use the maps in subsequent scholarly work seemed to be the motivator to continue. That said, I think the connections among mapping, software and technology are still very important issues for further investigation.

Conditions of Doing Scholarship of Teaching and Learning

Part of what made it possible to do this project was timing. The University of Wisconsin – Milwaukee has begun to look at the SOTL approach and has initiated a number of activities designed to inform faculty of its possibilities.

Being involved in some of the initial committee and planning meetings, I found myself getting very excited about the possibilities for research and scholarship around teaching and learning issues. So, when CIPD offered small grant opportunities to design SOTL projects, I applied. The grant funding was important because it did allow me to buy myself out of one course and to fund the typing of transcripts. However, more important to me was the acceptance of this kind of work by colleagues within my own department and across the University. Funding is great, but without a commitment by the institution and one's colleagues, it would be difficult to persist in work studying our teaching and learning practices in higher education.

Benefits of the Work

I see the benefits of this work as three-fold. First, the students benefit. By studying, analyzing, reflecting on and changing our teaching practices, we offer new insight to students and facilitate their learning in ways that we may not have thought about previously. Second, I , personally benefit. I found myself very excited about this project because it allowed me to look at my teaching and ask questions that I felt could only help me become a better teacher. It also motivated me to continue using mapping once I saw the results.

Finally, the institution benefits. As we develop an institutional reputation for focusing on teaching and learning, that reputation can only enhance our credibility and authenticity within the communities in which we live and provide our services to students.

Lessons Learned

As I think back on the lessons learned in this project, one of the things that struck me was how difficult it is to get learners to change their learning strategies. I knew there would be resistance to doing concept maps, but I did not expect students to articulate that one of the things they did not like about mapping was having to change their ways of thinking. It again points out to me the depth to which learning strategies are engrained. Cerbin (2000) seems to agree when stating, "I now believe much more firmly that changing students' minds, moving them to 'deep understanding,' is quite a bit harder than is usually recognized" (pg. 16).

I also learned that it is important to continue investigating the connections between learning and technology. In this project, students expressed how the use of software was important in learning to develop concept maps. Moreover, the on-line course results were in some ways different than the face-to-face results. This indicates to me that much more work is needed in this area.

Additionally, I think that I learned just how invaluable our peers can be and how much we can learn from them. Because this project was funded by CIPD, there were other Scholars working on SOTL projects on campus. A group of five Center Scholars met monthly. These group meetings provided a safe place to talk about the work, to discuss the set-backs and to offer peer-based critique and feedback.

Finally, I have come to believe in the strength of the SOTL approach in higher education. SOTL offers faculty a way to understand their teaching and student learning, as well as, to initiate deep and long lasting change in both. Pat Hutchings (2000) explains that SOTL is characterized by three factors. She writes, " . . . the scholarship of teaching and learning is deeply embedded in the discipline; its questions arise from the character of the field and what it means to know it deeply" (pg. 6), " . . . the scholarship of teaching and learning is an aspect of practice" (pg 8) and finally, "The scholarship of teaching and learning is characterized by a transformational agenda" (pg. 8). The discipline, practice and transformation are all aspects of SOTL that will continue to impact higher education as we move ahead in the future.

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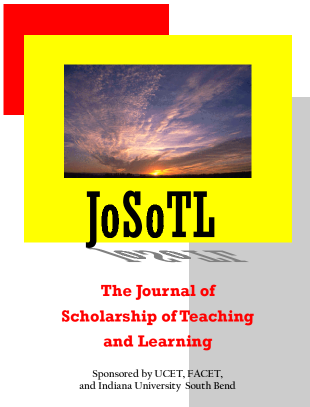

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Improving the Instruction of Engineering Calculus: Responding to Student Feedback

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Abstract

The purpose of this article is to illustrate how student feedback was used for instructional improvement in a sequence of Engineering Calculus courses. The methods that are employed here are appropriate for other classrooms and disciplines. This article describes the instruction that the students received and the feedback that the students provided. This feedback was used to design the next mathematics course that these students completed. After completing the next course, the students were asked to provide feedback on the changes that had been made.

An earlier version of this paper titled, "Using Student Feedback to Improve Instruction in Engineering Calculus", appears in the Proceedings of the Frontiers in Education Conference, Kansas City, MO, 2000.

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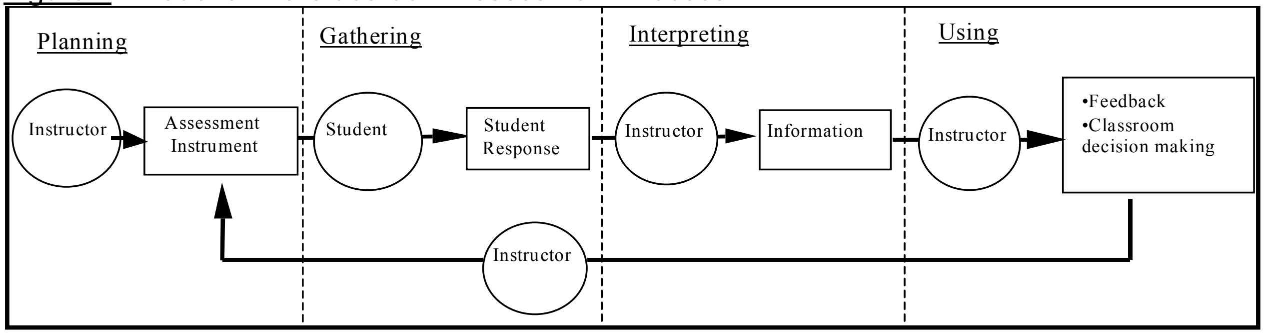
Figure 1. Model of the Classroom Assessment Process



In an article that was written for pre-college teachers, I proposed a model (Moskal, 2000a) of the classroom assessment process that consisted of four phases: planning, gathering, interpreting and using. This model is equally appropriate for college level instruction and is shown in Figure 1. The vertical columns divide the model into the phases of assessment and the rectangles represent the outcome of each phase. The primary mediators of each phase are distinguished in the model by circles. Each phase of the assessment process implies an action on the part of the instructor (i.e., the instructor plans, gathers, interprets, and uses) and each concludes with an outcome(s).

The *planning* phase includes the processes of selecting or developing assessment items and assembling these items into an instrument. The outcome of this phase is the attainment of an assessment instrument. Currently there is a large body of information that is available to assist college instructors in selecting appropriate assessment instruments. These instruments may be designed to assess individual performances, group performances or the effectiveness of a course (Angelo & Cross, 1993; Brookhart, 1999; Lewis, Aldrige & Swamidass, 1998; Mehta & Schlecht, 1998; Moskal, 2000b; Moskal, Knecht & Pavelich, 2001; Shaeiwitz, 1998). On-line databases are also available that can assist college instructors in finding assessment instruments that meet their classroom needs (Brisseden & Slater, 2001; Southern Illinois University, Edwardsville, 2001).

The *gathering* phase begins when the instructor administers the selected assessment instrument to students. The students then interpret the requests of their instructor and the tasks as they construct their responses. Unlike the previous phase, which is mediated by the instructor, the gathering phase is primarily mediated by the student. Although the professor administers the task to the students, it is the student who controls what appears in the response.

The *interpretation* phase consists of the instructor's efforts to make sense of students' responses and results in the acquisition of information. The interpretation phase is supported by the use of measurement tools (e.g., scoring rubrics or checklists) and often the application of statistical techniques (Angelo & Cross, 1993; Deek et. al., 1999; McNeil, Bellamy & Burrows,1999; Moskal, 2000b; Moskal & Leydens, 2000).

The assessment event, which is a single pass through the assessment process, concludes with the application of the acquired information to serve particular purposes. The *use* phase may have several outcomes. Two commonly identified uses of classroom assessment information are to assist instructors in making appropriate instructional decisions (Angelo & Cross, 1993; Brissenden & Slater, 2001; Brookhart, 1999) and to enable them to provide accurate feedback to their students (Brissenden & Slater, 2001; Brookhart, 1999; Shaeiwitz, 1998). How the information will be used should be considered in the planning phase in order to guide the selection of appropriate assessment instruments.

Current research (Angelo & Cross, 1993; Brookhart, 1999; Moskal, Knecht & Pavelich, 2001) has emphasized the importance of completing the entire assessment process, which includes the use phase. It is during this final phase that instructional improvements take place. Using assessment information for instructional improvement is one of the most important and the most frequently neglected components of classroom assessment (Angelo & Cross, 1993; Brookhart, 1999).
In many colleges, a common assessment practice that is designed to evaluate the effectiveness of a course is the administration of a student survey at the end of the semester. One purpose of this survey is to allow students to provide feedback that may be used to improve instruction in future courses. Since faculty often teach a different course the next semester, the information that is acquired at the end of a course may not be useful in the refinement of the next course. Additionally, if the selection of the assessment instrument is completed by the institution, the given questions may not be relevant to the instructional needs of the course instructor.

Poor evaluations are also often explained by the respective instructor as being a result of unmotivated students, heavy teaching loads or an invalid rating systems (Lucus, 1999). In addition, faculty have (Coburn, 1984) argued that students lack the technical expertise to evaluate course content or instructional style. This, they explain, may result in an over emphasis on the evaluation of the teachers' popularity rather than their teaching ability. Concerns have also been raised that an over emphasis on course evaluations results in grade inflation and a reduction in amount of material that is covered in a given course (Wilson, 1998).

A great deal of research has been completed that examines the validity and reliability of student course evaluations. Cashin (1995) has reported that more than 1500 articles and books have been written that address the development, design and appropriateness of student evaluations. Based on these resources, he determined that well-designed course evaluations can provide valid and reliable results. Other researchers have provided support for this claim (e.g., Coburn, 1984; Peterson & Kauchak, 1982). Researchers (Brookhart, 1999; Howard & Maxwell, 1980; Scriven, 1995) have also found that higher grades do not necessarily result in higher course evaluations. In other words, many of the concerns that have been raised with respect to course evaluations appear to be unfounded. A well-designed student evaluation system can produce valid and reliable results.

The purpose of this paper is to describe a two-course sequence of engineering calculus at the Colorado School of Mines (CSM) and to illustrate how student feedback was used for instructional improvement. The first course is Honors Engineering Calculus II, which covers vectors, vector functions, partial derivatives and multiple integrals. The students admitted to this course are first semester freshmen who scored a 4 or 5 on the AB Advanced Placement Test (Bath, 1999). The next semester, these same students completed Honors Engineering Calculus III, which covers vector calculus, sequence and series, and an introduction to differential equations. A variety of different instructional techniques were used in the first course and the students were asked to evaluate these techniques through a course evaluation. This information was used to guide the development of the next course, resulting in the completion of the assessment event. The students in the next course were asked to evaluate the impact of these changes —thus, beginning a new assessment event.

Honors Engineering Calculus II

This section describes the structure of Honors Engineering Calculus II, the evaluation techniques used in that course and the results of the evaluation.

Students

Of the 35 students who completed Honors Engineering Calculus II, 7 students were female, 1 student was international and 1 student was of Asian decent. The remaining students were Caucasian.

Textbook

The textbook was Calculus Concepts and Contexts by James Stewart (1998). According to the Preface of the text, it is designed to focus upon the development of students' conceptual understanding. This is achieved through a combination of geometric, numerical and algebraic approaches and the application of technology to problem solving situations.

Course Design

Honors Engineering Calculus II is a four-credit course. During the semester of interest, the class met for one hour on Monday and Wednesday and two hours on Friday. On Monday and Wednesday, a modified lecture format was used in which the students were encouraged to actively participate by asking questions and offering suggestions. Physical objects were brought to class to illustrate many of the concepts (e.g., a wire was used to illustrate a space curve and a ball was used to illustrate the concepts underlying the calculation of the surface area of a sphere). On Friday, the students met for two hours in the computer lab to solve problems in teams of three or four students. Sometimes the problems required the use of the computer program, Mathematica, and other times they did not.

The students' ability to manipulate physical objects and their ability to use Mathematica were not evaluated on exams. These activities were designed to deepen the students' conceptual understanding as concepts were introduced. The students were required to submit the completed Mathematica assignments.

Due to the rigorous structure of the course, there was very little time to answer questions on the assigned homework or to give in-class quizzes on the material. For this reason, the solutions to the homework were made available in the library and the quizzes were completed as take-home assignments.

Web-based Support

Throughout the course, electronic media were used to support the learning process. Lecture notes and solutions to quizzes were posted on the web. An electronic discussion group was maintained. Tests and solutions from prior years were made available electronically. Students had access to their instructor via e-mail. The option was also available for students to provide anonymous feedback to their instructor via e-mail at any point during the semester. Many of these resources could have been made available in a paper format; however, by using the web, the overall expense of distributing this information was reduced.

Closed Response Survey

At the end of Honors Engineering Calculus II, the students were asked to complete a survey in which they rated the extent to which each of the instructional techniques impacted upon their learning process. The four-point scale ranged from "No Impact" to "Significant Impact." Students were asked not to include personal identification on the survey and to indicate the grade that they expected to receive in the course.

Short Response Survey

The short response survey is administered at the end of each semester in all departmental courses. In the current course, the short response survey was completed before the closed response survey. The questions that comprise this instrument are as follows:

1. What aspects of instruction did you find effective for promoting your learning?
2. What recommendations would you make that would improve the instruction that you received in this course?
3. If you have any additional comments, please write them in the space below.

Closed Responses Survey: Across Students

Table 1 displays the activities that the students evaluated. A higher average rating suggests stronger student agreement that the given activity positively impacted their learning. Responses that indicated that a given activity was "Not applicable" were not included in this analysis.

The highest rated course component was the electronic availability of solutions to prior tests via the web. The other components of the course that were rated as having a "Strong Impact" were classroom instruction, the three unit tests, the textbook, access to information concerning the course via the instructor's web page and the take-home quizzes. These were closely followed by group work, availability of course notes on the web and the use of manipulatives in class. The activities in the course that were rated as having "No Impact" or a "Slight Impact" on student learning were: the use of the computer program, Mathematica; the availability of the electronic discussion group; the availability of providing electronic anonymous feedback to the instructor via the web and the availability of solutions to take-home quizzes on the web.

Closed Response Survey: Within Grade Categories

At the start of the survey, the students were asked to indicate the grade that they expected to receive in the course. Thirteen, sixteen and six of the students expected to receive an "A", "B", and "C", respectively. The actual assignment of grades resulted in 11, 17 and 7 students receiving an "A", "B", and "C", respectively. Since the student predicted distribution closely approximated the actual distribution of grades, it is likely that the student predicted grades were accurate indicators of the actual grade that they attained. The final grades in this course were high, which is not surprising given the demanding screening process to enter the course.

Table 1
Ratings of Instructional Techniques in Calculus II

Questions	Mean	"A"	"B"	"C"
Availability of previous tests and solutions on the web.	3.26 (n=34)	3.46 (n=13)	3.20 (n=15)	3.00 (n=6)
Classroom instruction.	3.23 (n=35)	3.15 (n=13)	3.31 (n=16)	3.17 (n=6)
The three chapter tests.	3.20 (n=35)	3.23 (n=13)	3.25 (n=16)	3.00 (n=6)
Textbook.	3.09 (n=34)	2.69 (n=13)	3.27 (n=15)	3.50 (n=6)
Access to course information via instructors' web page.	3.03 (n=34)	2.92 (n=13)	3.07 (n=15)	3.17 (n=6)
Take-home quizzes.	3.00 (n=35)	3.15 (n=13)	2.81 (n=16)	3.17 (n=6)
Group work.	2.97 (n=35)	3.23 (n=13)	2.69 (n=16)	3.17 (n=6)
Availability of course notes on the web.	2.94 (n=35)	2.92 (n=13)	2.94 (n=16)	3.00 (n=6)
Concrete manipulatives (physical objects).	2.89 (n=35)	2.77 (n=13)	3.06 (n=16)	2.67 (n=6)
Homework assignments.	2.79 (n=33)	2.67 (n=12)	2.93 (n=15)	2.67 (n=6)
Availability of solutions to homework problems.	2.72 (n=33)	2.17 (n=12)	3.13 (n=15)	2.83 (n=6)
Access to your instructor via electronic mail.	2.26 (n=31)	2.08 (n=12)	2.31 (n=13)	2.50 (n=6)
Availability of solutions to take-home quizzes.	2.08 (n=31)	2.08 (n=12)	1.93 (n=14)	2.00 (n=5)
Ability to provide electronic anonymous feedback.	1.85 (n=29)	1.82 (n=11)	1.75 (n=12)	2.17 (n=6)
Electronic Discussion Group.	1.79 (n=33)	1.85 (n=13)	1.73 (n=15)	1.80 (n=5)
The use of the computer program, Mathematica.	1.29 (n=35)	1.23 (n=13)	1.31 (n=16)	1.33 (n=6)

Out of the students who expected to receive an "A" in the course, the highest rated component of the course was the availability of solutions to prior tests on the web. This was followed by group work and chapter tests. Instruction and take-home quizzes were also highly rated. For the students who expected to receive a "B" in the course, instruction was rated highest and was closely followed by the textbook, the chapter tests and the availability of previous test solutions on the web. For the students who expected to receive a "C" in the course, the highest rated component of the course was the textbook. This was followed by classroom instruction, take-home quizzes, group work, and access to information concerning the course via the instructors web page. The only component of the course that was consistently rated in the top five across groups was instruction.

Across all three groups, the lowest rated component of the course was the use of the computer program, Mathematica. Across all three groups, the availability of the solutions to take-home quizzes on the web, the electronic discussion group, the availability of providing electronic anonymous feedback to the instructor via the web, and access to the instructor via e-mail were rated in the bottom five course components.

Short Response Survey: Students' Written Comments

The students' written comments provided further insight into why a given component of the course was or was not effective for promoting learning. Thirty-four out of thirty-five students completed the short response survey. Twelve students explained that classroom instruction was greatly enhanced by the visual aids. One student wrote, "Props (straws, balls, wire) are very effective in visualizing in 3D" and another student wrote, "The visual aids were always helpful as well as 'entertaining'." Although the students had not rated the manipulatives as highly as they had rated instruction on the closed response survey, their comments indicated that these activities had contributed to the high rating of instruction.

Another component of the course about which the students frequently commented was the availability of the notes on the web. Fifteen students commented on the effectiveness of this approach. One student stated, "The notes on the web is the biggest help." Although the students did not explain on the short response survey why this was useful, several students had stated during the semester that by printing the notes out before class they could spend class time listening rather than "frantically writing."

The students not only provided comments on what was effective, they also made suggestions as to how to improve the course. Overall, the students had highly rated the group work on Fridays. Four students had provided positive comments on the short-response survey on the effectiveness of the group work for promoting their learning. However, 13 students complained either that there was a need for more in class instruction or that the time spent in groups was too long. Their reactions indicated that although group work was helpful, it may have been overdone. For example, one student explained, "More time allotted for difficult concepts. We are sometimes pressured for time as we only have 2 hours in the classroom a week". The same student suggested, "3 hours in the classroom/1 hour in lab [group work]." Another student complained, "It is thrown at us for 2 days, then we get tested. Do we need to spend every

Friday just on w/sheets? [group activities]."

Three of the students complained about the take-home quizzes, "Friday quizzes are too long [group work]. Take home quizzes are even longer." However, 8 students commented on the effectiveness of this technique for promoting their learning. One student stated, "The quizzes, I hated doing, but they really helped me learn." In other words, the majority of the student responses supported the effectiveness of this technique.

Anonymous Feedback Via E-mail

Over the semester, I received three anonymous messages; one contained a sequence of nonsense letters and the statement, "Wanna learn gibberish?" and another student wrote, "If I did my homework, I would be much better off. So I think I will do some homework this weekend." The remaining message complained extensively about the amount of work that was required in the course. Although the given student was obviously unhappy, the feedback that he or she provided was not helpful for improving the course.

Honors Engineering Calculus III

This section describes the changes that were made in the next course, Calculus III, and the results of the student evaluations to these changes.

Students

I had 32 students in Calculus III. Twelve (38%) of these students had been in my class the previous semester. Nine students were female and one student was African American. The remaining students were Caucasian.

Changes

Calculus III, which was also a four-credit course, met four times a week. In response to the students' recommendations, I reduced group work to one hour a week and allowed more in-class time for questions. I continued to place my course notes on the web and use concrete materials to illustrate the concepts that were being addressed. My course web page provided the students with links to my notes, other instructors' notes, solutions to prior tests and solutions to quizzes. Although the students had indicated that the availability of the solutions to quizzes had only a minimal impact on their learning, maintaining this resource took very little time and it provided one form of feedback to my students on how to solve the problems. I stopped supporting the electronic discussion group and the option of providing electronic anonymous feedback. Mathematica was also eliminated.

Follow-up Surveys

An altered version of the closed response survey from the previous semester was administered at the end of Calculus III. The questions that referenced Mathematica, the electronic discussion group, and the option of providing anonymous feedback were eliminated from the survey. Additionally, the students were asked to indicate whether they had been in my class the previous semester. Four questions were added to the survey in which the students rated the changes that had been made on a four-point scale that ranged from "Very Bad Change" to "Very Good Change." The students also had the option of indicating that they had no opinion.

Closed Response Survey: Across Students

Twenty-nine students completed the closed response survey and their responses are summarized in Table 2. When a response indicated that a given activity was "Not applicable", it was eliminated from the analysis. Three of the activities that had been rated in the top five during the previous semester were rated in the top five during the current semester, i.e., chapter tests, availability of previous tests and solutions on the web and instruction.

The students rated the take-home quizzes as having the strongest impact on their learning experience. Group work, the three chapter tests, the availability of previous tests and solutions on the web, classroom instruction and access to information concerning the course via the instructors' web page were rated as having had a "Strong Impact" on learning. The remaining activities were rated as having had at least a slight impact on the student learning; none of the activities were rated as having "No Impact" on learning.

As discussed earlier, four questions had been added to this survey in which the students were asked to evaluate the changes that had been made since the previous semester. Only students who had been in my class the previous semester were included in this analysis. Nine students responded that the elimination of the computer program Mathematica was either a good change (n=2) or a very good (n=7) change. Four students indicated that the elimination of the discussion group was a good change and 4 students indicated that this was a bad change. Only 3 students responded to the question concerning the electronic anonymous feedback to the instructor and all three indicated that this was a good change. In response to the question concerning the reduction of group work, 1 student indicated that this was a "Very Bad Change", 9 students indicated that this was a "Bad Change" and 1 student indicated that this was a "Good Change".

Closed Response Survey: Within Grade Categories

As was done the previous semester, the students were asked to indicate the grade that they expected to receive in the course. Eleven, fifteen and three of the students expected to receive an "A", "B", and "C", respectively. The actual assignment of grades resulted in 8, 13, 10 and 1 students receiving an "A", "B", "C" and "D", respectively. Based on this distribution, many students over predicted the actual grades that they would receive.

Take-home quizzes were rated as the activity that had the greatest impact on learning by both students who expected to receive an "A" and students who expected to receive a "B" in the course. In all three groups, take-home quizzes, group work and the three chapter tests were rated in the top five activities. The lowest rated activity by the students who expected to receive an "A" was the availability of solutions to take-home quizzes on the web. The lowest rated activity for students who expected to receive a "B" or "C" in the course was access to their instructor via electronic mail.

Table 2

Ratings of Instructional Techniques in Calculus III

Questions	Mean	"A"	"B"	"C"
Take-home quizzes.	3.66 (n=29)	3.64 (n=11)	3.67 (n=15)	3.67 (n=3)
Group work.	3.41 (n=29)	3.45 (n=11)	3.40 (n=15)	3.33 (n=3)
The three chapter tests.	3.10 (n=29)	3.27 (n=11)	3.00 (n=15)	3.00 (n=3)
Availability of previous tests and solutions on the web.	3.07 (n=28)	3.18 (n=11)	3.14 (n=14)	2.33 (n=3)
Classroom instruction.	3.07 (n=29)	3.45 (n=11)	2.80 (n=15)	3.00 (n=3)
Access to course information via instructors' web page.	3.00 (n=26)	3.10 (n=10)	3.00 (n=14)	2.50 (n=2)
Homework assignments.	2.97 (n=29)	3.09 (n=11)	2.93 (n=15)	2.67 (n=3)
Textbook.	2.86 (n=29)	3.00 (n=11)	2.73 (n=15)	3.00 (n=3)
Concrete manipulatives (physical objects).	2.65 (n=29)	2.73 (n=11)	2.60 (n=15)	2.67 (n=3)
Availability of course notes on the web.	2.52 (n=27)	2.30 (n=10)	2.79 (n=14)	2.00 (n=3)
Availability of solutions to take-home quizzes.	2.43 (n=28)	1.90 (n=11)	2.67 (n=15)	3.50 (n=2)
Availability of solutions to homework problems	2.18 (n=22)	2.00 (n=9)	2.17 (n=12)	4.00 (n=1)
Access to your instructor via electronic mail.	2.00 (n=21)	2.25 (n=8)	1.92 (n=12)	1.00 (n=1)

also indicated that the notes on the web continued to be useful.

Short Response Survey: Students' Written Comments

In general, the comments that the students provided with respect to the course were favorable. This is illustrated in the following examples, "Enjoy your teacher and its easier to learn," and "I liked going to calculus this semester. The class wasn't just a regular old boring lecture." As had been the case in the previous semester, the written comments also indicated the aspects of instruction that had supported their learning process. Nine students commented on the effectiveness of the use of manipulatives. Two of these students suggested that even more visual demonstrations be made, i.e., "More visual aids!" and "MORE TOYS!"

Although many students had indicated that the reduction of group work was a bad change on the closed response survey, only 3 students commented on this component of the course on the short response survey. One student indicated, "I think that the course should be held 3 days a week with one two hour lab section, like Calc 2 honors." This was the only comment that strongly supported returning to the previous course design. The remaining comments indicated that the group work that had been completed during the current course had been useful.

By reducing the group work, I had more time in class to devote to student questions. Six students commented that this was an important component of their learning experience, e.g. "I think it's amazing that you can spend as much time answering the homework questions as you do and still get through all the material!" and "she is always willing to answer questions." Eleven students also indicated that the notes on the web continued to be useful.

Concluding Remarks

An important component of the assessment process is using the information that is acquired for instructional improvement purposes. In this study, I had the opportunity to collect information from my students and use the information to design the next course in the sequence. The changes that I made were: 1) the reduction of group work, 2) the elimination of Mathematica, 3) the elimination of the discussion group and 4) the elimination of the option of providing electronic anonymous feedback to the instructor. Both the elimination of Mathematica and the option of providing electronic anonymous feedback to the instructor were well received by the students. Their reactions to the other two changes were met with mixed results.

I continue to believe that Mathematica or some other 3 dimensional graphing software could have a positive impact on my students' understanding of calculus concepts. In interpreting my students' negative responses to this program, I have concluded that it was my method of implementation that was ineffective. I spent very little time introducing the software and assumed that my students would be able to use this tool effectively. Based on student feedback, this is not what happened. In the future, I intend on reintroducing Mathematica into my classroom. This time, I will do so slowly and with more careful attention to my students' learning needs.

Another change that I had made in my classroom was a reduction in the amount of group work. This provided me the opportunity to increase the time that was devoted to students' questions.

Although having more time for questions was well received, the reduction in group work was not. The students' responses suggest that they wanted more time for questions and more opportunities to work in groups. Increasing both of these activities is not feasible without increasing the time in class. During the semester that the course discussion group was available, I logged-in on a regular basis and responded to the students' questions. When this activity was eliminated, I had more time for planning class and organizing the course web site. The students had highly rated both classroom instruction and the course web site. In other words, for each of the changes that were made, there were tradeoffs of which the students were unaware.

In order to determine when the benefits outweighed the drawbacks, I needed to move beyond the student responses and consider how the evaluation was completed. The short response survey was administered before the closed response survey. This ordering was purposeful. The closed response survey directs the students to the specific changes that had been made and asks the students to evaluate the impact of each change. The short response survey allows the students to select what they will discuss. If I had administered the closed response survey first, the students' responses to the short response survey may have mirrored the concerns that had been raised through the closed response survey. In other words, the closed response survey could have directed the students to consider specific issues. By administering the short response survey first, I hoped to capture the concerns that were foremost in the students' minds.

In Calculus III, only one student indicated that there was an inadequate amount of group work on the short response survey. None of the students' recommended the reintroduction of the discussion group. The students needed to be directly asked about these changes before commenting on their impact. This suggests that these issues were not pressing concerns for the majority of students. Coupling this observation with the overall positive comments that were made to the short response survey, supports the assertion that overall the changes had improved the course.

Another observation that can be made through this study is the value of combining information that is collected through different forms of assessment. The importance of using multiple sources of data has been given a great deal of attention in the assessment literature (Angelo & Cross, 1993; Brissende & Slater, 2001; Brookhart, 1999). It was through the combination of the information that was provided through the closed response survey and the short response survey that I was able to make-sense of what was and was not working within the given courses. After changes were implemented, it was through the combination of information acquired through the two surveys and through the examination of the process used to administer the surveys that I was able to determine the extent to which the given changes had been effective.

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