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2017 Zone III Best Paper: Implementing Lecture-based Tutoring to Improve Student Learning

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Implementing Lecture Based Tutoring to Improve Student Learning

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Abstract

Lecture based tutoring is a recent development in active learning. This paper describes how to change from a lecture to a lecture based tutoring course. An example demonstrates how to implement this new teaching style. To assess the effectiveness of lecture based tutoring, a distance education class was changed to this new format. Statistical analysis shows that students have performed significantly better in the lecture based tutoring course than in the lecture class. Thus, lecture based tutoring increases student learning.

Keywords

Active Learning, Lecture Based Tutoring

1. Introduction

Lecture based tutoring[1] is a recently developed teaching method. Lecture based tutoring is classified as an active learning technique. Active learning[2-5] requires the students to participate in class and typically improves learning outcomes. Numerous active learning methods exist. Some of the most common methods are turn to your partner, small group discussions[6, 7] and project based learning[8, 9].

A teacher implementing turn to your partner poses a question or an idea and asks students to converse with their neighbor to derive an answer. After enough time is given, the teacher calls on various members of the class and these students report their discussions.

Small group discussions require the teacher to divide the class into reasonably sized groups. Each group is given a problem and time to discuss the issues. A leader is frequently selected for each group. The leader's primary responsibility is to report the group's findings to the class.

In project based learning, students are given a fairly complex problem and told to solve it typically in groups. The groups work to solve the problem and the instructor oversees the progress that the groups make. The instructor may also provide ideas to assure that the group is pursuing the project in the correct manner.

There are strengths and weaknesses in every teaching method. The primary strength of these active learning techniques is the students participation in the class. In this fashion the students feel an ownership in the material and are more likely to learn and retain knowledge.

A primary weakness of the previously mentioned methods is the requirement that the teacher relinquishes control of the classroom. During these periods, students may discuss topics that are not related to the subject and may delve into incorrect theories or principles. Since not all of the discussions are heard by the teacher, students may leave the class with misconceptions or incorrect ideas.

Lecture based tutoring eliminates the primary problem of these active learning methods. In a lecture based tutoring environment the teacher asks a particular student a question. The student is called by name and that student must respond. If the student does not answer correctly, then the teacher takes the opportunity to help the student answer the question correctly. This help should mimic the conversation that the teacher would have if the student were asked the question in the teacher's office. In other words, the instructor should effectively tutor the student to the correct answer.

Tutoring is simpler than teaching a large class. Wood and Tanner[10] provide tips on quality tutoring methods. Briefly, the instructor may ask simpler questions to help guide the student to the correct answer. The instructor may provide a partial answer or hint to assist the student in answering the problem. The point is for the teacher to help the student understand the material so that the student can provide a correct response.

Obviously, the student and teacher are not alone and other students may ask questions or even provide help. It is important that the teacher continue to assist the student that was asked the question prior to shifting the focus to the other students. In this fashion, the student feels successful in answering the original question.

This paper not only describes how to move a class from a lecture to a lecture based tutored course, but also provides the first statistical evidence that this new method improves student learning. The data is taken from a distance course and thus lecture based tutoring improves student learning even if students are only able to observe and not participate in this teaching style.

The remainder of the paper is organized as follows. The next section describes how to change a course to a lecture based tutoring format. An example of such a transformation is provided in the third section. The fourth section presents the student learning improvement that occurred when a course was changed to a lecture based tutoring framework. Some tips to effectively implement lecture based tutoring are discussed in section 5. The final section has a conclusion and topics for future research.

2. Changing a Course to Lecture Based Tutoring

The first step in developing a lecture based tutoring course is to determine a method to randomly call on students. The author's primary method is to keep a 3x5 card with the students name and picture (if the student is unfamiliar to the instructor). The teacher asks a question to the student whose name appears on the top card and places the card on the bottom of the pile. Occasionally, the teacher shuffles the cards throughout the semester. Other methods include calling on students according to their seating arrangement or alphabetically. Moderate care should be exercised so that each student is being asked nearly an equal number of questions throughout the semester.

The next step is to reduce a lecture into explanations, short questions, opinions and discussion topics. Each part has its own purpose in conveying material. A primary goal is to ask questions to at least 20 different students during a 50 minute class. Questions should flow very fast and move from student to student. Care must be taken to assure that each question can be answered in less than a minute.

The explanation portion is an extremely short lecture. The goal is to merely introduce the primary equations, algorithms, principles or problems associated with the class. This portion of the class should be short and could be moderately vague and leave the majority of the students completely confused. In certain situations, the teacher may even ask students questions to help derive the primary theory or principles.

After the primary topic is introduced, an example is typically given. Rather than the teacher working through a few examples on the board or in slides, the teacher should ask the students to work through the example. A problem is presented and a student is typically asked, "Where do you begin?" The answer is typically, "I have no idea." The teacher tutors this student until the student understands where to start. A different student is asked, "What is the next step?" and this process repeats until the problem is completed. In one example problem, numerous students should be asked to do a particular portion of the problem. These type of questions are called short questions. Developing effective short questions is the most critical aspect of lecture based tutoring.

Once the example is completed, students have a general understanding of the principles and methodology. The teacher should provide additional discussion. This discussion should clarify vague topics from the explanation, generalize the theories and assure that the topic has been sufficiently covered. During this time additional questions can also be asked. These questions typically involve understanding and extending the concepts to other areas.

At times in every course, there is not a set method to solve a problem. In these situations, opinion questions should be used. These type of questions are some of the easiest to ask and help facilitate classroom discussions. Common opinion questions include: What is your opinion? Why do you have this belief? How would you begin to approach this problem? What tools can you use to solve this problem?

Since the short questions are the most difficult to implement, the following section demonstrates how to teach the simplex method[11] in a lecture based tutoring format. For this paper, the tableau version of the simplex method is used to show this teaching technique. It should be noted that this section assumes no prior knowledge of the simplex method.

3. Implementing the Simplex Method in a Lecture Based Tutoring Format

The standard lecture technique to teach the simplex method is to present definitions and the algorithm. The teacher works through a few examples to demonstrate how the algorithm works and provides examples of the definitions. The teacher returns to the algorithm to provide some additional comments and insights to help the students understand the method.

To teach the simplex method in a lecture based tutoring format, the instructor should begin with a short 2-3 minute explanation. This short explanation should include that the basic variables can be identified with the identity matrix in the tableau. The value of these variables are the right hand side. All other variables are called nonbasic and have a value of 0 at the current solution. The algorithm finds the most improving column (most negative element in the first row) and enters it. The algorithm selects a row through the ratio test, which is the right hand side divided by the selected column element, if the column element is positive and infinity otherwise. The minimum value of the ratio test selects the row. The intersection of the selected row and column is the pivot element. A pivot uses elementary row operations to make the pivoted element a 1 and every other element in the column a 0. This process repeats until there are no more improving columns.

With this brief explanation, an example problem is presented. Consider the following linear program in standard form along with its associated tableau formulation, which is given in table 1.

$$\begin{aligned} \text{Maximize} \quad & z = 2x_1 + 3x_2 \\ \text{Subject to} \quad & -x_1 + x_2 + s_1 = 6 \\ & 3x_1 - x_2 + s_2 = 4 \\ & x_1, x_2, s_1, s_2 \geq 0 \end{aligned}$$

z	x_1	x_2	s_1	s_2	RHS
1	-2	-3	0	0	0
0	-1	1	1	0	6
0	3	-1	0	1	4

Table 1: Simplex Tableau 1

The teacher begins by asking student, "What is the current solution?" The student responds, "I have no clue." The student is then asked, "Which columns form the identity matrix?" The response may still be clueless. The teacher reminds the student that an identity column is a column with all zeros and only a single 1. The student can then say that the identity columns are z, s_1 and s_2. The student is questioned regarding the current solution. The student should be able to recall that the values of these variables are the right hand side (RHS). Thus, $z = 0$, $s_1 = 6$, $s_2 = 4$ and all other variables are nonbasic and have a value of 0, $x_1 = x_2 = 0$.

Student B is asked, "What is the next step?" Most likely the student is confused and the teacher states that the algorithm selects the most improving column. Student B identifies the entering column as x_2, because the -3 in the first row of the x_2 column is more negative than any of the other elements in the first row. Student C is asked, "How do we identify a row?" Perhaps this student understands the idea and says the ratio test. So the student divides the RHS by the x_2 column, with the exception of the objective row. The second row has 6/1=6. The third row has

4/-1 and the student selects the minimum, and states “It is the third row.” The teacher reminds the student of the special rules of the ratio test and anything divided by 0 or a negative receives a value of ∞. The student changes the answer to row 2.

Student D is now asked to pivot. Student D says, “Do what?” The teacher says make the pivoted element into a 1 and all other elements in the column a 0. The student says, that the second element in the x_2 column is already a one and the teacher says, then make all other elements in the column 0. The student does not recall elementary row operations and the teacher explains how to make a 0 in the bottom row, which is achieved by letting $R_3 = R_3 - (-1)R_2$. This row is changed on the board and Student D is asked to change the top row. This time the student sees the pattern and says $R_1 = R_1 - (-3)R_2$. The teacher now comments that an iteration of the simplex method is done and the resulting tableau is in Table 2.

z	x_1	x_2	s_1	s_2	RHS
1	-5	0	3	0	18
0	-1	1	1	0	6
0	2	0	1	1	10

Table 2: Simplex Tableau 2

Student E is asked “What is the current solution?” With some coaxing the student responds that they need to find the identity columns. These are identified as z, x_2 and s_2 with a corresponding solution of $z = 18$, $x_2 = 6$, $s_2 = 10$ and $x_1 = s_1 = 0$. Student F is asked, “What happens next?” With some reminding, the student identifies column x_1 as the most improving column. Student G is asked, “What row is selected?” The student remembers the special rule and observes that 6/-1 = ∞ and so the third row is the selected row with 10/2 =5. Student H is asked to perform the pivot. The student eventually divides the third row by 2, to make a 1 and after making the zeros in the column, the tableau is constructed as shown in Table 3.

z	x_1	x_2	s_1	s_2	RHS
1	0	0	11/2	5/2	43
0	0	1	3/2	½	11
0	1	0	½	½	5

Table 1: Simplex Tableau 3

Student I is asked, “What is the current solution?” The student should be able to answer the question correctly and if not, more tutoring occurs. The identity columns are z, x_2 and x_1 with a solution of $z = 43$, $x_2 = 11$, $x_1 = 5$ and $s_1 = 0$, $s_2 = 0$. Student J is asked "What happens next?" The student responds that there are no negative columns to enter. Therefore, the solution is optimal and the simplex method terminates.

In working through this example, the teacher most likely delayed answering a few questions that other students asked during the tutoring sessions. The teacher should return to these questions and determine if the student still has the same question or if the student has already had their question answered. The teacher provides additional discussions involving how the simplex method works and some of its theory. The teacher asks if anyone has any questions. In many situations, a student's question becomes a question to the next student on the list.

In an extremely short time span, at least 10 students have been required to participate in the class and either answered the problem correctly or been tutored to the correct answer. Furthermore, the instructor never relinquished control of the classroom. Thus, a standard simplex method lecture has been modified into a lecture based tutoring method.

4. Comparing Student Learning Outcomes

This section describes the student learning outcomes that occurred when a graduate online introductory operations research class was changed from a lecture to a lecture based tutoring format. The class, IMSE 680 offered at Kansas State University, is a core course in the Masters of Engineering Management and an introductory course to the Masters of Science in Operations Research. The class is offered every semester and has about 25 students enrolling over the course of a year.

The class began in 2005. The author taught the class in a lecture format without students and the videos were recorded and uploaded online. In 2014, with the help of a small grant from Kansas State University's distance program, the author changed this class to a lecture based tutoring format. Since the class is only offered to distance students, the grant paid to have six students attend the class. These students were sophomore and junior industrial engineering students and had not taken an operations research course. The paid students did not receive any credit and did not take any exams or do any homework assignments or projects. The paid students merely came to class and were asked questions so that the class would be in a lecture based tutoring format. These classes were recorded and are the lectures that any student currently enrolled in this class watches. The projects remained the same and the exams are almost identical with similar problems, but different numbers. The only substantial change to the course is the lectures that the students watch.

To receive a grade in IMSE 680, students must complete four projects and two exams. Due to the distance nature of the course, the teacher allows students to receive an incomplete as long as the class is completed within one semester. That is, a fall semester student has until the end of the spring term to complete the class.

Moving from a lecture based course to a lecture based tutoring course has been astonishingly effective. From Fall 2011 to Spring 2014, 97 students enrolled in IMSE 680. Of these students, only 26 students (27%) finished the class on schedule and a total of 77 (79%) finished the class by the deadline of the second semester. In contrast, since Summer 2014 through Fall 2015, 39 students enrolled in this class, 26 (67%) finished the class on schedule and 35 (90%) completed the class by the deadline. These mark a dramatic improvement in students' ability to complete the class both on time or even complete the class at all. Consequently, the author believes that lecture based tutoring has improved student learning.

Not only have a higher percent of students completed the class, but the students are performing better. The teacher has empirically observed fewer questions over the course material. To provide some rigor to this observation, the scores of the students' midterm exams are statistically compared.

The midterm scores of all of the students that completed the course from Fall 2011 to Fall 2015 are compared. The students are broken into two categories as to whether or not the students watched the lecture based tutoring course or the lecture course. The results of a two tailed t-test with $\alpha=.01$ is shown in figure 1. The t statistic is almost double the critical value and the p value is less than 0.0001. Consequently, with 99% confidence one can reject that the means of the midterms are the same. Thus, students watching lecture based tutoring videos are performing statistically superior than the students watching lecture videos for IMSE 680.

	Lecture Based Tutoring	*Lecture*
Mean	91.87	83.94
Variance	40.95	188.47
Observations	35.00	77.00
df	110.00	
t Stat	4.17	
P(T<=t) two-tail	<0.0001	
t Critical two-tail	2.62	

Figure 1: Statistical Analysis of Midterm Scores

5. Hints to Effectively Implement Lecture Based Tutoring

No teaching method is perfect and this section provides some hints to effectively implement lecture based tutoring. The single most important aspect of lecture based tutoring is to make failure acceptable. Students must feel comfortable answering a question incorrectly or admitting confusion regarding the question. A primary responsibility of the instructor is to lessen the fear of failure.

Occasionally asking an extremely difficult question, which may include research questions, is one method to lessen the fear of failure. After the first student fails, ask the question to a second student. Now two students share the failure. Next pose the question to the entire class. Suddenly the entire class has failed and failure becomes acceptable. The teacher may pose a question the he or she does not know the answer too and then everyone in the room has failed.

Effectively tutoring the student is vital. Helping the students move from failure to success is critical. Occasionally some students truly struggle to obtain the correct solution. In certain instances, the author modifies the order of the questions so that a struggling student receives an easier question and more advanced students receive more challenging questions.

Silence is awkward and yet students must be allowed time to consider and respond to a question. One technique is for the teacher to ask a vague question to the student. The teacher then spends time clarifying the question. Alternately, the teacher may repeat the question with different wording. Both instances enable the student to have additional time to consider the question without the awkward classroom silence. Similarly, the teacher should call on the student prior to the question being asked, to assure that the student is paying attention and maximizes his or her time to think about the question.

Some students are quiet or have accents, which make understanding the answer difficult. Even if the teacher understands the question, many in the class may not have heard or comprehend the answer. In these situations, the instructor needs to summarize the comments of the student or ask the student to repeat the answer with an apology that the teacher could not hear the response.

6. Conclusions and Future Research

This paper has described how to change a course from a lecture format to a lecture based tutoring format. An example is provided so that others can implement this new style of instruction. Students watching a lecture based tutoring class performed statistically superior to students watching a lecture based version of the same class. Consequently, lecture based tutoring improves student learning outcomes.

Several important research questions remain. Foremost is whether or not other instructors, besides the author, can successfully implement lecture based tutoring. Can more data be gathered and analyzed regarding the impact of lecture based tutoring on student learning? Finally, what other techniques can be created to improve student learning.

7. References

1 Easton, T. "Improving Student Ratings through Lecture Based Tutoring." Proceedings of ASEE Zone III Conference Gulf Southwest – Midwest – North Midwest Sections) September 2015, Springfield, MO, USA, 2015, 1-8.

2 Silberman, M. (1996). *Active Learning: 101 Strategies To Teach Any Subject*. Prentice-Hall, PO Box 11071, Des Moines, IA 50336-1071.

3 Meyers, Chet, and Thomas B. Jones. *Promoting Active Learning. Strategies for the College Classroom*. Jossey-Bass Inc., Publishers, 350 Sansome Street, San Francisco, CA 94104, 1993.

4 Prince, M. (2004). Does active learning work? A review of the research. *Journal of Engineering Education-Washington*, *93*, 223-232.

5 Faust, J. L., and Paulson, D. R. (1998). Active learning in the college classroom. *Journal on Excellence in College Teaching*, *9*(2), 3-24.

6 Smith, K. A. (1995, November). Cooperative learning: Effective teamwork for engineering classrooms. In *fie* (pp. 2b5-13). *IEEE*.

7 Hillyard, C., Gillespie, D., and Littig, P. (2010). University students' attitudes about learning in small groups after frequent participation. *Active Learning in Higher Education*, *11*(1), 9-20.

8 Johnson, P. A. (1999). Problem-based, cooperative learning in the engineering classroom. *Journal of Professional Issues in Engineering Education and Practice*, *125*(1), 8-11.

9 Easton, T., and Cassone, D. (2006, January). Vague-Goal Oriented Projects-A Tool To Motivate Students. In *IIE Annual Conference. Proceedings* (p. 1). Institute of Industrial Engineers-Publisher.

10 Wood, W. B., & Tanner, K. D. (2012). The role of the lecturer as tutor: doing what effective tutors do in a large lecture class. *CBE-Life Sciences Education*, *11*(1), 3-9.

11 Dantzig, G.B. (1951). "Maximization of a Linear Function of Variables Subject to Linear Inequalities," in T.C. Koopmans (ed.), Activity Analysis of Production and Allocation, John Wiley & Sons, New York, 339–347.

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