Effect Of A 'Look-Ahead' Problem On Undergraduate Engineering Students' Concept Comprehension

Kevin Goodman, Ph.D., University of Southern Indiana, USA
Julian Davis, Ph.D., University of Southern Indiana, USA
Thomas McDonald, Ph.D., University of Southern Indiana, USA

ABSTRACT

In an effort to motivate undergraduate engineering students to prepare for class by reviewing material before lectures, a 'Look–Ahead' problem was utilized. Students from two undergraduate engineering courses; Statics and Electronic Circuits, were assigned problems from course material that had not yet been covered in class. These assignments were collected and assessed. Grades from the 'Look–Ahead' problems, collected over a sixteen-week semester, were compared to overall exam performance. In addition, exam problem scores from specific correlating concepts/topics were compared with 'Look–Ahead' problem scores. Surprisingly, the data show very low correlation between student performance on 'Look–Ahead' problems and exams.

Keywords: Undergraduate Engineering Education; Motivating Pre-Lecture Studies; Flipped Classroom Environments

INTRODUCTION

If a student takes the initiative to study material from a class prior to the professor lecturing over the material, would the student end up with a better understanding of the concepts than having no exposure to the material prior to the lecture? Further, by what means could a professor motivate students to actually take the time to investigate a topic before lecture? A 'Look–Ahead' study was conducted in two undergraduate engineering courses to examine these two questions. The results of which were unexpected.

METHODS

For the serious student, the plan at the beginning of the semester usually contains the idea that they will keep up with, and even keep ahead of, the professor in class. The perfect world would be one in which the student has enough time before class to look over the material at home and exercise some cognitive thought on the subject to be covered. At the very least, one might think that if a student read through the material to be covered, this preemptive strike would help them better absorb the concepts during the lecture.

As it usually happens, soon into the semester the student finds him/herself playing a juggling game with time management (Sax et al., 2003). What initially seemed to be a well thought out plan of keeping ahead, often times turns into a reality of trying to keep up as the student's time and efforts are being spread across multiple facets (e.g. school, work, family and fun). This reality leads the student identifying what is most important on the list of what needs to be done, and applying what time and effort they can to the top of that long list. One of the topics that is not going to rise to the top of most students' lists is looking over lecture material prior to the actual lecture.

With this understanding in mind, an investigation into the matter at hand was carried out across two undergraduate engineering courses. The overall hypothesis to be examined was, "will directing a student to engage in a specific topic prior to the lecture covering that same topic bring about a better comprehension of the material for the student?" This concept follows the popular flipped classroom model currently utilized in classroom settings ranging from elementary school through the college level (Roehl et al. 2013), (Bishop, Jacob 2013), (McLaughlin et al. 2014), (Tucker 2012). An important characteristic of this experiment is that the students are given motivation for looking over the material prior to the lecture in the form of extra credit points.

The courses involved in the study include Statics and Introduction to Electronic Circuits, both taught at the University of Southern Indiana, USI. These courses are core classes in the Department of Engineering at USI for students on a path for a multidisciplinary Bachelor of Science in Engineering degree. Therefore, although each of these classes covers material in different engineering disciplines: Electrical and Mechanical, each class contains students with personal focus areas ranging across Civil, Industrial, Electrical, Mechanical, and Mechatronics Engineering. Circuits and Statics both contain students of all years except freshmen. Further, the bulk of students in Statics are sophomores, while the bulk of students in Circuits are juniors. Each of these classes has prerequisites of Calculus II, and the both are prerequisites for upper level courses. Circuits covers the normally anticipated materials for an introductory electrical circuits course; Ohm's Law, element combinations, Thevenin equivalents, AC principles, etc. Statics covers topics in particle and rigid body equilibrium. Twenty-three students from Circuits and over thirty students from Statics participated in the 'Look-Ahead' study.

In order to motivate the students to actually think about the material prior to lecture, problems which are being called 'Look–Ahead' problems were assigned. This was handled slightly differently between the two courses. For Circuits, students were given a problem covering material from the upcoming lecture. This problem was usually identified two to three days in advance of the day in which the material would be covered in lecture. Most of the time, the students were also told which section of the book covers the concepts that the problem introduces. The students had access to solutions to the problem as well, either in the book or via a solutions manual posted online in Blackboard.

During the first ten minutes of the class period in which the new concept was to be covered, the students were given the opportunity to solve the same problem identified earlier. Each problem was graded on a three-point scale, 0,1,2,3, where the grade was not based upon a precise answer, but rather if the students displayed any knowledge of how to approach and solve the problem. This score should then be a reflection of how much cognitive thought the student applied to understanding how to solve the problem prior to attending lecture. The student's motivation for looking at the ''Look–Ahead' problem came in the form of treating any points obtained from the 'Look–Ahead' problem as extra credit. These points earned were added to a test grade at the end of the semester. Over the sixteen-week course, the students were given the opportunity to solve nine 'Look–Ahead' problems. Each being worth three points, there existed a possible 27 extra credit points that could be added to a 100-point test at the end of the semester.

The students encountered a similar methodology in Statics. 'Look-Ahead' problems were assigned the lesson before each section. They were graded on a zero to 3 scale account for sketches, problem set up, equations, final solution and neatness of their solution; a similar grading rubric is used for their homework assignments and exams. In the case of the mechanics class, most 'Look–Ahead' problems have solutions/equations presented in back of book; these problems were still assessed for the accuracy of their sketches and neatness of presentation. Not all students recognized that solutions were present in the book.

Homework was assigned after each lesson but was graded once per week. Therefore, each homework set had two 'Look–Ahead' problems per week. Students were asked to work through the 'Look–Ahead' problem before the appropriate lecture section - they were on the honor system.

To determine the effects of students engaging in lecture material on their own prior to the actual lecture, 'Look–Ahead' problem scores were separately paired with two other outcomes from the students. First, each 'Look–Ahead' problem score from each student was paired with the overall test score received by the student on an exam containing problems similar in nature to the 'Look–Ahead' problem in question. Second, each 'Look–Ahead' problem score from each student was directly paired with the student's score on a test problem which involved the same concepts as the 'Look–Ahead' problem in question. For each of the 'Look–Ahead' problems assigned, the correlating dependent score (overall test grade or specific test question) was plotted against the score from the 'Look–Ahead' problem; 0, 1, 2, or 3. A linear regression analysis was used for each of these pairings in an effort to extract any correlation between the student's 'Look–Ahead' problem score and their score on each performance metric. If a correlation was seen, this would indicate a connection between students engaging in the material prior to lecture and their grasping of the concept. The results were unexpected.

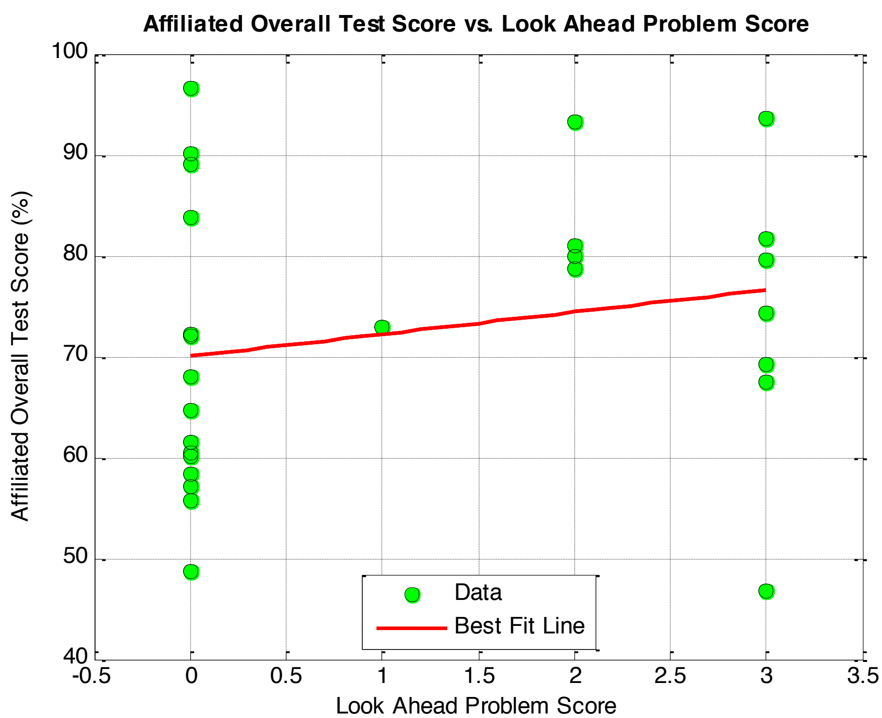
RESULTS

The first question of interest involves studying the motivation factor for the students to work ahead of class. Would a reward of 3 possible extra credit points per 'Look–Ahead' problem be enough to motivate undergraduate engineering students to study material on their own? To quantify an answer to this question, the average score for all students from all 'Look–Ahead' problems was calculated. This value came to be 2.4 out of a total possible 3 points. Using this as a metric, the data shows that the students studied the material on their own prior to lecture in enough depth to solve the 'Look–Ahead' problem 80% of the time. Thus, the 3 extra credit points does seem to be a suitable motivational factor for the students.

Looking at the effectiveness of the students' efforts, the data for each of the two scenarios yielding the *highest* coefficient of determination was separately plotted and is shown here. Figure 1 shows the relationship from one of the first comparison types, comparing a 'Look–Ahead' problem with an overall test score. Figure 2 shows the relationship from one of the second type of comparisons, comparing a 'Look–Ahead' problem score with a specific test question.

Notice that for the first plot, the R^2 value is 0.045 indicating there is no correlation between the students' score on a 'Look–Ahead' problem and their performance on a test which contains problem(s) similar to the 'Look–Ahead' problem. Figure 2 reveals the same theme as the first comparison. Yielding an R^2 value of 0.119, the plot indicates there is no correlation between the students' score on a 'Look–Ahead' problem with their performance on an exam question which utilizes the same concepts as the 'Look–Ahead' problem.

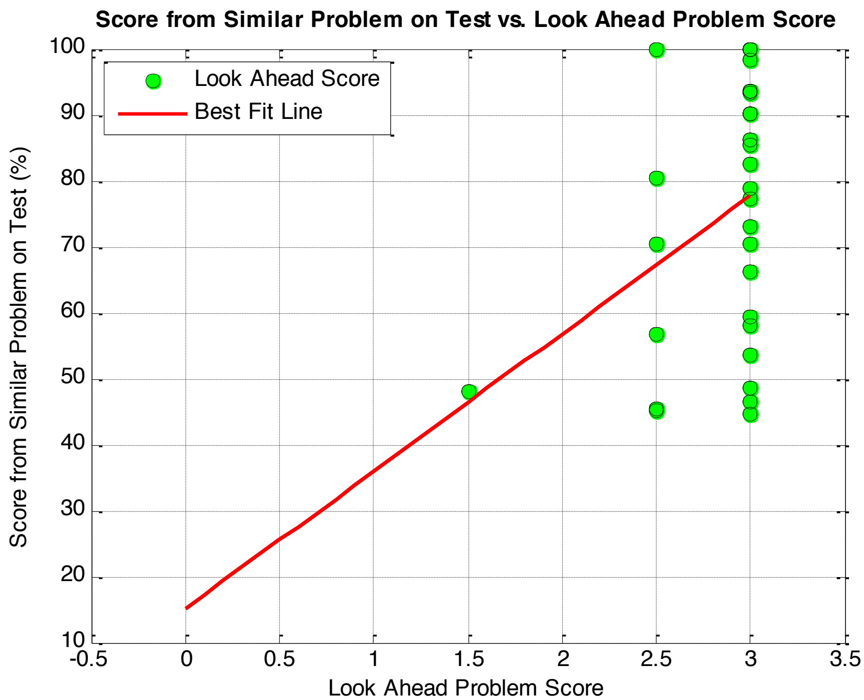
Figure 1. Affiliated Overall Test Score vs. Matching 'Look-Ahead' Problem Score.



Note: This data represents the highest coefficient of determination ~0.045, obtained from the homework and exam data. The data here if from 'Look-Ahead' Problem 1 compared to Problem 1 from Exam 1 from Statics.

These comparisons were made for seventeen 'Look–Ahead' problems across 3 exams, and the results were the same across the board. The data plotted here represents the highest correlation between the 'Look–Ahead' scores and performance on the affiliated test score. There was absolutely no correlation seen between a student's performance on a 'Look–Ahead' problem and their scores from exams which test the same concepts. The data indicates having a student study or practice a concept prior to attending lecture on that material has no impact on their ability to illustrate their understanding of the concept.

Figure 2. Score from a matched test and 'Look–Ahead' problem



Note: This data represents the highest coefficient of determination ~0.119, obtained by comparing a concept related 'Look–Ahead' problem and individual exam problem.

CONCLUSION

The authors discussed their experiment with peers prior to examining the results and none of them hypothesized the outcome that the data is revealing. The data reveals that motivating students to participate in a flipped classroom environment by offering them extra credit for their studying material prior to lecture has no impact on their ability to comprehend a concept. It is important to specify that this study examines not the flipped classroom environment itself, but instead, this study specifically examines one possible strategy available when utilizing the flipped classroom, that being the self-engagement of students in a concept prior to lecture. Other studies have shown that activities such as volunteer work do have a positive impact on students' professional development (Astin, Sax, Avalos, 1999). Since the results here show no benefit to studying material before lecture, and time is a precious commodity for students, careful consideration should be used when determining what is asked of students prior to lecture when utilizing flipped classroom atmospheres.

Examining the data to discover why there was not a trend seen relating the 'Look-Ahead' problem score with test performance unveiled a few possibilities. Students who did not study the material enough to perform well on the 'Look-Ahead' problem may have dedicated more time to the subject after performing poorly on the 'Look-Ahead' problem, but before the examination. Conversely, students who did perform well on the 'Look-Ahead' problem may have not actually put the effort into learning the material, but rather only memorized the solution. This would explain poor exam performance even after excelling on a 'Look-Ahead' problem. For each of these scenarios, implementing the following changes may result in a more direct correlation between the 'Look-Ahead' problem performance and examination performance. For the first scenario, a larger reward could be issued for successful completion of the 'Look-Ahead' problems. This would entice more students to study the material in preparation for the 'Look-Ahead' problems, not just prior to exams. A means to resolve the second scenario would be to not indicate the exact problem which will represent the 'Look-Ahead' problem, thus removing the possibility of direct memorization of the answer forcing students to delve into the content more.

Other future recommendations for this technique of asking students to spend time in cognitive thought on a topic prior to lecture stem from studies seen in recent literature. As McMahon and Pospisil have shown (McMahon & Pospisil 2005) millennials tend to favor group activities and social projects. Utilization of a group activity in an environment where students are asked to work collectively on a topic prior to lecture may lead to a better absorption of the concept at hand rather than the method presented here where students were not specifically grouped when asked to work on the 'Look–Ahead' problems. Further, Tune, Sturek, and Basile (Tune & Sturek 2013) demonstrated that having medical students watch recorded lectures prior to class was effective in increasing student performance vs. a traditional classroom lecture setting. A major difference between Tune and Sturek's method and the method presented here is that Tune and Sturek's students utilized technology during their pre-lecture studies as opposed to traditional study from a textbook as was utilized here. This idea of millennials utilizing technology to successfully absorb material agrees with McMahon and Pospisil's findings as well.

Anecdotally, the authors did discover, from discussion with students during this experiment that the students would often experience an 'aha-Moment' in class during the explanation of solving the 'Look–Ahead' problem after they just completed the 'Look–Ahead' problem. This however does not seem to correlate to their ability to retain the concept upon time of the examination.

AUTHOR BIOGRAPHIES

Kevin Goodman, Ph.D., is an assistant professor of Engineering at the University of Southern Indiana. He received his Ph.D. and a M.S. from the University of Notre Dame, along with a M.S. from the University of Arkansas following a B.S. from Northern Illinois University. He currently teaches courses focused in Electrical Engineering including Circuits, Microelectronics, and Semiconductors as well as Engineering Statistics and Freshmen Engineering. Email: kdgoodman@usi.edu.

Julian Davis, Ph.D., received his Ph.D. from Virginia Tech in Engineering Mechanics in 2007. He spent a semester teaching at community college in the area and then spent two years at University of Massachusetts – Amherst continuing his research in finite element modeling and biomechanics while continuing to teach. In 2010, he began his current tenure track position at the University of Southern Indiana. Professor Davis teaches courses in freshman engineering, statics, dynamics, vibrations, dynamics of machinery and finite element analysis. Email: jldavis2@usi.edu

Thomas McDonald, Ph.D., is associate professor of Engineering at the University of Southern Indiana. He received his Ph.D. from Virginia Polytechnic Institute and State University, MS, Clemson University, Industrial Engineering, and BS, Clemson University. Email: tnmcdonald@usi.edu

REFERENCES

Astin, A. W., Sax, L. J., & Avalos, J. (1999) *Long-Term Effects of Volunteerism During the Undergraduate Years. Higher Education.* Paper 88.

Bishop, J. L., & Verleger, M. A. (2013) *The Flipped Classroom: A Survey of the Research. 120th ASEE Annual Conference & Exposition* Paper 6219.

McLaughlin, J. E., Roth, M. T., Glatt, D. M., Gharkholonarehe, N., Davidson, C. A., Griffin, L. M., Esserman, D. A., & Mumper, R. J. (2014) *The Flipped Classroom: A Course Redesign to Foster Learning and Engagement in a Health Professions School*. *Academic Medicine*, 89 (2) 236-243.

McMahon, M., & Pospisil, R. (2005). *Laptops for a Digital Lifestyle: Millennial Students and Wireless Mobile Technologies*. *Proceedings of the 22nd ASCILITE conference: Balance, fidelity, mobility.* Brisbane, Queensland: Australia.

Roehl, A., Reddy, S. L., & Shannon, G. J. (2013). *The Flipped Classroom: An Opportunity to Engage Millennial Students Through Active Learning Strategies*. *Journal of Family and Consumer Sciences,* 105 (2), 44-49.

Sax, L. J., Lindholm, J. A., Astin, A. W., Korn, W. S., Saenz, V. B., & Mahoney, K. M. (2003) *The American Freshmen: National Norms for 2003.* Higher Education Research Institute, UCLA.

Tucker, B. (2012) *The Flipped Classroom. Education Next.* 12 (1).

Tune, J. D., Sturek, M., & Basile, D. (2013). *Flipped Classroom Model Improves Graduate Student Performance in Cardiovascular, Respiratory, and Renal Physiology. Advances in Physiology Education,* 37*,* 316-320.