Can adding discussion-only active learning increase student learning in materials science class?

Amir Saeidi
Chemical Engineering and Materials Sicence
University of California, Irvine
Irvine, USA
saeidis@uci.edu

Adrienne Williams
Teaching and Learning Research Center
Univeristy of California, Irvine
Irvine, USA
adriw@uci.edu

Natascha Buswell
Mechanical and Aerospace Engineering
Univeristy of California, Irvine
Irvine, USA
nbuswell@uci.edu

Daniel Mumm
Chemical Engineering and Materials sicence
University of California, Irvine
Irvine, USA
mumm@uci.edu

Kameryn Denaro
Teaching and Learning Research Center
Univeristy of California, Irvine
Irvine, USA
kdenaro@uci.edu

***Abstract*—This Research-to-Practice Full Paper describes how Active Learning (AL) was implemented in two discussion sections of an "Introduction to Materials Science" course in a large classroom with 172 students. We studied the effect of group work on students' learning, and whether 50 minutes of AL is sufficient to increase students' performance in this course. To do so, worksheets for the discussion sections were designed. There were four discussion sections, two of which were chosen as the treatment group. In the treatment group the students worked on a worksheet of problems in groups of 3 while a teaching assistant was present to answer their questions. In other sections, the control group, the same problems were presented using PowerPoint slides and solved by the same teaching assistant. To assess students' learning, their performance in two midterm exams and the final exam are considered. Moreover, to evaluate students' interest in engineering, the Jones et al. (2010) survey was used to study students' motivation and interest in engineering. We found implementing AL for a short amount of time in each week did not change students' performance. We hope this paper will encourage educators to spend more time on AL, in their classrooms.**

Keywords—Materials science, group work, active learning.

I. Introduction

One of the major goals of the education system is to improve students' learning and prepare them for future jobs. It is reported that professional skills such as collaboration, creativity, critical thinking, etc. are necessary skills for new professionals entering the work force [1, 2]. It has been demonstrated that Active Learning (AL) not only enhances students' performance [3, 4], but also provides an opportunity for the students to practice and improve these skills [5]. However, active techniques are not frequently used because of barriers such as time, motivation, training associated with its implementation, and institutional barriers [6, 7, 8, 9]. The University of California, Irvine (UCI) has a Pedagogical Fellows Program to train future faculty about scientific teaching and get the chance to create their own activities and practice them in action [10]. After graduating from this program, the first author decided the best opportunity to implement active learning techniques is the discussion sessions of an "Introduction to materials science" class. Since discussions are supposed to help the student to solve numerical problems, we chose group work [11] as the appropriate AL technique for this class. After implementation of group work, we studied students' performance in active and traditional classes to see whether AL had any significant effect. Some works show AL reduces the learning gap for first-generation students [12], female students [13] and URM students [14]. In our work we considered students' gender, first-generation status, gender and URM status, to see the effect of AL.

In the following sections, we will explain our methods and class design, present our results and findings, discuss the implication of the results, and finally propose future work. The worksheets we used in this class will be shared upon request, so that other instructors can use them for their own class.

II. Methods

A. *Course structure*

We designed and performed this study on a large classroom with 172 students which was offered during a 10-week quarter. Students had three 50-minute lectures and one 50-minute discussion session every week. During lectures, the content was conveyed by PowerPoint slides, and a few clicker questions were used as formative assessment [15] to evaluate students' understanding. Students had weekly homework that was submitted online and graded automatically. The course had two midterm exams and a final exam in weeks 4, 8 and 11, respectively. The exams were cumulative, and the grades on these exams are used to compare students' performance who were in the active versus traditional discussion sections. All the

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exams were graded by a teaching assistant who was not involved in the discussion sections.

B. Discussion and worksheets

There were four discussion sections for students to register for. Attendance in discussion sessions was mandatory and they were all in the same day. All the sections were facilitated by an experienced teaching assistant who was familiar with scientific teaching and trained to use AL in class. In two of the sections, students collaborated on a worksheet in groups of three. Groups were formed randomly by the instructor and remained the same throughout the whole quarter. Collaborative problem-solving was required in class. In the other two sections, the teaching assistant did the same problems on the board for the students, which we consider the "traditional" approach. To hold the students accountable, each discussion session ended with a multiple-choice quiz on the content of the day. Depending on the difficulty of the content, the worksheets had 3 to 5 questions. Fig. 1 shows an example of the questions that were used in the worksheets.

C. Survey

The Jones et al. [16] survey measures expectancy-related (self-efficacy, and expectancy of success) and value-related beliefs (interest, attainment, utility, and identification with engineering) and relates them to achievement and career plans of students. We used this survey to see whether active learning changed any of these values and motivations in students. Students did the survey online in the beginning and end of the quarter. We report the change in the students' answers.

D. Student demographic

Table 1 shows the demographic of the students. About 50% of the students enrolled in this course were majoring in mechanical and aerospace engineering, the rest of the students were from materials science and engineering, civil engineering, biomedical engineering and chemical engineering. The class was diverse as we had 37.6% under representative minority (URM) students, 22.7% female students, and 43.5% transfer student. We considered students' URM status, gender and first-generation status to see the effect of active learning on students' performance.

Assume these planes cut through a) BCC and b) FCC unit cells. Draw the planes and show how atoms that are positioned on them.

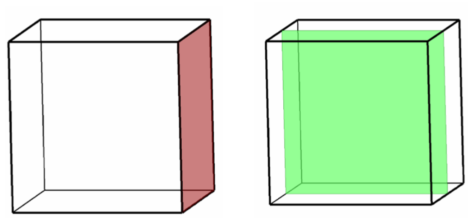

Fig. 1. Example of one of the problems in the worksheets

E. Exclusion

Students without SAT and ACT score data were excluded from our analysis. Students with only ACT scores were included in the analysis by converting the ACT score to an equivalent SAT score.

III. RESULTS

A. Effect of active learning on students' performance

Boxplots in Fig. 2 compare performance of the students in exams 1 and 2 and the final exam. Performance of both groups of the students in all the exams is almost identical and our intervention did not improve students' grades.

To further investigate the relationship between active learning and final exam scores, we ran a linear mixed model [17,18,19,20] with fixed effects for active learning, student demographics (gender, class level, transfer student status, under-represented minority status, and whether or not they were a first-generation college student), student preparation (high school GPA and GPAO) as well as random effects [21, 22] for the class that students were enrolled in. From this model we found that the only significant predictor of final exam grades was GPAO—grade point average of the students' other courses taken that quarter. There was not a significant difference in final exam scores for active learning, student demographics, and high school GPA.

B. Survey results

Fig. 3 shows the average difference of post- and pre-survey results. Fig. 3 describes the 7 categories of interest in the survey as explained in [16]. Active students tend to show no change or very little positive change in categories 4 (Attainment), 5 (Utility), 6 (Identification) and 7 (Career). Non-active students show no change or little positive change in categories 3 (Interest) and 7 (Career). Both groups show decrease in categories 1 and 2. Comparing active and non-active students, shows a likely difference in category 3, where non-active students show higher interest, and category 4 where active students show higher interest in doing well in engineering. Due to time constraints, we did not measure statistical significance in the survey results.

TABLE 1. POPULATION OF THE STUDENTS.

Category	Percentage
Under-represented Minority	37.6%
Female	22.66%
Transfer Student	42.5%
First Generation College Student	50.8%
Major	
Mechanical Engineering	49.2%
Class Standing	
Sophomore	15.70%
Junior	59.88%
Senior	24.42%

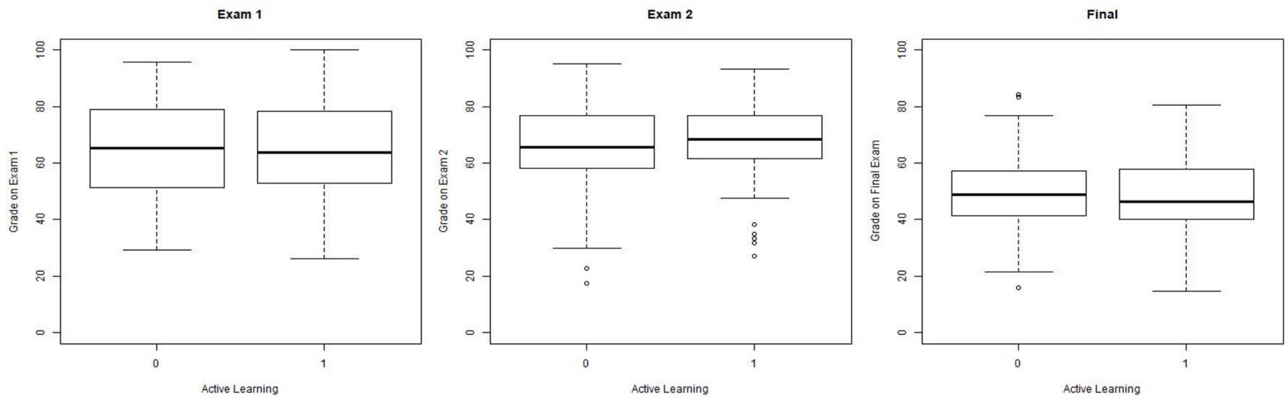

Fig. 2. Comparing students' performance in Exam 1, Exam 2 and the final exam. (0 means traditional lecture-based class and 1 means active learning class)

IV. Discussion/Implications

Our work supports the hypothesis that more time should be spent on AL to observe its effect on students' performance. Quantitative analysis of students' final scores indicates AL did not help any group of students to perform better than their peers in traditional classes. This is not consistent with other studies and can be attributed to the difficulties in implementation of AL, such as:

- While many new concepts are covered each week in this course, students meet only 50 minutes to do group work.
- There was no summary and conclusion at the end of each discussion session, this does not give the students the time to reflect on what they just worked on. We should have had immediate feedback during each session [23].
- There was only one instructor for the active classes with >40 students. Students could benefit from having more resources to get hint or to ask more questions.
- Many exam questions were so difficult that all students missed them, so there was little variability between AL and non-AL scores.

The survey results were not fully analyzed, but they seem to indicate that at the end of the course, the active students tended to have a higher attainment value, which means doing good in engineering is considered core personal value [16], compared to non-active students, while non-active students show higher interest in persistence in engineering.

V. Conclusion and Future work

Our work supports the hypotheses that instructors must dedicate more time in class to AL to observe an enhanced performance of students. Our results also indicate it may be possible to change students' attitude towards engineering and make it more valuable to them by using AL for a short time each week. Our model showed the only significant predictor of final exam grades was their grades in other courses, regardless of their background and the type of pedagogy used in their class.

As for our future work, we will measure statistical differences in the survey results to explain quantitatively how AL changed attitude of students toward engineering.

Acknowledgement

We would like to thank Dr. Daniel Mann, Dr. Julie Schoenung, Kliah Soto Leytan and Komal Syed for their help and support during this project.

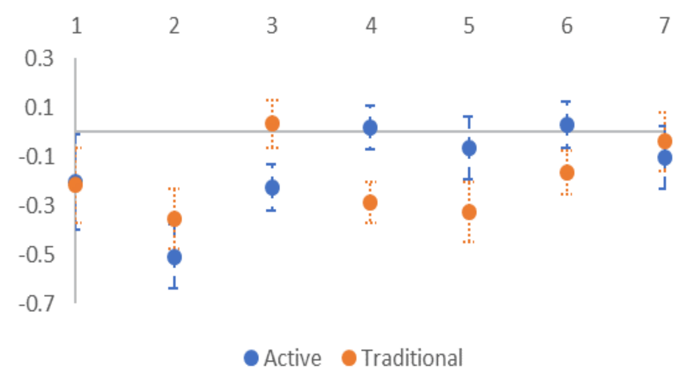

Fig. 3. The average post-pre differences of survey responses and their respective standard errors are shown for 1, self- efficacy, 2, expectancy, 3, interest, 4, attainment, 5. utility, 6, identification, and 7, career.

References

[1] World Economic Forum, 2016. The future of jobs: Employment, skills and workforce strategy for the fourth industrial revolution. World Economic Forum, Geneva, Switzerland.

[2] Voogt, J. and Roblin, N.P., 2012. A comparative analysis of international frameworks for 21st century competences: Implications for national curriculum policies. Journal of curriculum studies, 44(3), pp.299-321.

[3] Prince, M., 2004. Does active learning work? A review of the research. Journal of engineering education, 93(3), pp.223-231.

[4] Virtanen, P., Niemi, H.M. and Nevgi, A., 2017. Active Learning and Self-Regulation Enhance Student Teachers' Professional Competences. Australian Journal of Teacher Education, 42(12), p.1.

[5] Boyce, G., Williams, S., Kelly, A. and Yee, H., 2001. Fostering deep and elaborative learning and generic (soft) skill development: the strategic use of case studies in accounting education. Accounting education, 10(1), pp.37-60.

[6] Shekhar, P. and Borrego, M., 2017. After the Workshop: A Case Study of Post-Workshop Implementation of Active Learning in an Electrical Engineering Course. IEEE Transactions on Education, 60(1), pp.1-7.

[7] Kalamas Hedden, M., Worthy, R., Akins, E., Slinger-Friedman, V. and Paul, R.C., 2017. Teaching sustainability using an active learning constructivist approach: Discipline-specific case studies in higher education. Sustainability, 9(8), p.1320.

[8] Olson, S. and Riordan, D.G., 2012. Engage to Excel: Producing One Million Additional College Graduates with Degrees in Science, Technology, Engineering, and Mathematics. Report to the President. Executive Office of the President.

[9] Felder, R.M., Brent, R. and Prince, M.J., 2011. Engineering instructional development: Programs, best practices, and recommendations. Journal of Engineering Education, 100(1), pp.89-122.

[10] http://dtei.uci.edu/the-pedagogical-fellowship/ date: 04/02/2018

[11] Smith, K.A., Sheppard, S.D., Johnson, D.W. and Johnson, R.T., 2005. Pedagogies of engagement: Classroom ‐ based practices. Journal of engineering education, 94(1), pp.87-101.

[12] Eddy, S.L. and Hogan, K.A., 2014. Getting under the hood: how and for whom does increasing course structure work?. CBE-Life Sciences Education, 13(3), pp.453-468.

[13] Lorenzo, M., Crouch, C.H. and Mazur, E., 2006. Reducing the gender gap in the physics classroom. American Journal of Physics, 74(2), p.118.

[14] Haak, D.C., HilleRisLambers, J., Pitre, E. and Freeman, S., 2011. Increased structure and active learning reduce the achievement gap in introductory biology. Science, 332(6034), pp.1213-1216.

[15] Nicol, D.J. and Macfarlane‐ Dick, D., 2006. Formative assessment and self‐ regulated learning: A model and seven principles of good feedback practice. Studies in higher education, 31(2), pp.199-218.

[16] Jones, B.D., Paretti, M.C., Hein, S.F. and Knott, T.W., 2010. An analysis of motivation constructs with first ‐ year engineering students: Relationships among expectancies, values, achievement, and career plans. Journal of engineering education, 99(4), pp.319-336.

[17] Bates, D., Machler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models using lme4. Journal of Statistical Software, 67, 1-48. doi:10.18637/jss.v067.i01

[18] Pinheiro, J.C., and Bates, D.M. (2000) "Mixed-Effects Models in S and S-PLUS", Springer.

[19] Raudenbush, S. W. & A. S. Bryk. 2002. Hierarchical Linear Models: Applications and Data Analysis Methods. 2nd ed. Thousand Oaks CA: Sage.

[20] R Core Team. (2017). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Available from https://www.R-project.org/ date: 04/02/2018

[21] Laird, N. M. & J. H. Ware. 1982. “Random-Effects Models for Longitudinal Data.” Biometrics 38:963—974

[22] Longford, N. T. (1993). Random Coefficient Models. Oxford Statistical Science Series 11. Oxford Univ. Press, New York. MR1271143

[23] Andrews, T.M., Leonard, M.J., Colgrove, C.A. and Kalinowski, S.T., 2011. Active learning not associated with student learning in a random sample of college biology courses. CBE-Life Sciences Education, 10(4), pp.394-405.