Extended Abstract with Poster

Evaluating Effects of the Arlington Undergraduate Research-based Achievement for STEM (AURAS) Program on the Performance of Engineering Students in Chemistry Courses

Priscila Martinez-Avila, Emmanuel Varona, Doug D. Carlton Jr., Abegayl Thomas, Kevin A. Schug

Department of Chemistry & Biochemistry
The University of Texas at Arlington

Abstract

The current study was designed to evaluate the effect of supplemental instruction on academic achievement and to develop credible research to assess the learning of students in general chemistry courses. At The University of Texas at Arlington, completion of general chemistry is a core requirement of the engineering curriculum, and the Chemistry for Engineers course effectively combines traditional first and second semester general chemistry courses into a one semester course. Similar to other institutions, our students face obstacles to learning chemistry. These are evident from the low passing rates that are reported in literature and seen in our classrooms. The university has instituted the Arlington Undergraduate Research-based Achievement for STEM (AURAS), a National Science Foundation-funded program to promote success in general chemistry, and ultimately increase retention and graduation rates of engineering students.

General chemistry is identified as a "high-risk" class because it impacts both retention and graduation rates. In general chemistry, students are taught basic science principles and they acquire academic skills that are necessary to solve engineering problems in subsequent classes[1,2]. A thorough understanding of the material is associated with a positive outcome for the student in the engineering program. The University of Purdue reported an average graduation rate of 57 percent over a period of 15 years for engineering-bound students[2]. The percentage of engineering graduates increased to 89 percent when calculated among students who had successfully completed "high-risk" courses. Unfortunately this average does not take into account the nearly 50 percent of unsuccessful students commonly found in introductory chemistry courses[3,4].

Through the AURAS program, sessions of supplemental instructional were offered to students enrolled in the Chemistry for Engineers course for the fall 2011 semester. Only one class section was offered, therefore, all students compared in this study attended the same lecture taught by one instructor. One ESP section with a capacity of forty students was available. It was led by two

Proceedings of the 2013 ASEE Gulf-Southwest Annual Conference,
The University of Texas at Arlington, March 21 – 23, 2013.

teaching assistants (TAs) and two undergraduate Peer Academic Leaders (PAL) that were present at all times and stayed constant throughout the program. Subjects were recruited by advisors and registered for the program prior to the first session. Separately from regular classroom and laboratory sessions, students attended four hour sessions of supplemental instruction scheduled once a week, in which material was reinforced using the model of a Treisman-style Emerging Scholars Program (ESP)[5,6]. In ESP, an emphasis is placed on building community among the students through active learning and fostering collective efforts aimed to solve challenging problems.

Students enrolled in ESP, henceforth the ESP group, received the benefits of the AURAS program while the comparison non-ESP group did not. Our hypotheses were that the experimental group would attain higher marks on examinations and a higher percentage of students would pass the course (attaining marks of A, B, or C), compared to non-ESP students. The first hypothesis was proven. As shown in **Figure 1**, ESP students had statistically higher grades in the Exam 1, Exam 2, Exam 3, and the final exam ($p < 0.05$). ESP students retained a higher average for Exam 4, which approximated significant value ($p = 0.06$). Due to a holiday break mid-week, only one ESP session was administered to prepare students for Exam 4 and the exam covered two chapters in the textbook. This could be the reason that no significance was found on Exam 4. The second hypothesis was proven by comparing the passing rates in each group. The ESP group had a higher passing rate than the non-ESP group (85% versus 57%) From Pearsons' chi-square test we can say there is a minimal probability (0.5%) that the difference in grades is a result of random chance. Data on demographics and academic background variables (SAT/ACT scores) is currently being analyzed to decipher if the groups come from the same population. If the groups are comparable, we can safely say that attending AURAS and success in chemistry are dependent on one another ($\chi^2(1)_{.005} = 7.88$, $\chi^2_{calc} = 10.57$, $p < 0.005$).

Both summative and formative assessments were used throughout the AURAS program to promote a thorough understanding of the material taught in class. For this purpose, a list of learning outcomes was distilled from the learning objectives provided for each chapter of the textbook *Chemistry for Engineering Students*, Second Edition, by Brown and Holme[7]. Learning outcomes were statements of the knowledge and skills students were expected to master. At the beginning of each session, students were administered short quizzes or extended test review packets, depending on the date proximity of the formal examination. All questions administered to the students were coded with the learning objective/outcome that was being tested. The performance of the class was computed for each test by averaging the grades over the questions coding one objective. This average is termed class mastery. Class mastery is a measure of how well the class understood the concepts, and could apply the skills, outlined in a given outcome. Content validity on of the learning outcomes was established by the course instructor who reviewed and modified the list.

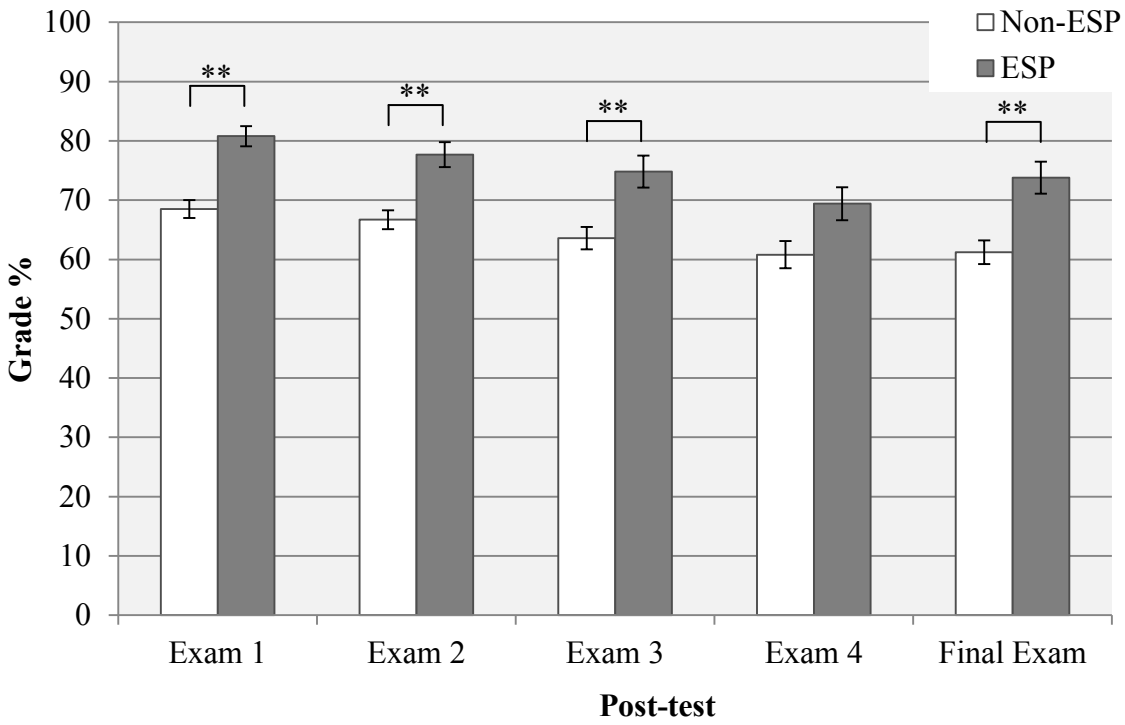

Figure 1. Mean scores for each of the five post tests: T-statistics were used to test for significance (*$p < 0.05$; **$p < 0.005$). Standard error bars shown.

The scores obtained from the learning outcomes were used to evaluate the combined ability of the traditional course and the ESP instruction to effectively deliver course themes (summative evaluation), while the scores obtained from the detailed learning objectives were used to monitor students learning and to provide ongoing feedback to the students and ESP instructors (formative assessment). TAs developed lesson plans with integrated activities, such as Process Oriented Guided Inquiry Learning (POGIL) real world problems to foster collaborative learning, while emphasizing challenging concepts. PAL students tutored individual students or groups, based on their discretion, and regularly updated TAs to ensure ESP lessons transitioned at the same pace as that of the course. It was hypothesized learning would increase over time, which would in turn result in a continuous increase of class mastery from test to test.

On average, students had a mastery of 59.1% (SD = 14.0) when the outcome was originally tested in AURAS (pre-test). Mastery of chemistry content increased to 78.6% (SD = 7.8) on the formal examination given in class (non-comprehensive/immediate post-test). When the outcomes were tested in the comprehensive final examination, the average class mastery was 74.8% (SD = 13.9). Repeated analysis of variance (ANOVA) was used to test the effect ESP- supplemental instruction had on class mastery of chemistry content. A significant increase in content mastery was found for the range of learning outcomes, $F(2,16) = 12.45$, $p = 0.00001$. *Post hoc* comparisons revealed significant differences between the pre-test and imidiate post-test and the

pre-test and the final post-test. The results indicate that the class had a significant increase in understanding prior to being tested in class. We can confidently say that the program enhanced the course and resulted in improved student attainment of the material. This is evident from both the learning outcomes assessment and the comparison of exams grades between the ESP and non-ESP group. We further postulate that in addition to enhanced learning, ESP instruction resulted in learning retention, which is shown by the significantly higher mastery of chemistry content between the pre-test and final post-test. No significant differences were noted between the initial and final post-test scores. This could be interpreted in two ways: (1) knowledge increase was not continuous from immediate to final post-test or (2) knowledge decay was insignificant. Future research using learning outcomes based assessment would benefit from an analysis testing the effect of repeated assessment on the learn–forget curve model [8,9].

References

1 Felder, R.M., Forrest, K.D., Baker-Ward, L., Dietz, E.J., Mohr, P.H., 1993, "A longitudinal study of engineering student performance and retention: I. Success and failure in the introductory course", *Journal of Engineering Education*, Vol. 82, No. 1, pp. 15-21.

2 Budny, D., Bjedov, G., LeBold, W., 1997, "Assessment of the impact of the freshman engineering courses", *Proceedings of the Frontiers in Education Conference*, IEEE, pp. 1100-1106.

3 URL: http://digital.library.unt.edu/permalink/meta-dc-9858

4 Gilmer, T.C., 2007, "An understanding of the improved grades, retention and graduation rates of STEM majors at the Academic Investment in Math and Science (AIMS) Program of Bowling Green State University (BGSU)", *Journal of STEM Education*, Vol. 8, No. 1-2, pp. 11-21.

5 Treisman, U., 1992, "Studying students studying calculus: A look at the lives of minority mathematics students in college", *The College Mathematics Journal*, Vol. 23, No. 5, pp. 362-372.

6 Duncan, H., Dick, T., 2000, "Collaborative workshops and student academic performance in introductory college mathematics courses: A study of a Treisman model math excel program', School Science and Mathematics", Vol. 100, No. 7, pp. 365-373.

7 Brown, L.S., Holme, T., 2010, Chemistry for engineering students, Brooks/Cole Publishing Company, California

8 Jaber, M.Y., and Bonney, M., 1997, "A comparative study of learning curves with forgetting", *Applied Mathematical Modelling*, Vol. 21, No. 8, pp. 523-531.

9 Jaber, M.Y., and Kher, H.V., 2004, "Variant versus invariant time to total forgetting: the learn–forget curve model revisited", *Computers & Industrial Engineering*, Vol. 46, No. 4, pp. 697-705.

PRISCILA MARTINEZ-AVILA

Priscila is a Master of Biomedical Engineering candidate, and a senior undergraduate at the School of Social Work. She served as a Peer Academic Leader in the AURAS program for fall 2011. Her most current positions have been Teacher Assistant of Chemistry for Engineers, and Teacher Assistant of Laboratory Principles. Priscila received the first of five installments dedicated to Latino youth forging a new Hispanic Heritage in the field of science.

EMMANUEL VARONA
Emmanuel Varona currently a senior majoring in Biological Chemistry at the University of Texas at Arlington. Former ESP student fall 2010 and is currently an Auras Peer Assisting Leader (PAL).

DOUG D. CARLTON
Doug Carlton is a Ph.D. candidate in his 4th year at the University of Texas at Arlington studying Analytical Chemistry under the direction of Dr. Kevin Schug. His research expertise includes liquid and gas chromatography and mass spectrometry applications. His current research is various analytical investigation of groundwater from the Barnett Shale region for any indication of contamination from the natural gas extraction process.

ABEGAYL THOMAS
Ms. Abegayl Thomas is currently a PhD student in the Department of Chemistry and Biochemistry at the University of Texas at Arlington. Over the past two years she has served as a teaching assistant for general chemistry labs as well as an instructor for the AURAS program to help engineering students be successful in Chemistry for Engineers.

KEVIN A. SCHUG
Dr. Schug is Associate Professor in the Department of Chemistry and Biochemistry at the University of Texas at Arlington. His field of research involves the development of methods for qualitative and quantitative analysis of molecular recognition systems by mass spectrometry, with applications in drug discovery, chiral separations, and elucidation of biochemical interactions. He is co-investigator of the AURAS program, leading the ESP supplemental instructions for chemistry.