



The first Year of an Undergraduate Service Learning Partnership to Enhance Engineering Education and Elementary Pre-Service Teacher Education

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Dr. Jennifer Kidd is a Senior Lecturer in the Department of Teaching and Learning at Old Dominion University. Her research interests include engineering education, computational thinking, student-authored digital content, classroom assessment, especially peer review, and diversity issues. She currently has support from the National Science Foundation for two projects related to engineering education for preservice teachers.

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Dr. Gutierrez received her B.S. in Biology from the University of North Carolina at Chapel Hill in 2001, M.Ed. in Secondary Science Education in 2005 from the University of North Carolina at Wilmington, and Ph.D. in Science Education in 2016 from North Carolina State University. Dr. Gutierrez is currently serving as an Assistant Professor of Science Education in the Department of Teaching and Learning at Old Dominion University. She teaches elementary science methods and secondary science and mathematics methods courses with emphasis on multicultural education and equity pedagogies. Her research interests include both formal and informal STEM education, with specialization in the integration of engineering and computer science into science education through preservice and inservice educator development.

Dr. Orlando M Ayala, Old Dominion University

Dr. Ayala received his BS in Mechanical Engineering with honors (Cum Laude) from Universidad de Oriente (Venezuela) in 1995, MS in Mechanical Engineering in 2001 and Ph.D. in Mechanical Engineering in 2005, both from University of Delaware (USA). Dr. Ayala is currently serving as Assistant Professor of Mechanical Engineering Technology Department, Frank Batten College of Engineering and Technology, Old Dominion University, Norfolk, VA.

Prior to joining ODU in 2013, Dr. Ayala spent three years as a Postdoctoral Researcher at the University of Delaware where he expanded his knowledge on simulation of multiphase flows while acquiring skills in high-performance parallel computing and scientific computation. Before that, Dr. Ayala held a faculty position at Universidad de Oriente at Mechanical Engineering Department where he taught and developed graduate and undergraduate courses for a number of subjects such as Fluid Mechanics, Heat Transfer, Thermodynamics, Multiphase Flows, Fluid Mechanics and Hydraulic Machinery, as well as Mechanical Engineering Laboratory courses.

In addition, Dr. Ayala has had the opportunity to work for a number of engineering consulting companies, which have given him an important perspective and exposure to the industry. He has been directly involved



in at least 20 different engineering projects related to a wide range of industries from the petroleum and natural gas industry to brewing and newspaper industries. Dr. Ayala has provided service to professional organizations such as ASME. Since 2008 he has been a member of the Committee of Spanish Translation of ASME Codes and the ASME Subcommittee on Piping and Pipelines in Spanish. Under both memberships, the following Codes have been translated: ASME B31.3, ASME B31.8S, ASME B31Q and ASME BPV Sections I.

While maintaining his industrial work active, his research activities have also been very active; Dr. Ayala has published 90 journal and peer-reviewed conference papers. His work has been presented in several international forums in Austria, the USA, Venezuela, Japan, France, Mexico, and Argentina. Dr. Ayala has an average citation per year of all his published work of 44.78.

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Dr. Krishnanand Kaipa is an Assistant Professor and director of the Collaborative Robotics and Adaptive Machines (CRAM) Laboratory in the Department of Mechanical and Aerospace Engineering at the Old Dominion University. Dr. Kaipa received his BE (Hons.) in Electrical Engineering from Birla Institute of Technology and Science, Pilani, India in 1998, and his MS in 2004 and PhD in 2008, both in Aerospace Engineering from Indian Institute of Science, Bangalore. He worked as a postdoctoral associate at Department of Computer Science, University of Vermont and later at Department of Mechanical Engineering, University of Maryland, where he was also a research assistant professor. Dr. Kaipa's research interests include biologically inspired robotics, human-robot collaboration, embodied cognition, and swarm intelligence. Dr. Kaipa is a member of ASME and IEEE.

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Abstract

This IUSE project was designed to address three major challenges faced by undergraduate engineering students (UES) and pre-service teachers (PSTs): 1) retention for UESs after the first year, and continued engagement when they reach more difficult concepts, 2) to prepare PSTs to teach engineering, which is a requirement in the Next Generation Science Standards as well as many state level standards of learning, and 3) to prepare both groups of students to communicate and collaborate in a multi-disciplinary context, which is a necessary skill in their future places of work. This project was implemented in three pairs of classes: 1) an introductory mechanical engineering class, fulfilling a general education requirement for information literacy and a foundations class in education, 2) fluid mechanics in mechanical engineering technology and a science methods class in education, and 3) mechanical engineering courses requiring programming (e.g., computational methods and robotics) with an educational technology class. All collaborations taught elementary level students (4th or 5th grade). For collaborations 1 and 2, the elementary students came to campus for a field trip where they toured engineering labs and participated in a one-hour lesson taught by both the UESs and PSTs. In collaboration 3, the UESs and PSTs worked with the upper-elementary students in their school during an after-school club. In collaborations 1 and 2, students were assigned to teams and worked remotely on some parts of the project. A collaboration tool, built in Google Sites and Google Drive, was used to facilitate the project completion. The collaboration tool includes a team repository for all the project documents and templates. Students in collaboration 3 worked together directly during class time on smaller assignments. In all three collaborations lesson plans were implemented using the BSCS 5E instructional model, which was aligned to the engineering design process. Instruments were developed to assess knowledge in collaborations 1 (engineering design process) and 3 (computational thinking), while in collaboration 2, knowledge was assessed with questions from the fundamentals of engineering exam and a science content assessment. Comprehensive Assessment of Team Member Effectiveness (CATME) was also used in all 3 collaborations to assess teamwork across the collaborations. Finally, each student wrote a reflection on their experiences, which was used to qualitatively assess the project impact. The results from the first full semester of implementation have led us to improvements in the implementation and instrument refinement for year 2.

Introduction

Engineering education faces the challenge of retention of and continued engagement of undergraduate engineering students (UESs), while the education of preservice teachers (PSTs) is now faced with increasing requirements to include engineering in all levels of K-12 education, from Next Generation Science Standards (NGSS) to state level requirements. This multi-

disciplinary service learning project was developed to address these educational challenges faced by both UESs and PSTs when it comes to learning engineering content required for their respective disciplines, along with non-technical skills required for their future work environment, including working in teams and collaborating with a range of audiences. This was accomplished by pairing three separate engineering and technology classes: 1) an introductory level mechanical engineering class paired with a foundations course in education, 2) a fluid mechanics course in mechanical engineering technology paired with a science methods course, and 3) a course requiring programming (i.e., computational methods or robotics) paired with an educational technology course. All three collaborations involved the multidisciplinary undergraduate teams teaching 4th, 5th or 6th graders about engineering.

Both multidisciplinary collaborative learning and service learning were combined in this project because both methods have shown to improve student learning outcomes. Specifically, students who participate in collaborative learning have shown improvements in long-term retention of content [1] when compared with students who attend lectures or participate in class discussion. Additionally, students reported increased motivation to work hard, understanding of the material, and retention of the material when service learning was integrated into their classes [2]. Empirical peer learning inherent in the project may also enhance students' understanding: engineering students will teach education students about engineering concepts, while the education students will teach the engineering students about communicating with non-technical audiences (i.e., PSTs and P-6 students). These mutually beneficial interactions may contribute to deeper learning by activating both motivational and cognitive processes. The purpose of this paper is to explain the implementation and lessons learned from each of these collaborations in the first year of the project.

Collaborations and Preliminary Data Collection

Collaborations 1 and 2 used a similar implementation strategy, where 4th or 5th graders came to campus for a field trip where they toured engineering labs and a residence hall, ate lunch on campus, and participated in a one hour lesson taught by both the UESs and PSTs. These collaborations used a collaboration tool built in Google Sites and Google Drive, was used to facilitate the project completion. Specifically, each Google Site included scaffolded assignments to aid in project completion [3], including, but not limited to student bios, a team charter, and templates for brainstorming activities, the lesson plan, and slides for lesson delivery. Students in these collaborations worked together outside of class time, however, the instructors were in close communication with their students and each other to ensure that the assignments were progressing and the projects were progressing as required. The courses for collaboration 1 were a 100 level mechanical engineering course, called Information Literacy in Mechanical and Aerospace Engineering with a 300 level Foundations of Education Course. The courses for collaboration 2 were Fluid Mechanics in Mechanical Engineering Technology and a 400 level Science Methods course. In collaboration 1, projects were selected by providing a broad range of suggested topics, to help keep students engaged in a project that they were interested in. In collaboration 2, projects were selected based on specific topics covered in fluid mechanics (i.e., drag, lift, viscosity, forces, friction, density).

In collaboration 3, the UESs and PSTs worked together during class time on smaller assignments, and then with the upper-elementary students in their school during an after school club. The projects developed in the after school club involved both engineering design and computational thinking, therefore different mechanical engineering courses involving programming (i.e., a 400 level elective called bioinspired robotics and computational methods) collaborated with a 400 level educational technology class. The projects in collaboration 3 involved building and programming simple robots.

In all three collaborations lesson plans were implemented using the Biological Sciences Curriculum Study (BSCS) 5E instructional model [4], an inquiry-based lesson format which has been proven effective in teaching science [5, 6]. Specifically, the lesson plan included sections labeled Engage, Explore, Explain, Extend, and Evaluate. These tasks aligned with the engineering design process, which was taught to the undergraduate students, and in turn taught to the elementary students during the lessons.

Instruments were developed to assess knowledge in collaborations 1 (engineering design process) and 3 (computational thinking), while in collaboration 2, knowledge was assessed with questions from the fundamentals of engineering exam and a science content assessment. Comprehensive Assessment of Team Member Effectiveness (CATME) was also used in all 3 collaborations to assess teamwork across the collaborations. Finally, each student wrote a reflection on their experiences, which was used to qualitatively assess the project impact. Similar data are being collected from comparison groups, which are students in the same courses, who participate in a group project contained within the class. In collaborations 1 and 2, the comparison classes are being taught by the same instructors as the treatment classes.

Preliminary Results and Discussion

The results from the first full semester of implementation have led to needed improvements for the implementation of the project and as well as the assessments. For the implementations of collaborations 1 and 2, undergraduate students were given freedom to pick topics of interest because we hypothesized that would keep the UESs engaged. However, the UESs struggled with connecting their chosen project with science and engineering concepts that they were trying to convey to the elementary students. Specifically, in collaboration 1, while the initial intent was to allow the 100 level students explore applications that were exciting to them, it was difficult for the students to connect those applications to specific concepts to explain to the PSTs and elementary school students. Further, UESs and PSTs had difficulty connecting the 5Es lesson plan format with the engineering design process. Similarly, in collaboration 2, while the UESs may have had a clearer understanding of the Fluid Mechanics concepts, they were challenged with how to turn them into lessons that connected those concepts to a lesson involving engineering design. For example, many UES/PST teams selected paper airplanes to demonstrate the concept of lift. However, the elementary students spent more time either learning how to fold a paper airplane or folding their favorite airplane, that the concept of how to modify the plane to

improve lift wasn't conveyed. Therefore, the next collaboration will limit the choices of projects to more specific topics, and some instructional time will be spent ensuring that the undergraduate students think critically about the connection between the engineering concepts and the lesson they are teaching. Additionally, the lesson plan template will be updated, to connect the 5Es to the engineering design process, and template for a google slide show will be added to the Google site.

One of the biggest challenges in collaboration 3 was that the educational technology class had significantly fewer students than the computational methods class that it was paired with. Therefore, the PSTs had different groups of UESs to work with on small assignments during class, instead of a larger project throughout the semester, to avoid groups where the UESs would significantly outnumber the PSTs. A pilot of this class prior to this grant combined a small, bioinspired robotics course with PSTs in the educational technology course, where the UESs and PSTs could work together on a larger project. Therefore, future collaborations will include either the bioinspired robotics course or electromechanical systems course, both which have smaller class sizes.

Preliminary results [7,8] suggest that the instruments developed for collaborations 1 (engineering design process) and 3 (computational thinking) may not be sensitive enough to detect changes in content knowledge. Therefore, additional research is being implemented to improve those assessments. The reflection assignments provided valuable information on both what students learned and how they viewed the lessons. Finally, the CATME assessment showed a positive impact on teamwork skills [9]; however, CATME may not be possible in a comparison class, if the class does not have a collaborative project. Therefore, we are working on developing a tool that can assess teamwork skills in this setting.

The first semester of implementing this collaborative multidisciplinary service learning project indicated that this approach may improve outcomes in undergraduate STEM education; however, some modifications should be made to improve student outcomes.

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