Enhancing teamwork skills through an engineering service learning collaboration

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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 over one hundred 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 42.80.

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Enhancing teamwork skills through an interdisciplinary engineering service learning collaboration

Abstract

The purpose of this research paper is to explore whether participation in an interdisciplinary collaboration program partnering Preservice Teachers (PST) and Undergraduate Engineering Students (UES) results in an increase in teamwork effectiveness. The interdisciplinary collaboration was designed as a service-learning project within existing undergraduate programs that included the development and delivery of engineering content to a K-12 audience. The collaborations were integrated into existing courses in two colleges, engineering and education. The Behaviorally Anchored Rating Scale (BARS) version of the Comprehensive Assessment of Team Member Effectiveness (CATME) was used midway and at the end of the project to evaluate teamwork effectiveness. Results of the analysis indicated that both PST and UES were rated significantly higher in team-member effectiveness at the end of the project across four of five factors: interacting with team members, keeping the team on track, expecting quality, and having relevant knowledge, skills and abilities. The gain in the teamwork effectiveness did not differ across majors, with both UES and PST showing similar gains. A noticeable positive increase in student attitudes towards the task was also observed between the midway and the end of the project. Findings from this study provide some preliminary evidence that an innovative interdisciplinary service learning experience partnering engineering and education students was conducive to the development of teamwork skills.

Keywords: teamwork skills, service learning, interdisciplinary teams

1. Introduction

Teamwork skills have an unquestionable value in both academic and professional settings. In the academic environment, engaging in collaborative work as part of courses has been linked to enhanced learning outcomes (Park et al., 2015). But the most significant benefit of teaching teamwork skills in an academic setting is their potential to transfer to the workplace (Vogler et al., 2018). The growing complexity of the global economy demands greater cooperation and coordination, bringing the need for collaboration skills to the forefront of organizations (Ritter et al., 2018). A survey on critical skills in the workplace by the American Management Association (2012) identified the need for a workforce equipped with teamwork skills to face the dynamism in business and to compete at the global level (Halfhill & Nielsen, 2007). Effective communication, leadership, teamwork, conflict resolution, and interdisciplinary perspective are often recognized as the most valuable professional skills in a variety of organizational settings (Barker et al., 1998; Halfhill & Nielsen, 2007; Ritter et al., 2018). These traits are also recognized as essential engineering skills. The Accreditation Board for Engineering and Technology (ABET) includes criteria such as “an ability to communicate effectively with a range of audiences” and “an ability to function effectively on a team” (ABET 2020). These criteria are intrinsically linked to the idea of multidisciplinary collaboration. Recent research suggests that being able to work effectively in multidisciplinary teams is a highly desired engineering skill. According to practitioner engineers in leadership positions, educators should raise students’ awareness about this need (Wisniewski, 2018).

Undergraduate education presents an ideal platform to support the development of professional competencies and abilities sought by employers (Vogler et al., 2018). However, some of the traditional instructor-centered learning environments in higher education do little to support the development of these skills (Fisher & Newton, 2014; Pazos et al., 2016). One of the greatest challenges instructors face is creating learning environments that help students learn professional skills to become employable (Hora et al., 2018; Pazos et al., 2019). Research has suggested that professional skills are often more difficult to develop than disciplinary skills among college students (Loughry et al., 2014). Recent studies have demonstrated some success through interventions using project-based learning (Pazos et al., 2016; Pertegal-Felices et al., 2019). This project builds on those efforts.

The primary purpose of this study was to determine whether participation in cross disciplinary collaboration contributed to enhancing teamwork skills for participating college students. Ed+gineering is an interdisciplinary partnership between education and engineering in which undergraduate engineering students (UES) and preservice teachers (PST) work in small teams to collaboratively plan and deliver hands-on engineering lessons to an elementary school audience. The college students develop the engineering lessons in the context of their college coursework as a collaboration project bridging two disciplines, engineering and education.
To facilitate effective teamwork, the interdisciplinary student teams used a web-based collaboration tool (SCOL) built on freely accessible web-based software available through Google Apps for Education, including Google Sites, Google Docs, Google Drive, Google Hangouts, and script language (Pazos et al., 2019). It provides an adaptable interface to support project-based, real-time communication and collaboration for teams of 4 to 10 students. SCOL was selected because of its evidence of success in promoting effective teamwork, ease of use, ability to tailor to specific course projects, and broad and free availability in most universities. SCOL incorporates scaffolds in the form of group activities, tasks, and templates that have been thoroughly tested and are built on evidence-based best practices in teamwork (Pazos & Magpili, 2015; Pazos et al., 2016; Pazos et al., 2019). The scaffolds are used to provide direction and structure for critical collaborative processes (planning, role assignment, progress tracking, and feedback) and guide the lesson development process.

2. Related work and theoretical framework

Although partnerships between UES and PST have been used in the past as a strategy to introduce engineering content in K-12 settings (Fogg-Rogers et al., 2017), there is little research that looked at these types of interdisciplinary partnerships from a teamwork effectiveness perspective. This research provides insight into this issue through partnerships between PSTs and UESs and faculty. In the *Paired Peer Mentors* project (Fogg-Rogers et al., 2017), pairs of PSTs and engineering students presented engineering design challenges to primary school children. Both groups of college students showed sizable gains in teaching engineering self-efficacy and subject knowledge confidence after the project. In a study exploring a similar partnership model, PSTs and engineering students collaboratively planned robotics activities for early childhood students using LEGO WeDo robots (Bers & Portsmore, 2005). PSTs used robotics to help elementary students explore concepts in math and science supported by engineering student peers. Although these studies have begun to explore the potential of partnering PSTs with engineering students, there is much to learn about the benefits of these types of partnerships and their impact on a variety of learning outcomes.

The Ed+gineering collaboration model between engineering and education students relies on small-group learning and is grounded in social constructivist learning theory. According to this theory, cross-disciplinary collaboration prompts students to experience new and different perspectives as they build knowledge (Piaget, 1985) and engages them in a common purpose. These settings provide an ideal opportunity for peer learning (Boud et al., 2014), both through knowledge exchange (e.g., engineering students explain basic technical concepts and PSTs share pedagogical approaches), collaborative problem solving (e.g., groups work together to design a viable lesson), communication, and teamwork (Hirsch et al., 2001). The interdisciplinary partnership was built to promote undergraduate students learning through interaction with others in their teams while building a common understanding (Svinicki, 2004). Students learned through creating and delivering engineering content through collaborative processes that promote social learning including researching and planning, peer mentoring, teaching and receiving feedback, and reflecting on and revising their content. All these processes took place with ongoing support and feedback from subject matter experts in education and engineering.

3. Method

This study was undertaken during the spring semester 2019 at a large public university in the Mid-Atlantic region. The main goal of the research was to explore whether undergraduate student participation in an interdisciplinary service-learning collaborative project resulted in an increase in their teamwork effectiveness.

Participants

Seventy-six undergraduate students were recruited to participate from two colleges: Preservice Teacher Students (PST, N_1=34) and Undergraduate Engineering Students (UES, N_2=42) at a University in the Mid-Atlantic region. Their participation was associated with courses they were taking as part of their degree programs. Table 1 and Table 2 show the distribution of participants by gender and ethnicity respectively for each degree program.

Table 1. Distribution of participants by program and gender

Gender	Education (PST)		Engineering		Total	
	n	%	n	%	n	%
Female	22	65	5	12	27	35.5
Male	9	26	34	81	43	56.5
No Information (N.I.)	3	9	3	7	6	8

Table 2. Distribution of participants by program and ethnicity

Ethnicity	Education (PST)		Engineering		Total	
	n	**%**	**n**	**%**	**n**	**%**
White or Caucasian	19	55.9	22	52.4	41	53.9
Black or African American	10	29.4	9	21.4	19	25
Asian or Asian Indian	-	-	4	9.5	4	5.3
Hispanic, Latino or Spanish	2	5.9	1	2.4	3	3.9

Native American or Alaska Native	-	-	1	2.4	1	1.3
Other	-	-	1	2.4	1	1.3
No Information (N.I.)	3	8.8	4	9.5	7	9.2

Sample data revealed that overall, 56.5% of students were males, compared to 35.5% females. Within the PST sample, most students (65%) were female compared to only 12% in the engineering student sample. In terms of race or ethnicity, the sample broke down as follows: White or Caucasian (53.9%), Black or African American (25%), Asian or Asian Indian (5.3%), Hispanic, Latino or Spanish (3.9%), Native American or Alaska Native (1.3%), Other/N.I (10.5%).

Procedure

Both PST and UES were assigned to small teams of 4 to 7 using the team formation feature in CATME. Teams had at least two students from each discipline. Students collaborated in semester-long service learning projects that included the development and delivery of engineering lessons to elementary students (4th and 5th grade). Teams were encouraged to identify and develop their lessons based on engineering content aligned with the specific grade level.

Teams used a collaboration platform, which included scaffolds (team member bios, a team charter, and a file repository including required assignment templates) to support project completion (Pazos et al., 2019). Students used the platform to collaborate, store and submit all the project related documents.

Measures

Teamwork effectiveness. The Behaviorally Anchored Rating Scale version of the Comprehensive Assessment of Team Member Effectiveness (CATME-B) was used to measure students' teamwork effectiveness. The CATME-B was developed and validated by Ohland et al. (2012) as an alternative version of the CATME proposed by Loughry et al. (2007). CATME-B allows individuals to provide self and peer-evaluation on five teamwork categories: contribution to the team's work, interaction with team members, keeping the team on track, expecting quality, and having relevant knowledge, skills, and abilities (Ohland et al., 2012).

Attitudes towards the task. Data also included survey items assessing student attitudes towards the task: *task commitment* and *task attraction* included in the CATME-B instrument. Task commitment refers to individual team members' perceived alignment with the team goals and the level of shared aspirations for good team performance. Task commitment was measured using a three-item scale by Carless & De Paola (2000) adapted to this study. A sample item is "Our team is united in trying to reach its goals for performance". Task attraction refers to individual team members' feelings, or affect, about their involvement in the tasks of the group (Loughry & Tosi, 2008). Task attraction was measured using a three-item scale by Loughry & Tosi (2008). A sample item is "Being part of the team allows team members to do enjoyable work". All items were anchored with a five-point Likert scale.

CATME was selected based on an extensive literature review related to team effectiveness. Besides its theoretical foundation, the self and peer-evaluation system included in the CATME has shown benefits for teamwork research. CATME is also considered an effective instrument that allows participants to be accountable for team performance (Hernandez, 2002). Moreover, completing self and peer evaluations contributes to the students' learning process on teamwork skills (Thomas et al., 2011), self-awareness and realistic judges of their performance, and experience on multi-rater systems (Ohland et al., 2012).
Participants' responses were collected through the web-based interface CATME.org at two different time points: mid-term and at the end of the project. The data collection protocol was approved by the University's human subjects review board.

The use of cross-disciplinary collaboration exposes the participating students to new perspectives and experiences as they build knowledge together by developing and delivering the lessons (Piaget, 1985). The following hypotheses were proposed:

H1: Team member effectiveness will improve over time for each teamwork category
H2: Attitudes towards the task will improve over time
H3: There is a positive relationship between teamwork effectiveness factors and attitudes towards the task at the end of the project

4. Analysis and Results

For hypotheses 1 and 2, the analysis helped us determine whether there was a change in teamwork effectiveness and attitudes towards the task over time. Paired samples T-Test compared data from students at two different time points during the project, midway, and end (Field et al., 2012). The analysis included validation of assumptions related to normality and homogeneity of variances. To test Hypothesis 3 we used correlation analysis.

Table 3 shows the mean and standard deviation of the five core team effectiveness categories (contribution to the team, interaction with team members, keeping the team on track, expecting quality, and having relevant knowledge, skills and abilities), and of the two teamwork behaviors (task commitment and task attraction) from both mid- and end-term assessment.

Table 3. Descriptive statistics of teamwork categories and behaviors

		Mid-term		End-term	
Teamwork Effectiveness Categories	n	Mean	SD	Mean	SD
Contribution to the team's work	76	4.100	0.479	4.149	0.455
Interaction with team members	76	4.142	0.389	4.314	0.375
Keeping the team on track	76	4.060	0.463	4.214	0.433
Expecting quality	76	4.039	0.381	4.272	0.411
Having relevant knowledge, skills and abilities	76	4.226	0.336	4.353	0.370
Attitudes Towards the Task					
Task Commitment	73	4.283	0.706	4.148	0.787
Task Attraction	73	4.012	0.6377	4.158	0.6358

A paired t-test was used for hypotheses 1 and 2 and the results are provided in Table 4. There was a significant increase over time with respect to interaction with team members ($t=4.251$, $p<0.0001$), keeping the team on track ($t=2.887$, $p<0.005$), expecting quality ($t=5.265$, $p<0.0001$) and having relevant knowledge skills and abilities ($t=3.511$, $p<0.001$). There was no evidence of an increase in contribution to the team between the two instances. Hypothesis 2 was also supported with a significant increase over time in task attraction ($t=2.004$, p-value<0.049) indicating that, on average, students felt more connected to the task as they neared project completion. There was a marginally significant increase in task commitment over time.

Table 4. Results of paired samples test

	Mean difference	T-Test	
Teamwork Effectiveness Categories		t	sig.
Contribution to the team's work	0.049	0.965	0.337
Interaction with team members	0.172	4.251	0.000
Keeping the team in track	0.153	2.887	0.005
Expecting quality	0.233	5.265	0.000
Having relevant knowledge, skills and abilities	0.127	3.511	0.001
Attitudes Towards the Task			
Task Commitment	0.160	1.852	0.068
Task Attraction	0.146	2.004	0.049

Additional analysis was done to assess potential differences between majors (PSTs and UES). There was no evidence that the gain in teamwork effectiveness differed across majors.

Table 5. Correlation matrix: teamwork categories and attitudes towards the task (post-test)

	1	2	3	4	5	6	7
1. Contribution to the team's work	1	.839**	.783**	.728**	.794**	0.046	0.153
2. Interaction with team members		1	.764**	.772**	.692**	0.187	0.223
3. Keeping the team in track			1	.856**	.701**	0.166	.263*
4. Expecting quality				1	.678**	0.171	.268*
5. Having relevant knowledge, skills and abilities					1	0.015	0.125
6. Task Commitment						1	.487**
7. Task Attraction							1

**Correlation is significant at the 0.01 level (2-tailed)
*Correlation is significant at the 0.05 level (2-tailed)

Table 5 shows the correlation matrix of all teamwork effectiveness measures (1-5) and attitudes towards the task (6-7). The analysis of the data suggests that all teamwork effectiveness measures were highly correlated. Also, as attraction to the task increased, students were more active in keeping the team on track and contributed to higher levels of quality from the team. There was no relationship found between commitment to the task and teamwork effectiveness measures.

5. Discussion and Conclusions

Both undergraduate engineering students and preservice teachers showed significant gains in CATME teamwork effectiveness factors throughout the course of the project. Participants reported a significant increase in their own and their peers' abilities to interact with other team members in their interdisciplinary teams, keeping the team on track, the expected quality from the team, and their knowledge, skills, and abilities to accomplish the task. There was no significant difference in team member contributions towards the project between the start and end of the project, suggesting that students were equally engaged throughout. These results suggest that the interdisciplinary collaboration between preservice teachers and engineering students resulted in statistically significant increases in team effectiveness over time suggesting that students experienced a benefit from interacting in teams with others from a different discipline. As part of the CATME data collected, a number of students included qualitative comments that help illustrate some of the benefits they observed as a result of the interdisciplinary partnership. The following quotes from participating students help illustrate some of the observed benefits:

> *"I feel as a team we all bring different important skills to the table. We all have one goal to accomplish." Undergraduate Engineering Student.*

> *"I really enjoyed working with my group on this project. The engineer boys helped a lot since I don't know much about engineering and they were cool to be around and bounce ideas off of." Preservice Teacher.*

The context of this study provided an opportunity for peer learning (Boud et al., 2014) within and across disciplines. The learning occurred through knowledge exchange (e.g., engineering students explained basic engineering or science concepts and PSTs shared approaches to engage student audiences), collaborative problem solving (e.g., groups work together to identify a viable design problem), communication, and teamwork (Hirsch et al., 2001). The interdisciplinary partnership used a scaffolded approach to collaboration that has been validated and successfully implemented in prior research (Pazos & Magpili, 2015; Pazos et al., 2016; Pazos et al., 2019). Students learned through creating and delivering engineering content while receiving periodic feedback and reflecting on and revising their content. A significant gain in teamwork effectiveness was observed through the participation in the interdisciplinary collaboration experience.

With regards to teamwork behaviors, task attraction increased over time between the middle and the end of the project for both undergraduate engineering students and PSTs. Task attraction refers to individual team members' feelings, or affect, about their involvement in the tasks of the group (Loughry & Tosi, 2008). Task commitment assessed the team members' perceived unity in pursuit of the project goals, and the level of shared expectations for good overall performance (Carless & De Paola, 2000). Our results suggest that participating students observed an increase in feelings of enjoyment associated with the task. Their perceived sense of unity in pursuit of the team goals also increased over time, although only marginally. Overall, the study suggests that the interdisciplinary service learning collaboration resulted in more effective teamwork over time for all participating students regardless of the discipline. Tasks assigned to the teams were focused on delivering engineering lessons to an elementary student audience. Although these tasks can appear more relevant to preservice teachers since the deliverable is an actual engineering lesson, we saw a similar rate of increase in teamwork effectiveness from the engineering students. The project was presented to the engineering students as an opportunity to participate in an interdisciplinary service learning project. Interdisciplinary service learning has been shown to benefit student outcomes in a variety of settings (Oakes et al., 2000). This study provides some evidence that undergraduate engineering students benefited from the service learning experience through an increase in their ability to work effectively as part of an interdisciplinary team which is considered a key outcome in undergraduate engineering programs (ABET 2020).

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