Learning Engineering in Teams: Perspectives from Two Different Learning Theories

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***Abstract**: Engineering is a multifaceted profession. Hence, the study of engineering learning can be approached from many directions. This study examines one component of engineering, teaming, from the perspective of two learning theories: social cognitive theory and social constructivist theory. These frameworks guided the data analysis and interpretation. Both of these theories argue that learning occurs in a social context; however, they differ in their focus on factors that support learning. This study compares how these two theories explain engineering learning when students work in collaborative teams. The data consist of semester-long video recorded observations of first-year engineering student teams when they were solving design problems. The results suggest that both theories are critical in explaining student learning when working in teams and can be used as a combined framework for research and to develop effective engineering curriculum and instructional strategies.*

Introduction

John Dewey's short essay, education as engineering, states that the science of learning can advance education through pioneering developments on the ground of schools (1992). In engineering education, many groundbreaking developments are occurring today as engineering educators strive to innovate traditional teaching methods with team-based, project-based, and problem-based strategies. However, educational innovations would not be as meaningful and fruitful if we cannot explain them through the frameworks of learning theories. Just like engineers design tools and methods using scientific laws and principles, as educators we design learning tools and strategies based on learning theories. This paper provides a contextual example of how different learning theories can help guide instructional decisions related to team-based learning in engineering by examining the same set of data from the perspectives of two learning theories.

Theoretical Framework

Bandura's social cognitive theory (Bandura, 2001) and Vygotsky's social constructivist theory (Vygotsky, 1978) have many commonalities as they both define learning as an emergent result of human interactions. A key difference between the two theories is that social cognitive theory is more concerned about the learner's internalization process while social constructivist theory focuses more on the scaffolding the learner receives. According to Bandura, learning occurs as an emergent result of a dynamic relationship between human behavior, environment, and human agent (Bandura, 2001). Along with these interactions, self-beliefs are also influential on learning because self-efficacy beliefs translate perceptions of the environment and individual characteristics into behavior (Bandura, 1997; Pajares, 2007). Self-efficacy is one's beliefs about his/her capability to perform a task and can be improved or diminished as a result of social interactions.

According to Vygotksy, the construction of knowledge is a social process and that learning experiences expand students' abilities beyond what they can do individually. Vygotksy uses the term, zone of proximal development, which he defines as the distance between what a learner can do alone and his or her potential ability when guided by an adult or more capable peers. In a peer discussion setting, discourse and argumentation can provide learning opportunities within students' zone of proximal development and hence support learning.

The historical expansions of the social cognitive and social constructivist theories led to the formation of two different frameworks that had been used to study collaborative learning in the classroom. Bandura's self-efficacy theory, emerged from the social-cognitive theory, states that learning is facilitated when students experience mastery and receive positive and supportive verbal persuasions. In contrast, the scientific argumentation theory, which historically emerged from Vygotksy's social constructivist theory, states that argumentation and challenging ideas foster knowledge construction.

Research Questions

The main goal of this study is to analyze and explain team-learning from two different theoretical perspectives. This paper also provides a contextualized example of how learning theories can help guide instructional decisions. The guiding question is: How does the use of different theoretical frameworks lead to different understandings of student learning?

Methods

This paper uses a three-stage sequential mixed-methods approach (qualitative → quantitative →qualitative). Data are collected in a first-year engineering classroom during a semester using video and audio recordings. The first and second stages involved the coding of student talk and correlation analyses between self-efficacy, achievement, and discourse type (Yasar-Purzer, et.al., 2008). The goal of the third stage was to further investigate and explain what led to the results revealed through the previous stages of the study. The reliability and validity of the instruments and the coding are described in detail in another paper (author, 2008)

Results

Perspective from Social Cognitive Theory

To examine the data from a social cognitive theory perspective, students were given a self-efficacy survey. Their self-efficacy results were then compared with their team interaction characteristics using Pearson correlation analysis. Results from the quantitative data analysis showed a statistically significant positive correlation between the amount of *supportive* comments given and the self-efficacy of the giver ($R= 0.43$, $p<0.05$). There was also a negative correlation between self-efficacy and engagement in *disruptive* behaviors ($R= -0.48$, $p<0.05$). Furthermore, initial self-efficacy was found to be a predictor of *responsive* behavior ($R= 0.46$, $p<0.05$). However, neither being challenged by peers nor receiving negative feedback revealed significant correlations with student self-efficacy. Finally, no significant correlations were found between any of the team interaction behaviors and student achievement. These findings suggest that positive team discourse did not directly impact student achievement; however, the effect of team interactions on individual student achievement was indirectly mediated by self-efficacy.

Following these analyses, three teams with the highest support-oriented, response-oriented, and disruptive discourse were examined in detail. Table 1 shows the normalized self-efficacy gain scores of these three teams. Among these three teams, Team B had the highest gains in self-efficacy while Team A had the lowest gains. Team E also received the lowest cumulative course grade.

Table 1. Descriptive Statistics for Three Teams

Team Name	Team Size	Normalized Self-Efficacy Gain of the Team Mean (SD)	Cumulative Team Grade Mean (SD)
Team B	4	.46 (.26)	88.32 (5.02)
Team E	3	.33 (.16)	82.99 (1.21)
Team A	4	.31 (.22)	87.12 (5.84)

Perspective from Social Constructivist Theory

The qualitative data analysis did not reveal any significant correlations between neither learning-oriented discourse nor challenge-oriented discourse. Based on the social constructivist theory such a correlation would have been expected. One explanation for the results is that students rarely engaged in challenge-oriented discourse requesting data and evidence for explanations. In addition, the learning-oriented discourse included more questions asking for factual or procedural information and less often students would ask questions that involved meaningful learning. To better understand why significant correlations did not exist, I also examined the nature of student discourse.

In the following excerpt, Team B is brainstorming different concepts for their pharmaceutical lozenge design project. The goal of the lozenge project was to design a procedure to improve the molding process for making personalized drugs. Key constraints of the project included FDA (Food and Drug Administration) regulations and therefore the team could not make radical changes to the project. Students were given the tools currently used by the pharmaceutical company (a mold and a blade) and teams used wax as the lozenge material. Two questions the team discussed was how to ensure that each lozenge will have equal amounts of wax and how to easily release the wax lozenge from the mold. During this discussion, Brenda proposed a new idea, cooling the mold. Barb showed disagreement with this concept. However, Bryan's comment, "it is an interesting idea", allowed them to maintain a positive team discussion and accumulate as many alternative as possible during their brainstorming process. This team engaged in both supportive- and challenge-oriented discourse. This balance between the two was managed by their team leader, Bryan. While this excerpt represents an effective brainstorming process, it also shows how supportive discourse can reinforce the positive team environment where fruitful ideas can be produced.

Another team, Team E, showed a discourse pattern that was different than Team B. The following excerpt is from a team discussion when Team E was brainstorming different design concepts for the street crossing problem. Eric's agreements with his team members were short and mostly in the form of "yeah"; however, the fact that his team members frequently sought his approval reflected his decision-making role. While Team E worked very efficiently and engaged in minimal off-task discussions, they did not have a team environment where they made collective decisions. Despite their efficiency and task-orientation, Team E completed the semester with a low mean achievement score of 82.99 which was below the class mean of 87.46 (SD=4.45). This team rarely engaged in challenge-oriented discourse. In addition, learning-oriented discourse mainly involved Eddie and Elvin asking questions about the procedures or requesting the approval or evaluation of Eric on key decisions.

E2: Eddie	Ok. I think. You think we should get going on some design concepts now?
E3: Eric	Sure
E2: Eddie	If we can't think of any more criteria and constraints.
E3: Eric	Yeah
E2: Eddie	To put across
E3: Eric	Yeah.
E1: Elvin	All right so, traffic light
E3: Eric	And then, to improve on that solar power traffic light.
E1: Elvin	Solar… (writing)

E3: Eric	And then just a simple stop light, red light, you stop, no red light you don't.
E1: Elvin	So, solar powered pedestrian?
E3: Eric	Yeah, solar powered pedestrian.

Discussion

The use of both social cognitive and social constructivist theories is essential when studying engineering student team interactions. In Team B, Bryan had a significant influence on the development of a positive team atmosphere. Team B also had arguments and discussions when they had disagreements but they reach a team consensus and made decisions collaboratively. These findings are aligned with Bandura's self-efficacy theory and suggest that learning can be facilitated when students experience mastery and receive positive and supportive verbal persuasions. In Team E, discussions were focused on the task but did not include any significant supportive social interactions. In addition, key decisions were made by one individual without in-depth team discussions. This finding suggests that a complete lack of argumentation can be problematic. Vygotsky's social constructivist theory and other studies on scientific argumentation and collaborative learning support this claim (Kittleson & Southerland, 2004; Oliveria & Sadler, 2008). Students need opportunities to challenge each other's ideas and co-construct knowledge together.

This paper explained team-learning from two different theoretical perspectives. The findings suggest that both social cognitive and social constructivist theories can help explore team learning in the context of engineering. The use of different theoretical frameworks can lead to the development of more effective instructional tools and methods.

Recommendations

This study raised questions in two areas. One relates to the design of teaching tools and strategies that would support learning and motivation when students are working in teams. The other one relates to the study of learning in group settings. Creative research methods are needed to study learning of science and engineering concepts in teams, not just the study of teaming skills. Currently, most of these studies employ qualitative methods with small sample sizes. There is a need for studies with larger sample sizes while maintaining the in-depth perspectives of qualitative methods. One possible approach is studying dyads using mixed-methods approaches. I hope this paper sparks further discussions and ideas on how to study learning that is reinforced through human interactions.

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