Assessing Group Learning Opportunities in a First Semester Calculus Course

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The purpose of this study was to examine how undergraduate calculus students positioned themselves within group work and how that positionality influenced their own and others' learning opportunities. Using qualitative methods, this study examines the specific group social interactions and positionalities that led to productive and unproductive group problem solving. The study used a sociocultural lens to identify productive group work and learning. The findings of this paper suggest the roles students assume are very fluid throughout the problem solving process. In addition, the roles that the students assume influenced the learning opportunities. Furthermore, groups that utilized individualistic group practices were not able to build opportunities for conceptual understanding nor have productive group learning.

Keywords: Calculus I, Collaborative Learning, Positionality

This study adds to the body of research on group work and collaborative learning in the mathematics classroom. Prior research suggests that collaborative learning aids in positive learning outcomes. For example, research suggests that in the mathematics classroom small group learning can increase academic achievement and promote positive attitudes to learning mathematics (Draskovic, Holdrinet, Bulte, Bolhuis, &Van Leeuwe, 2004; Smith, McKenna, & Hines, 2014; Springer, Stanne, & Donovan, 1999). Forbes, Duke and Prosser (2001) found that students perceive group-based instruction as effective as traditional lecture based learning models. A related body of literature examines group compositions and how to promote productive group learning (Cohen, 1994; Dolmans, Wolfhagen, Scherpbier, & Vleuten, 2001; Engle & Conant, 2002; Esmonde, 2009; Haller, Gallgher, Weldon, & Felder, 2000; Johnson & Johnson, 1999; Webb, 1991). Cohen (1994) recommends moving away from the standard academic achievement measures and examining group interactions and group engagement as a means of defining successful group work. Additionally, this body of research suggests that status within groups can cause inequitable interactions and learning discrepancies (Haller et al., 2000). This research is mainly situated in primary and secondary mathematics classrooms with very little research at the undergraduate level and more specifically within the context of a first semester Calculus course. The purpose of this study is to add to this collection of literature a meaningful analysis of how group interactions and positionality impact the learning opportunities and problem solving process.

Theoretical Framework

Two bodies of literature are utilized to build the theoretical framework for this study. The first, sociocultural theory, provides a means for understanding and defining conditions in which learning occurs. The second body of literature is the work on positionality and roles within groups as defined by Cohen (1994), Draskovic et al. (2004), and Esmonde (2009).

Sociocultural Theory and Defining Learning Opportunities

Sociocultural frameworks are rooted in the Vygotskian school of thought where all learning is socially constructed (Goos, 2004). Within this framework all knowledge is constructed through the lens of social interaction institutions (Nasir et al., 2008). Saxe (1999) identifies

cultural activities as integral to understanding cultural changes but also cognitive change. It is in the cognitive change where knowledge is developed through a communicative process engaging and reacting to others. Lastly, learning is facilitated through the use of tools and language available to the student. It is the social interactions in which the individual participates that generates the Zone of Proximal Development (ZPD) (Steele, 2001). Within the ZPD there is an intersection of individual meaning making and social constructs that allows for active engagement in the learning process. ZPD is the space between the individual's current understanding and potential for new understanding. Within this space is where learning and growth occur within the sociocultural framework (Lerman, 2001).

Defining Roles and Positionality

Another body of literature that informs this study examines how group interactions develop, nurture, or impede upon the learning and growth of the individual. How individuals choose to participate and are positioned influences learning (Draskovic et al. 2009; Esmonde, 2009; Webb, 1991). Results have shown some roles aid in productive group work and others hinder the process. One significant role within groups that has been studied is the role of *facilitator* (Cohen, 1994, Esmonde, 2009, Draskovic et al. 2004). Facilitators or tutors direct the path of knowledge and problem solving by providing explanations and rationales to the group. This role is significant for two reasons. First, this role provides a valuable resource to the other group members, aiding in the extension of knowledge and potential for learning of others within the group. Secondly, the individual assuming this role is able to build conceptual understanding through articulating his or her ideas. Esmonde (2009) identified the complementary roles of expert and novice. Experts have significant influence over the direction of the group and provide a source of information and resources. However, contrary to the facilitator role, experts go unquestioned with their authority. This role can cause a problem in instances when experts provide incorrect knowledge to the group. The counterpart to this role is the novice. The novice is the receiver of the knowledge from the expert. This role is counterproductive to aiding in building conceptual knowledge or the problem solving abilities of either role. In Vyogotskian thought, learning is developed through conversation that supports understanding and meaning making. In the roles of expert and novice, the unidirectional communication is directive rather than conversational. Thus, meaning making and conceptual learning is severely restricted when students assume these two roles.

Although many studies have found positive gains through collaborative learning, there are positionalities that impede upon learning in a group context. Dolmans, Wolfhagen, Scherpbier, and van der Vleuten (2001) recognize the impact of *sponging* on the learning of the individual and overall group. Sponging occurs when an individual sits idle with little to no input yet expects to profit from the work of others in the group. Additionally, a dominant personally as described by De Grave, Dolmans, and van der Vleuten (2001) can also impede the overall group interactions and learning. Draskovic et al. (2004) hypothesize that collaborative group problem solving aids in positive knowledge gains when the occurrences of undesired positionalities are mitigated.

The goal of this study is to examine students' positionality as a means of understanding productive group problem solving and learning opportunities. With a dual perspective that learning is constructed through social interactions and developed through internalization of the individual's new constructs with existing constructs, the primary research questions are (1) How does an individuals' positionality in the group influence the group problem solving process? (2) How do the roles that students take influence their learning opportunities?

Methods

The participants of this study were enrolled in a first semester calculus course (Calculus I) at land-grant institution in the Mid-Atlantic region of the United States. Participants in this study were placed in groups based upon student major. This particular grouping method was significant in order to control for the individuals that may be automatically placed in the role of expert by the group due to field-specific knowledge relevant to solving the problem. Group A consisted of four female biology majors. Group B consisted of three males and one female bio-chemistry majors. There was no preference given to gender or prior academic performance in the course in the group construction.

Data Collection and Analyses

This study examined the group interactions in a clinical setting where students were presented the group work within the context of their normal recitation portion of the course. Students were first presented with standard pedagogical methods for introducing optimization problems to first semester calculus students as part of their standard lecture-based instruction. These instructional methods are out of the scope of this study. However, as noted by Crooks and Alibali (2013), the way students encode prior knowledge significantly influences how students perceive and ultimately solve problems. The findings of Llinares and Roig (2008) suggest that students use particular cases in the development of the modeling process. Given a particular case, students will base mathematical decisions from the model constructed. This encoding was addressed by presenting each group with a novel optimization problem related to their intended field of study. Both groups were required to minimize the resistance of blood flow in veins. Minimizing of resistance problems required the participants to have some understanding of the biological concepts to aid in the orientation phase in the problem.

The group problem solving cognitive process was documented through video recording. This structure builds upon the work of De Grave, Boshuizen, and Schmidt (1996) as a way to investigate cognitive and metacognitive processes in a group problem solving setting. Recording the problem solving process without interfering provides an authentic representation of students' conceptualization and problem solving. The recordings were transcribed for analysis.

To understand the group interactions and positionalities the transcripts were coded using the work of Esmonde (2009). The first round of coding identified the group work as collaborative, individualistic, or helping. Collaborative group work was identified as interactions where the group members asked questions, debated ideas, and worked together toward a common goal. Individualistic group work was identified as situations in which the individual group members worked separately and then used each other as a resource for checking and verifying purposes only. Lastly, helping group work involved one or more individuals who instructed other group members. In this case there was no back and forth conversation or questioning of ideas. Rather, helping was clearly a unidirectional flow of information from one individual to another.

The second tier of coding examined the roles each group member held. First, phases of the problem solving process were identified for each group, including the orienting, planning, executing, and checking phases as described by Carlson and Bloom (2005). Within each phase the work of Esmonde (2009) was used to develop provisional categories of facilitator, expert, and novice to describe the positionality of each individual. Through reiterative coding, additional categories were defined of associate and by-stander. These two positionalities were not identified in the work of Esmonde (2009). Associates were fully engaged in the group discussion, however were not considered facilitators as they were not the gatekeepers of information. Associates were individuals that were perceived as equals in knowledge acquisition. By-standers were still

engaged in absorbing information, however these individuals did not provide feedback, questions, or suggestions. Unlike a novice, by-standers were not directly engaged with an expert and appeared when other group members were engaged as associates. By-standers did not provide any meaningful direction to the problem solving.

Preliminary Results and Discussion

The analyses revealed there were two key findings. The first finding suggests that the roles that students hold significantly impact the individual's and the group's learning opportunities. These roles were very fluid throughout the problem solving process. Secondly, the group's work practices influenced the learning opportunities. For example, the group that utilized individualistic group practices did not have the same learning opportunities as the group that utilized more collaborative group practices nor successful completion of the problem.
Phases of the problem solving process become more fluid in a collaborative setting. This allowed the individuals the opportunity to take on various roles throughout the entire process. Figures 1 and 2 show the fluidity of the roles individual group members held. Several of Group B member's phases were individualistic and therefore positionality could not be determined. Thus, a sixth category, individualist, was introduced to describe the positionality of the group.

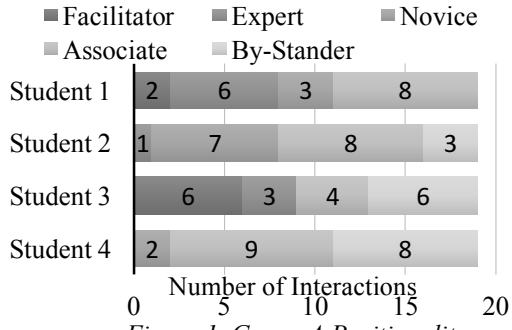

Figure 1. Group A Positionality

Figure 2. Group B Positionality

By examining the positionality of each group member, the expectation is to understand how the positionality of the individual influenced learning opportunities. Results of this analysis indicate that, although the roles of facilitator and expert are critical in successful problem solving, students in those roles do not necessarily benefit from the collaborative work. However, students benefit from the role associate as a means of building conceptual knowledge and mathematical skills. The roles of facilitator and expert can be interpreted as knowledge disseminators. These key roles are distinctive in a way that these students are the knowledge holders. In Vygotskian thought, students in the expert role are not in a position to learn. The only case in which learning would occur would be if there was a contradiction between the meaning held of the student and the interpretation of the other group members. This was not observed due to unquestioned authority of experts. Therefore, only a facilitator who is engaged in conversation with others would have the opportunity for learning. Interestingly, in both groups, even if the content knowledge from the expert was incorrect or the explanation by the facilitator was inappropriate, the other group members failed to recognize the inconsistencies. This may be due to the fact that students in both of these roles where viewed as having stronger mathematical knowledge, leading to these students not being questioned thoroughly or at all. It was only in the role of associate that group members questioned each other and expected full explanations. In these instances, students used the approaches cautiously until either the approach was validated by the instructor or a consensus among the group. Within the sociocultural framework, students

engaged in the associate role found themselves in the ZPD by positioning themselves with the highest potential for learning and growth to occur. Thus, in terms of productive group work, it is suggested that students be encouraged to engage in this equal playing field of questioning ideas and approaches.

The role distribution played a significant function in whether a group could successfully complete the problem. Thirty-eight percent of Group A's interactions were identified as associate role. Contrary to this, only 29 percent of Group B's interactions were identified as associate roles. Furthermore, the problem given restricted the students' ability to model a previous example to solve the problem. There was evidence that both groups used the diagram provided in order to relate to a previous example. However, Group A was able to dismiss the incorrect approach through a continuous back and forth discussion. Group B continuously reverted back to individualistic roles once a strategy was introduced. This led the group to continue down paths that led to incorrect solutions. Group B struggled significantly at orienting themselves to the problem and determining a clear and defined approach to solve the problem. This group relied heavily on the instructor for direction and clarity.

The group work practices also contributed to the groups' ability to complete the problem. Group A never worked in an individualistic manner. All the interactions were either collaborative or helping. This led to more group discussion thereby creating ZPD. In the Vygotskian thought, these dialectic conversations created more learning opportunities for this group. In contrast, Group B spent over a third of the interactions working individually rather than collaboratively. This may be attributed to the group composition. Group A was entirely female whereas the majority of members in Group B were male (three out of four). The findings here support those of Haller et al. (2000) who found women prefer collaborative interactions to competitive interactions. The all female group solely utilized collaborative group practices. The primarily male group not only utilized collaborative work practices less, but the group applied individualistic practices which are more indicative of competitive interactions. Furthermore, this may have significant impacts for the one female in Group B (Student 4). She spent 60 percent of her interactions as either a by-stander or working individually compared to Group A where only 22 percent of interactions were described as by-standers (no individualistic interactions were recorded). This significantly reduced Student 4's group discussion and therefore significantly reducing her learning opportunities.

Conclusion

This study confirms the findings of Draskovic et al. (2004) and Esmonde (2009) where positive group interactions lead to successful learning opportunities in a group context. However, it was found that within the role of associate, where the students provided meaningful back and forth dialog and questioning, that one can find evidence of increased ZPD and learning opportunities. Moreover, individualistic group work can lead to unproductive group work and this may be more prevalent in male dominated groups opposed to female groups. These results of this study suggest that educators should be fostering a strong back and forth dialog amongst students and help initiate those types of interactions. Furthermore, additional research should focus on the gender gap that was observed in the positionality and group practices of the group along with the potential impact on women in male-dominated groups. Lastly, future research may include the student perception of roles and the impact on positionality.

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