The Critical Role of Group Affect in Engineering Design Tasks in High School Biology (Fundamental)

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Abstract

This paper examines how student perception of group affect relates to learning during three small group activities in engineering design in high school biology. Taking into account the “triple problem solving space” in which content, social/relational, and affective components of collaborative work are developed and maintained, we use a mixed methods approach to evaluate connections between various forms of affect and learning during the tasks. Preliminary quantitative findings suggest that minimal levels of psychological safety are correlated with stronger learning outcomes, and qualitative analysis of video data show that groups experience a wide range of emotions during engineering design tasks, not all of which are likely to support learning.

Introduction

Classroom activities using in secondary science have often featured student work in small groups to reduce teacher-centeredness and reliance on prepackaged material and to maximize the autonomy of students (National Research Council, 1996). Yet, there are many challenges to academically productive “group work.” In an overview of the research on small groups and learning in science, Bennett, Hogarth, Lubben, Campbell and Robinson (2010, p. 86) found that published studies reported positive links between small group discussion and subsequent student understanding. Yet, they caution that authors of these studies were often “advocates” of the small group approach. These authors also note “[t]here is a growing body of evidence ... that teachers lack skills and do not feel confident in small group discussion”. (2010, p. 71) At the same time, Johnson and Johnson (2009, p. 375) state that one approach to small group work, cooperative learning, is now “a standard and widespread teaching procedure” across the world and “an educational psychology success story.” Cooperative learning is based on a clear theoretical foundation (social interdependence theory), and their review of the research validates its positive effects on student achievement, interpersonal relationships and on psychological health across subjects, grades and educational settings.

Proponents claim that collaboration within a group leads to shared goals and values and develops collective and individual responsibility, stronger engagement, interest and motivation. Well-structured and managed group work allows students to develop communication skills by defending their work based

on evidence, to learn from other groups, and to engage in problem solving that mirrors future work and life experiences. Asking questions, articulating arguments, using models or analogies to explain concepts, conducting investigations, analyzing and evaluating data, proposing solutions, and creating various ways of communicating results are all aspects of cooperative learning. These processes are also features of both scientific and engineering practices. Small group activities may therefore support learning of such practices.

Yet, many factors influence the ability of small groups to collaborate effectively. Barron (2003) first extended Teasley and Roschelle's (1993) cognitively focused model of small group problem-solving, to encompass a "dual-space" model of collaboration in which groups must attend to and develop the "content space" and the "relational space" (social interactions in the group). More recently, affect has been shown to impact small group interaction in upper-elementary math tasks (Linnenbrink-Garcia, Rogat, & Koskey, 2011). Consequently, Nieswandt, Affolter and McEneaney (2014) argue that academically successful small groups must co-construct the "triple problem-solving space" in which content, social/relational, and affective components are developed and maintained. It is critical to understand how small groups in high school can navigate – and how teachers can support -- the challenges of design problems that are open-ended and often ill-defined, demanding cycles of divergent and convergent thinking, design development, refinement and evaluation (Dym, Agogino, Eris, Frey, & Leifer 2005).

The complex and indeterminate nature of engineering design offers both great potential and challenge for teaching/learning, especially during small group work. Engineering design tasks in particular provide a rich learning context addressing cognitive and affective aspects of learning because they "engage a natural desire to make something and they tap into the curiosity that comes from wanting to learn how things work" (Brophy, Klein, Portsmore, and Rogers, 2008). However, realistic engineering design problems are open-ended and often ill-defined; the first (and often recurring) step for an engineer is to carefully define the problem. Moreover, engineering design is an iterative process, characterized by cycles of divergent and convergent thinking (concept generation and selection), design development, refinement, and evaluation (Dym et al., 2005). Providing students opportunities to iterate - to generate, test, and refine ideas in a cycle of continuous improvement - is essential for optimal design solutions; finding time for such iteration can be challenging in the classroom setting, and students unaccustomed to this process may become frustrated. Frustration can be heightened because although the design task provides an interactive approach to learning, students often need assistance making the connections between the scientific knowledge and the design task at hand (Puntambekar & Kolodner, 2005; Roth, 2001; Crismond, 2001). Moreover, realistic design tasks usually incorporate multiple scientific topics/disciplines (Layton 1993). These features of teaching and learning engineering design in school settings suggest that the optimal small group learning process may vary substantially from that involved in science inquiry group work, and that affect within the group – excitement, frustration, interest, and feelings of psychological safety may play a critical role. This paper, a work-in-progress, explores the role of affect during small group work in high school biology.

Data and Methods

The analysis reported here is part of a larger study comparing collaborative learning processes in engineering design versus scientific inquiry activities in high school biology. For this paper, we report on small groups in 9 introductory high school biology classes (either 9th or 10th grade), all located in public schools in the Northeast of the U.S. The assigned tasks were: oil spill containment and clean up, design a pill coating, and develop a heart valve. All tasks were substantially revised from publicly available lesson plans, such as those available at teachengineering.org to include specific constraints and performance measures, as well as to ensure multiple points of entry, depending on a student's prior knowledge. (Task lesson plans and supporting materials are available upon request.) The tasks were also aligned to the relevant state curriculum standards for high school biology. Quantitative surveys, including measures of group psychological safety, were administered to all participating students (n=185) in a total of 51 groups. The *affective* component of the problem-solving space was measured using Edmondson's (1999) Psychological Safety scale, while controlling for perceptions of the *cognitive dimension*, measured with the Group Interaction Questionnaire (Visschers-Pleijers, Dolmans, Wolfhagen, & van der Vleuten, 2005) and the *social/relational dimension* using Sargent and Sue-Chang's (2001) Social Cohesion scale and the Social Loafing and Positive Group Interaction scales (Linnenbrink-Garcia, et al. 2011). The target group size for all classes was four members, although some groups had only 3 members and several had 5 members, due to total class sizes not divisible by 4, or students transferring out of or into the course. Group membership was therefore stable through the three engineering design tasks that were the subject of this analysis. In each of the classes, two groups were randomly selected to be videorecorded (yielding a total of approximately 140 hours of video), and focus group interviews were also conducted with these video groups, after 1 engineering design task was completed and again after all group tasks were completed at the end of the biology course. Video recordings were summarized using an elaborated running record approach (Rogat and Adams-Wiggins, 2014), while focus group interviews were transcribed fully. Learning outcome data was collected through a mixture of closed-ended and open-ended questions, developed with input from participating teachers that were either included as part of a unit test or asked students to complete as part of a class assignment.

We used a sequential explanatory mixed method design (Creswell & Plano Clark 2011) by analyzing quantitative data on affect and learning outcomes statistically and then conduct thematic analysis (Braun & Clarke 2006) on the video data to understand in more detail what the conditions generating various forms of affect were and how they might influence learning in the small group context.

Results

Preliminary quantitative analysis found that avoidance of extreme negative affect in the group (i.e., mistakes held against you, rejecting others if different, difficult to ask help) is significantly correlated with overall learning and learning about engineering design practices ($r=.35$, $p<.01$; $r=.28$, $p=.029$ respectively). This level of statistical significance did not hold when controlling for social and cognitive dimensions of group work. Moreover, a broader measure of perceived

psychological safety in the group context was not significantly correlated with learning outcomes.

Follow up analysis of the 18 videorecorded groups based on the elaborated running records highlighted a range of affective experiences generated by the engineering design task work. Most video groups elicited intense interest in the task, ranging from momentary triggered interest to prolonged, sustained interest. Moments of shared excitement, particularly during the test and redesign phases, also seemed to kindle and sustain interest. Outside of the moments of prototype testing, when affect tended to be collectively constructed (such as the excitement of a prototype meeting design criteria during a test), often these positive emotions were held only by a subset of group members, typically diffusing along gender lines or prior friendship connections. It should be noted that sometimes the diffusion of affect from one student to other group member(s) occurred immediately, while in other situations there was a delay. Finally, much more so than comparable scientific inquiry tasks, the engineering design tasks often elicited frustration, quite frequently due to the tension between the clear performance standards and the fact that no clues were given about possible solutions. Individual group members sometimes demonstrated frustration when other group members did not listen or rejected suggestions. Motivation in one video group dropped noticeably when a satisfactory solution in the oil spill task was ruled out by the teacher because the group used materials in the classroom that had not been designated as available for the task. Student frustration was palpable for the remainder of the task, and group members spoke at length and with notably negative affect during the focus group interview weeks later. Thus, while the novelty of engaging in engineering design stimulated moments of excitement and interest, it also engendered frustration that sometimes undercut motivation. More detailed analysis is needed to determine whether there are links between qualitative manifestations of affect (psychological safety, interest, excitement, frustration) and quantitative measures of learning for the members of the videorecorded groups, as well as a more in-depth analysis of teacher interventions with the groups that either managed group affect appropriately or failed to channel group-level affect in academically productive ways.

Conclusion

The study highlights the importance of all three dimensions of small group dynamics to support student learning in design-based science, but the affective component, understudied and not emphasized in teacher development, is particularly vital as adolescents engage in complex and open-ended engineering design tasks.

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