Distributing Cognition or How They Don't: An Investigation of Student Collaborative Learning

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Introduction

In recent years, collaborative activity has become more prevalent in both the worlds of work and schooling. In the workplace, its function is generally to ensure that complex problems are solved through the combined application of various types of expertise. Industrial design teams exemplify such a process. In the development of new products, teams composed of engineers, marketers, industrial designers, and financial managers work together to bring a design concept to market. Individuals in such teams apply their particularized expertise to parts of a problem and rely largely on the project manager to make sure that the parts are pulled together in a seamless unified way. This might be thought of as the "divide and conquer" model whereby varied domains of knowledge are brought together for the purpose of complex problem-solving which culminates in the optimization and realization of a new product. This variety of collaboration is appropriate and desirable because when it works it results in the desired goal of innovative product design.

A somewhat different form of collaboration is exemplified by groups of scientists working in laboratories. In Dunbar's [1993] six month study of four molecular biology laboratories, he found that when teams of scientists from diverse backgrounds and worlds of knowledge collaborated, they achieved impressive breakthroughs. Members of these laboratories were able to help one another at crucial times by offering analogies from their domains of expertise. New analogical mappings often forced a struggling colleague to think of a new hypothesis which served as a mechanism for the conceptual change needed at that point to move forward. In this model of workplace collaboration, the integration of differing forms of knowledge and the incremental distribution of expertise across disciplines serves as a powerful mechanism for developing understanding and progressing on hard problems.

These contrasting models of collaboration reflect the differing goals of these two communities of practice. The design team model is indicative of engineering practice where the processes of inquiry and development aim to progressively develop and optimize a product. This is achieved through experimentation, proto-typing and iterative design. The aim of collaboration in such contexts is to give birth to a new product [Schauble, Klopfer, & Raghavan, 1991]. In contrast, scientific research endeavors to identify and understand causal relationships between variables and outcomes. Collaborative activity in such settings aids understanding and the unfolding of new types of knowledge. These differing aims produce contrasting models of collaboration, an engineering model and a science model, yet each is legitimate given the differing community goals and practice.

In schools, collaborative activity has been touted as a way to help students construct knowledge and acquire strategies for coping with complex, ill-structured domains [Brown & Palincsar 1989]. This characterization of student groups as learning organisms assumes the science rather than the engineering model of collaboration. Like the scientists in Dunbar's study, students are thought to scaffold one anothers' cognitive development and learning. This belief is inspired by Vygotskian [1978] and neo-Vygotskian conceptions of learning which assert that cognitive change and development occur when cognitive processes which are initially situated in a social context later become internalized by the individual. Feltovich et al. [1995] suggest some features of group interactions that facilitate the learning of complex material. Specifically, the presence of multiple representations, points of view, and meanings which characterize collaborative negotiations increase the possibility that the group will construct a broader understanding of the problem domain. Students in groups can observe this and learn how to later invoke the multiple perspectives necessary to cope with complex and ill-structured domains of knowledge. And when these domains are approached in this way, more flexible transfer of knowledge to a new domain is possible.

Additionally, these researchers suggest that when " reasonable, defensible, but ostensibly conflicting interpretations" among members become resolved in reaching a higher order synthesis of methods and ideas, students begin to develop an understanding of the complexity found in higher order systems. This appreciation for the value of resolving conflict in moving to a higher level can become, for the individual student, a model for tackling a new domain of knowledge or problem. Both types of interactional features first encountered in the group process are expected to gel into newly gained skills and expertise which become "cognitive residue" [Salomon, Perkins and Globerson 1991] available for coping with other problem domains and learning contexts. For this to happen, however, a science mode of collaboration where expertise and understanding are distributed is presumed to occur.

However, numerous research studies show that not all groups of students who work collaboratively make the kinds of achievement gains predicted by advocates of group learning. Barnes and Todd [1977] in a pioneering study found that for groups to work effectively together, certain types of interactional behaviors, both social and cognitive needed to be present. Corroborating this finding, Cohen and her colleagues found that the amount and kind of task-related interaction directly related to gains on content-referenced tests [Cohen &Intili 1981; Cohen, Lotan & Leechor 1989]. The other factor frequently cited in the literature that affects learning in collaborative groups is the kind of task assigned. Unless the task calls for interdependence among group members such that the members must depend on each other to achieve task completion, there will be relatively little interaction and little likelihood of distributing expertise across groups [Johnson, Johnson & Stanne 1990]. Moreover, controversial as it may be, reward interdependence also figures prominently in the success of a group ([Slavin 1983, 1987]. Slavin and his colleagues devised a model whereby a group score was awarded based on how well each of the individual members had done relative to her past performance. Such an incentive explicitly encouraged the distribution of understanding across the group in order for the team to succeed. These studies all suggest that a science model of collaboration must in some way be scaffolded for students to achieve the kinds of gains often touted as arising from collaborative learning.

In the case studies we describe here, we examine students' use of collaboration in two project-based engineering courses. Our objective was to understand what uses mature students naturally make of collaborative activity when coping with ill-structured problem domains. In both courses, the engineering model of collaboration was evident. Students divided tasks among group members and later "stapled together" individual products with little attention to or concern for integration of knowledge or distribution of expertise among members. Group learning opportunities that should have been afforded were by and large either avoided or ignored. The studies suggest that if the intent of using student collaboration is to afford opportunities for the distribution of expertise and development of cognitive processes, students need help understanding and carrying out the science model of collaboration.

The Case Studies

The Method:

Several sweeping questions drove this preliminary research on naturally occurring student collaboration. What uses do students make of collaborative activity? Do they utilize opportunities to distribute expertise across the group and learn from each other? Are there identifiable instances of a cognitive residue that results from such collaboration that is transferable to another domain or context? To begin to answer these questions, we conducted our research in two phases. Initially, the first author used the ethnographic techniques of participant observation, respondent interview and artifact collection to gather qualitative data in a project-driven mechanical engineering design course. The objective was to experience and then interpret the collaborative experience as the participants on the competing student teams would. To this end, she attended all the classes, took field notes, joined a student design team as a member, took notes on team meetings and undertakings, completed a portion of all assignments, and helped build the team entry for the end of term competition. In addition, she interviewed both her own team and other team members during and at the completion of the course, as well as the professor. The findings reported here are based on interpretations of events she witnessed or participated in as a class and design team member. In the second phase, findings from the first study were used to inform both the development of a student survey instrument and more focused observation of the collaborative process across groups in a course on sustainable engineering. Findings presented here are based on those surveys and classroom observations of students collaborating in groups.

Study #1: Mechanical Engineering 3110: Creative Decisions and Design

The Context:

This is the first design course in the mechanical engineering curriculum. In teams of four to six, students must solve a serious problem which requires them to design and build an engineered solution. One quarter they may need to build an evacuation device, while another quarter a device that will transport and drop sleeping potion in enemy territory. Over the ten weeks of the course, a design specification is transformed from an imperfectly written description of an outcome into a working mechanism that has to perform in a competition. Students experience this movement from ideas to mechanism as a team. They grapple with an ambiguously represented open-ended problem trying to achieve the best possible solution given the constraints they identify within the problem and in real terms. They write about their efforts, they make presentations on their solutions and they build for competition. In this context, the students plan their activities for the quarter, allocate resources (cost, time, and so on), and have a device ready to demonstrate under competition conditions near the quarter's end. The problem is too complex for individual students to build the mechanism alone, so the function of the teams is to ensure that the complex problem-solving required to design and build such mechanisms occurs. If students learn from one another, that is a welcome but not sought after by-product, according to the professor.

The Findings:

What uses do students make of collaborative activity? Students on the researcher's team , as might be expected, adhered to an engineering model of collaboration. Using a divide- and-conquer strategy, the team harnessed the varied types of expertise in the group to design and build a product. At the first team meeting, students identified their particular areas of expertise and strengths as they would pertain to the project ahead. One student had good math skills, another was a tinkerer-builder and another was a good writer. Weekly assignments for which the team was responsible were sliced into tasks to be done individually and assigned to the person with the appropriate skills. Individually members completed their tasks, and, minutes before the class each week, the pieces were assembled in a binder. The mechanism built by the team was undertaken in the same fashion. Each student took responsibility for a subsystem of the whole mechanism. Working independently, each developed a concept for that subsystem which was later incorporated into the whole mechanism. The student in charge of the drive train on the project then assumed responsibility for making sure the subsystems interfaced well with each other. Students did not seek opportunities as a group to use their differing types of expertise to enhance the individual pieces or to consider ways to integrate the pieces into unified wholes. As might be expected, group assignments could be characterized as having a "stapled-together" quality even when the assignment called for an integrated piece. The mechanism did work but the interfacing of the different subsystems was problematic instantiating a certain stapled together quality in the artifact itself.

Do they utilize opportunities to distribute expertise across the group and learn from each other? Rarely did the team create opportunities for exchanging skill sets or distributing expertise across the group. Two events illustrate this. For one assignment, each student had to turn in an abstract of their subsystem. Two members of the team had no idea what an abstract was while a third did. The two struggled alone turning in what they thought it might be and, as might be expected, were wrong. The second missed opportunity occurred when students were developing gearing for the drive train. Given that these students were learning to be engineers, a valuable learning opportunity was lost. The drive train student expert could have explained gearing, a notoriously difficult topic in mechanical engineering, but instead he went off and built the mechanism alone. The others never benefited from his understanding of this area or the possibility of using the construction of the mechanism as an excellent way to understand this concept. Had the group seen both these instances as opportunities to develop understanding or a new skill set, needed expertise possessed by one individual could have been distributed across the group. As it was, the team was focused on product realization not knowledge acquisition or understanding.

Study #2: Sustainable Development and Technology

The Context:

This is a case-based course in sustainable development and technology. Sustainable development and technology are terms for engineering that considers current needs as well as those of future generations.

Students from the schools of chemical engineering, mechanical engineering and civil/environmental engineering enrolled this term. Develop- ment of sustainably engineered solutions requires weighing the qualities of different proposals from a variety of perspectives: ethical, environmental, technological and economical. The course is designed so that students can learn what their own disciplines have to say about the issues as well as recognize other issues that arise and which disciplines can contribute to the solution. Student teams work collaboratively to understand case studies in sustainable technology and develop solutions to the problems presented in these cases. The goal of each case is to expose students to real-world problems while having them draw upon their disciplinary knowledge to collaboratively develop solutions. Group oral presentations and written reports constitute the ways that students instantiate their solutions. Collaborative activity in this course is supposed to help students develop multiple perspectives on cases and to provide opportunities for students to begin to develop understanding in fields of engineering other than their own so that they might better appreciate the conflicts inherent in designing sustainable solutions to engineering problems. So, for the course, the science model was an explicit goal of the collaboration.

Findings:

What uses do students make of collaborative activity? Like the group discussed above, most groups used the divide and conquer approach to solving the problems. Each student worked on a small portion of the problem and wrote a small report. The final reports on the cases consisted of these mini-reports stapled together with no regard for integration of the whole. As a result, the reports often contained contradictory paragraphs suggesting that students never discussed in their groups what each had found. What they learned from each case was limited to their own little portion of the broader and more complex picture that exists in developing sustainable technological solutions.

Do they utilize opportunities to distribute expertise across the group and learn from each other? Again, as we saw with the mechanical engineering design team, opportunities afforded for the distribution of expertise were rarely taken advantage of. As the group tackled the case, the learning issues falling out of the cases were assigned to individual students based on existing expertise. The very technical issues, or what might be terms, the traditional engineering issues, went to the members who knew that domain. In one case, to solve the problem, the team had to estimate what the impact of an industrial accident might be which required calculating the energy balance of a particular chemical reaction. The team gave the learning issues surrounding this task (the technical issues) to the chemical engineers and assigned the more generic learning issues to the others. The problem was that the technical group never communicated about these issues with other members of the group but only provided the results which appeared in the report. The others, consequently, never saw how the calculations were done and seemingly, never came to appreciate the importance of these numbers or the process of achieving them.

Discussion

The findings in these two studies suggest that when mature students engage in collaborative activity, they most naturally adopt an engineering mode that focuses on product development and task completion. In a course where product development is the goal, this is unfortunate but not deadly. It is particularly important to know and take into account, however, in courses like our sustainable technology course. Here the impetus for group work was explicitly to foster the expression of multiple points of view and the distribution of expertise across disciplinary boundaries, a more science-like mode of collaboration. It is also important to take into account in other situations where students are expected to be learning from each other.

There are several explanations for this behavior. The most obvious is that our subjects were engineering students and can naturally be expected to act as engineers. Dividing the problem into subsystems and then getting on with the process of product realization is what they have been trained to do, and this is what they did. Moreover, many of the assignments in the ME 3110 course explicitly supported a "divide and conquer" approach. Students were required to turn in three extensive individual pieces of work on their own subsystem as part of a larger group package. Interface issues were postponed by the pedagogical sequence of assignments until the fifth week, so the need for problem-solving types of interactions was not a regular part of the team process. The individually focused nature of the assignments was not the case, however, in the sustainable technology class. Nevertheless, assignments although assigned to the whole team were executed in a "subsystem like" fashion. Whether there is something in the training of engineers that implicitly cues them to look for and work in ways that support the development of separate but interfaced subsystems is a question raised but not answered by this study.

Another obvious explanation for the lack of distribution of expertise is that these students were often operating under severe time constraints. Many had heavy course loads and little time to meet with group members regularly. Opportunities to really compare and exchange disciplinary perspectives or learning issues were hard to find with busy schedules. Rather than meeting for lengthy interactive session, they often structured the meetings to be short for purposes of interfacing existing documents. Perhaps if class time had been set aside for specific kinds of interactions, greater exchange of expertise might have occurred.

We suspect, however, that less obvious factors were at work here as well. The conventional teacher-directed classroom and the testing that accompanies it assume that learning is an individual process. The students in these two studies who have achieved success in a competitive engineering school have clearly mastered the solo performance demanded in this culture of schooling (Resnick 1987). Virtuosity is what they have been trained for. We cannot, therefore, suddenly expect them to become members of the orchestra, blending their talents with those of others. Undoubtedly learning from groups does occur out of school; however, students seem unable to connect what they learn from their friends in the dorm with the potential for learning from classmates in a course. For the types of learning that Feltovich et al. suggest can occur, students need help in attending to group process as a source for increased understanding and shared learning. Assistance can come from the teacher who facilitates the process, the kinds of tasks assigned to students, and the assessment coming out of those assignments. If the focus in the class shifts from realizing a product to exploiting ways to develop group understanding, the shared cognition that very probably characterizes learning that goes on outside of class might be harnessed for learning in class.

Another possible explanation for shunning the science model of collaboration is that students fail to construct other team members as having expertise that can be distributed. In scientific labs, team members recognize that their colleagues have skills and knowledge to bring to the group. Possibly students do not have this regard for their fellow students and thus fail to use the opportunities for learning that groups afford. In other words, students may be operating with the same deficit model of their peers that their instructors often assume for them-- black boxes wanting to be filled but bringing little of value to that task. It becomes necessary, then, to reveal to students the breath of expertise, variety of relevant experiences, and talents that a group affords and from which they can benefit. Until this happens, collaborating across groups as a means to effect cognitive consequences within individuals needed for complex domains will not be realized.

Conclusion

Collaborative activity across age groups and curriculum is on the rise. This movement away from didactic modes of instruction to more interactive, cooperative modes is long overdue. However, the findings in this preliminary study suggest that for the kinds of cognitive gains touted as coming from group activities to occur, specially designed tasks, new forms of assessment, and skillful teacher facilitation of the process have to occur. Undoubtedly further research with non-engineering students, younger students and professional students is needed to determine whether the preferred collaborative mode found in these studies was group specific. It is the authors' belief, however, that this orientation toward task completion rather than knowledge accrual would be found across groups. If this is found to be the case, to effect the types of situated learning that Vygotsky identified as accruing from social interaction, students very probably need assistance of various kinds in moving away from the engineering mode of collaboration toward a science mode that seeks understanding.

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