Reflections and Evolution of an Interdisciplinary Research Team

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Abstract

How do interdisciplinary research teams get started and then how do they evolve? This is a brief description of one such team and the lessons that team members learned from each other. Specific examples of research projects are provided to illustrate how team members contributed different skills, abilities, and levels of expertise to the joint endeavor. This paper provides a largely narrative description of one interdisciplinary team's lifespan over a five year period. Some lessons learned are described to potentially impact other teams' efforts.

Introduction

How do interdisciplinary research teams get started and then how do they evolve? This is a brief description of one such team and the lessons that team members learned from each other. Specific examples of research projects are provided to illustrate how team members contributed different skills, abilities, and levels of expertise to the joint endeavor. The interdisciplinary team members had their own agendas prior to coalescing into a team, but found the interdisciplinary experience to benefit and to expand these agendas. This is their story.

Team Formation

The authors are members of an interdisciplinary team effort that began during the 2004-2005 academic year at the University of Alabama in Huntsville. At the start of this effort, there were three clear research paths being pursued more or less independently:

- In the College of Engineering, faculty and graduate students in Engineering Management were studying how project teams develop across time [1], [2]. They were conducting observations of students in capstone project development teams, and comparing their observations of team performance to popular models of team development. They were working to create tight observational criteria to test the models.
- In the College of Liberal Arts, a faculty member and graduate students in psychology were studying group processes – entitativity (i.e., the "groupness" of groups) and allocentrism (i.e., the valuing of group membership and processes) [3]. The research psychologist also had expertise in psychometrics (i.e., developing behavioral measurements of abstract constructs, such as "being supportive" and "encouraging participation," and creating measurements to assess the reliability and validity of those measures).
- In the College of Science, faculty members in Computer Science had expertise in conceptual graphs and metrics for evaluating programs [4]. They were using conceptual modeling to support various technical activities, such as software analysis and design [5] [6], database security and analysis, information system development processes [7], software understanding [8] and visualization of healthcare cost factors [9].

These three groups each had their own areas of expertise and an existing publication record, but all recognized limitations inherent in their disciplines that, if overcome, would enable broader research efforts.

At the start, Engineering Management researchers were interested in including colleagues from other disciplines in their endeavor, and invited the research psychologist to work with them on creating observational measurements of team processes. After working together for a while, a subset of this research group decided to focus more specifically on cognitive aspects of team development. They became interested in how mental models of taskwork (technical details of the project/product at hand) and teamwork (how team members behaved in accomplishing the details) affect team processes and performance. They were intrigued by the possibility that the quality of the project outcome/quality depends on the way team members (a) conceptualize the task and its sub-tasks and/or (b) understand group dynamics. They speculated that teams whose members had better shared mental models of the task and group dynamics would be more successful. The goal of the new research initiative was thus (a) to identify the aspects of shared mental models of teamwork and taskwork most essential to success and (b) to find a way to compare team members' models to each other in order to identify areas of agreement, disagreement, or confusion.

The key research questions became:

- How can mental models be elicited from team members in a way that is reliable, valid, flexible for eliciting information from various types of teams, and easy for team members to use?
- Once the mental models are obtained, how can they be compared to each other?
- What types of shared aspects of team mental models are most critical for success?
- What metrics related to mental models are most important to capture?
- How do mental models develop across time in teams and become shared? What variables impact this development?

Given the research questions, the researchers thought it would be ideal if mental model elicitation and comparison could be done in a standardized way. Potentially, mental model comparison could be automated, through the use of a computer software program. At this point in the research project, discussions were started with faculty from the Computer Science department, to ascertain their interest in the project, their expertise with formal models, and their ability to create the desired software tools. Two computer scientists were interested and joined the research team. After another graduate student, interested in both teamwork and software development, became a member of the group, the interdisciplinary research team was complete. Based on the diversity of expertise on the team, the interdisciplinary group was potentially poised to solve the research problems that they posed for themselves.

Incorporating each others' disciplines

In the fall of 2005, the team began to meet on a weekly basis, calling themselves the Mental Models group. First, the engineers, research psychologist, and computer scientists needed to learn each other's lexicon, share information about disciplinary theories and empirical research, and understand each other's areas of expertise. A better understanding developed across time, but the group still found it necessary to educate each other in the language and conceptual grounding basic to their own disciplines. Fortuitously, since their topic of research was on the benefits of shared mental models among team members, such that the researchers willingly took the time to share, explain, discuss, argue about concepts, and deliberate about how to best design research to address their questions. We began to see that we ourselves were a technical project team undergoing the same processes as the teams we proposed to study. Over time, the researchers have developed transactive memory; they knew "who knows what." Moreover, they decided that studying transactive memory (i.e., knowing who has expertise on tasks, knowledge of tools) in teams would complement their research on shared mental models. Transactive memory is especially important in teams that are interdisciplinary or cross-functional. Team members need to know the skills and the knowledge set of their team members, for more optimal functioning.

The computer scientists suggested that a good strategy for comparing mental models to each other would be to use conceptual graphs (CGs). CGs have the advantage of being a mature technology, with a large body of international researchers making progress through a long-standing conference series; they have a formal basis in first-order logic, making it possible to perform automated reasoning and inference; they can be exchanged with other systems through use of an international standard for logic; and they have a graphical display form that helps human understanding, and thereby assists in the validation of the models. Thus, CGs seemed a good option for capturing and comparing mental models, and the researchers benefited from the expertise of the computer scientists in the application of CGs to these research questions.

The team found, however, that creating CGs directly (i.e., drawing them from scratch) is not intuitive for most people. Thus, mental models would need to be elicited using a much simpler or more intuitive method and then converted into CGs for comparison. The team decided to conduct research on whether people can be trained (relatively easily) to generate diagrams that have enough similarity to CGs that a direct translation is possible. The research psychologist designed a study, with significant input from the other team members, to evaluate whether people who didn't know CGs could create CG-like graphs to depict a process (specifically, in this study, how to print a syllabus using WebCT, a course management system).

Undergraduate psychology students were given written descriptions of a process and asked to "graph" it using sticky notes. Different colored sticky notes represented different types of concepts and relations for CG conversion. Students' sticky note graphs were converted to CGs by two undergraduate students who had been trained by one of the computer scientists on the research team. The extent to which the two students' conversions matched each other was assessed to determine inter-rater reliability. The resulting CGs were compared to an "expert" CG that was developed by the researchers. The number of concepts and relations in common with the expert CG were considered to be evidence of students' understanding of (a) the process of printing a syllabus and (b) how to depict the process using the sticky notes. To isolate the effect of participants' differential knowledge of the process, participants completed a quiz about the steps involved in printing a syllabus using WebCT. A regression analysis showed that both knowledge of the process and ability to depict the process using sticky notes influenced the number of concepts and relations in the CGs that had been converted from sticky notes.

Researchers on the interdisciplinary team were all familiar with the procedures of basic experimentation, issues of reliability and validity, and how to analyze the obtained data, but all benefitted from the discussion of options in design and analysis. For each member, however, different issues were salient, and were brought forward to inform the team. Thus, team members "enforced their discipline" while working in an interdisciplinary team and learned from each other. Another advantage of this particular project was that the undergraduate psychology students who translated the sticky note graphs into CGs learned the basic principles of CGs and had the opportunity to work with computer science faculty.

Applying Team Ideas to Education

While working together, the researchers discussed the fact that eliciting and comparing mental models had applications beyond those of teamwork. They concluded that their research on the extent to which students' graphs of a process matched an "expert model" of a process could directly apply to learners' understanding of new information (a natural extension since the researchers all work in a university). That is, an "expert model," in the context of education, is the rubric or criteria that teachers and professors use when grading student responses to homework assignments and exams. The researchers therefore undertook a study focused on how the degree to which students' responses to an essay exam question matched an "expert model" (i.e., grading criteria) predicted grades on the exam question. The exam question that was chosen for the research was for a course in Engineering Management. The team found that different members of the team differentially coded students' responses as matching the expert model. This is not surprising, given that not all members of the research team had expertise in the subject of the question.

The team used this opportunity to further discuss and conceptualize how a more automated process would be ideal for making comparisons between mental models. Two thorny issues raised their heads during this project: level of detail and ontology. These are well-known issues in knowledge acquisition, but it was interesting to find them so clearly evident in our analyses. To illustrate these, an expert model might (theoretically) specify "couch" as an appropriate response, whereas a student response might offer "furniture" (indicating a different level of lexical categorization) or "sofa" (indicating a potential synonym). Discussion ensued amongst the interdisciplinary team members about levels of analysis and potential synonyms, and how to equate, compare or manage them. The team found that understanding patterns of responses was a complex undertaking. They shared and explored divergent ideas and knowledge about metrics and analyses. They have used a variety of analyses in their research: Analysis of Variance, correlations, regression, and cluster analysis, to name a few. They moved forward, they backtracked, they re-examined. Currently, the computer scientists on the research team are working to develop software to that can elicit and compare mental models to each other.

Benefits and Lessons Learned

This interdisciplinary research team evolved over time, to better understand each others' perspectives, to learn from each other, and to contribute unique perspectives and expertise to the research agenda. As with any team, the group had challenges with finding concurrent meeting times and having different times of high workload not related to the research (e.g., teaching, service, personal obligations). The team was fortunate, however, in that the members continue to be interested and invested in the research questions and were understanding and considerate of other members' obligations. In fact, two of the members who were originally graduate students have maintained their membership on the team after obtaining their doctorates; one is co-located with the rest of the team, another has taken a faculty position in another state. The degree of camaraderie on the team, undoubtedly, affected the persistence of the membership on the team.

This particular team had another significant advantage, in that team behavior and performance were our explicit areas of expertise and study. This meant that introspection was not just an exercise but an integral part of what we have been attempting to understand. Teams whose taskwork does not include evaluation of the team's own performance may not be as interested or have enough expertise to analyze their own teamwork.

Beyond the previously discussed advantages of an interdisciplinary team, additional advantages to team members, less directly related to the research content were:

- The research has impacted the faculty members' classroom activities. More of the faculty members are now incorporating teamwork projects into their classes. This is potentially beneficial to students and to industry, as employers of students graduating in engineering or computer science, especially, are increasingly concerned that newly minted graduates have inadequate interpersonal and/or teamwork skills. Thus, students are indirectly benefitting from the research.

- Graduate and undergraduate students were directly exposed to teamwork dynamic issues as they conducted this research, which will benefit them in their future academic experiences or post-graduate employment.
- The interdisciplinary team members also learned about the differential criteria for deeming a research project worthy of publication across disciplines. For example, some disciplines require a larger number of participants before the results of an experiment might be considered valid; other disciplines require a proof of concept to evaluate quality. Some disciplines encourage publishing groundwork for future efforts, whereas other disciplines may be more focused on results.
- The team comprised seven members at its largest. This may seem to be a "small" team in some sense, but in sharing data and documents, there was still significant time spent organizing our information and deciding on a file structure, file sharing software support, etc. This is certainly an issue for any team, but it again reminded us that how we organize our information involves decisions about team goals, team priorities and team roles.
- A non-trivial issue is the differing styles in which research reports/articles are framed or written. These diverge dramatically between disciplines, with some prescribed as being very structured (i.e., psychology) while others are more free-form (e.g., computer science).
- For academics (with typical publication expectations from their institutions), even the "meaning" of different venues for information dissemination varies, with certain professional conferences being the most valued methods of dissemination in computer science and engineering, whereas psychologists consider conference presentations to be much less prestigious and rigorous than the publication of a peer-reviewed journal article.

The interdisciplinary team has written articles [10] and submitted multiple funding proposals, some successful, some not, yet they keep moving forward. A potential threat to such an interdisciplinary team is that it might lack focus, given the myriad of perspectives on the team. Goals need to be evaluated, set, and re-set frequently. Mental models of the taskwork and teamwork, and transactive memories of the team members need to be made explicit. What has made the group described in this article successful and what makes them want to continue working together is that everyone contributes, they change leaders depending on the task at hand, they have fun, they respect each other, and they can resolve issues while maintaining their relationships.

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