The Effect Knowledge Dissemination Structures Play in Increasing Design Efficiency in Small Design Teams

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Abstract – In design projects, decisions made in the latter stages of the process are dependent on previously presented information. When this information is not easily accessible or effectively communicated between team members, inefficiencies and rework are abundant. To mitigate these complications, specific knowledge dissemination structures may be used to facilitate formal communication. Working with three-member teams in a mining engineering senior design course, a graduate student mentor assisted the implementation of two tools: a master spreadsheet used to track essential design variables and an online filebox used to store this spreadsheet and other relevant files. The implementation difficulty and efficiency gained from these tools was anecdotally assessed by personal interviews. The results show that these tools are highly effective in increasing group productivity. The analysis and applicability of these results is discussed along with a plan for extended, quantitative research.

Keywords: small teams; information sharing; mining engineering

INTRODUCTION

In today's engineering classroom, design projects are often assigned to teams, rather than individual students. While many instructors expect fluid teamwork and use peer evaluation as part of assessments, few actually teach students the methods and skills needed to produce effective teams. One area of such deficiency is the implementation of knowledge dissemination structures needed to expedite information sharing among team members. Though students generally understand that their research and design work must be accessible to other teammates, most do not take the time to develop formal means of communication, often relying on simple word-of-mouth or sporadic emails. While informal communication is effective and necessary during certain stages of the design process, these methods do not always allow information to be readily available or tracked.

Conversely, formal communication structures, such as online collaborative programs and databases, provide all group members real-time access to the most up-to-date information and design work. Since many design projects are iterative, future work often depends on variables which continually change as the project is better understood. Formal databases provide a capacity for tracking these changes as the project advances. With real-time data at hand, group members do not question the location or condition of the most contemporary design version. While the role of knowledge dissemination structures is evident in large, organizational design teams, less research has assessed their usefulness in small student teams.

With the aid of a graduate student mentor, three-member teams from a capstone senior design course in mining engineering were encouraged to implement formal knowledge dissemination structures. These tools included a master spreadsheet containing design variables and an online file sharing system used to store the spreadsheet and other essential files. All members were given read and write access to the online system, and after one semester the

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students were asked to evaluate the use of both tools in terms of implementation ease and increased design efficiency.

This paper assesses the utility of these devices in small design groups. First, a review of previous research pertaining to information systems and teamwork efficiency is provided. Next, details of the design course, knowledge structures, and the implementation methods are described. Once explained, current assessment methods and results are analyzed. Finally, limitations and opportunities for future research are considered.

PRIOR RESEARCH IN INFORMATION SHARING

Much research has been conducted in the areas of effective communication, team performance, and information distribution [3] [4] [5]. All data confirms the importance of information sharing in group success, and current areas of emphasis include geographically distributed and virtual teams. Research conducted at IBM shows that when given similar objectives and deadlines, geographically distributed teams will use different communication and hand-off tools than comparably-staffed, co-located teams [4]. The difference between these strategies is the distinction between codified knowledge and personalized knowledge. Distributed teams tend to rely extensively on 'codified' knowledge, utilizing online databases and technology to collaborate, share ideas, and communicate. Alternatively, co-located teams tend to use 'personalized' knowledge. Information is usually shared by face-to-face conversations and real-time meetings. Although each technique is quite distinct in theory, neither is mutually exclusive. Distributed teams may use live chats to exploit the personalized strategy, while co-located teams may utilize technology to employ codified strategies. Results show that when elements of each communication strategy are implemented, the efficiency and quality of the products are similar despite geographic locality [4]. Related to this research, Griffith and Neale address the psychological processes and outcomes associated with knowledge availability, sharing, and storage in purely virtual teams [3].

Other research has addressed the nature of teamwork and social behavior in design groups [2]. One experiment, conducted at a teambuilding workshop, monitored the communication of a three-member team immediately after a design problem had been introduced. The team members all work for the same firm and have nearly equal work experience. From the observations, the researchers were able to develop several conclusion sets, with one focused in the area of information gathering and sharing. The observations show that, generally, information dissemination is not formalized. The group did not take time to organize processes for product research. Simply, one member hesitantly volunteered to look through information, in the same manner that one would volunteer to keep notes or keep track of the time during a meeting. When an interesting point was found in the research, the volunteer would then entice the other group members to look at the article. Formal records were rarely kept, and, as the session continued, many of the original requirements and discussion were simply forgotten, resulting in rework and inefficiencies [2].

Engineering education research has also confirmed the benefits of collaborative tools in design groups. At the University of Oklahoma, researchers have developed a tool known as the Internet Design Studio [6]. This program allows student teams to work collaboratively over the internet in real time in three distinct design stages: House of Quality development, concept selection, and CAD model discussion. The program employs Macromedia Flash Communication tools, which allow group members to present their ideas on their own computer while other group members interact remotely. While the program is undergoing continually development, it has been integrated into graduate level design courses. Preliminary evaluations indicated that the tools assisted the students' degree of formal record keeping and provided an alternative means of conducting design discussions when the groups were geographically distributed [6].

Other engineering education researchers have identified requirements for functional shared workspaces while advocating the use of commercial collaborative design tools, including Microsoft SharePoint [1]. Some of the more significant requirements include access control and role designation, messaging, information storage and exchange, and task management. First, read and write access must be available solely to group members, and each member's role in the group must be well defined both tangibly and virtually. These restrictions will promote appropriate work flow and prevent sabotage. While messaging need not be real-time, some outlet for online group communication must be available, especially when dealing with large, geographically distributed groups. Furthermore, a document repository provides group members availability to the same information, while providing a means of long-term record keeping. At the University of Western Ontario, instructors implemented Microsoft SharePoint as a collaborative workspace tool that meets these requirements. Preliminary evaluation in two undergraduate design courses shows that while students recognize the potential utility of the program, many fail to fully exploit the program's numerous features. Nevertheless, the researchers conclude that the program did significantly enhance group collaboration and recommend such a tool for all team-oriented design projects.

THE SENIOR DESIGN COURSE

At Virginia Tech, seniors in the Department of Mining and Minerals Engineering are required to complete a two-semester capstone senior design course sequence. Working in teams of three or four, students produce a 16 chapter mine feasibility study, completing eight chapters and two presentations each semester. Each chapter corresponds to a distinct element of the mine design process, addressing topics such as: location, data interpolation, geologic modeling, equipment selection, mining plans, mill design, haulage system design, health and safety considerations, mine closure, and economic feasibility. Throughout the semesters, the chapters are completed sequentially, with a new chapter due every one to two weeks.

As a "writing intensive" course, the students are subject to dual assessment. The technical quality of each chapter is evaluated by the official instructor, a professor of mining engineering. Additionally, the written quality, including structure, grammar, style, and visual presentation, is assessed by an expert in technical writing. Each evaluation constitutes half of the final grade. In this structure, students are required to research and design a significant element of the mining process as well as write and edit a legitimate technical report (10 to 15 pages) every week. Also, as the chapters progress, students discover that previous designs need to be edited or amended to accommodate newly discovered constraints or availabilities.

At the conclusion of each semester, students are required to resubmit all chapters, incorporating advice from the mining engineering professor and the technical writing specialist. These final assignments should fully integrate all changes, and present a cohesive, stand-alone document. Typically, the lead time between the final suggestions and the submission date is half a week.

Given the high turnover and short allotted timeframe to complete each chapter, inefficiencies in the design phase directly influence the amount of time available to write and edit the report. Such inefficiencies may include poor task division and knowledge communication among team members. Also, if changes are not adequately tracked, valuable time may be spent searching the text of prior chapters for critical design variables. One example of such a design variable is ore density. In the design reports, ore density is first identified in Chapters 2 and 3, which describe the area geology and borehole exploration studies. However, ore density is used in more than half of the remaining chapters, as it is crucial to equipment selection, mine planning, mill design, mine closure, and haulage system design. If a student is not aware of the ore density, he or she must search the appropriate chapters until it is found. Also, a single typo may produce an error that is carried over several times.

IMPLEMENTATION

To potentially mitigate these design inefficiencies, the use of specific knowledge dissemination structures was implemented during the fall semester of 2009 in the mining engineering senior design course. During that semester, the course consisted of 14 three-person groups, two of which (henceforth labeled groups A and B) volunteered to receive the assistance from a graduate student mentor who had completed the course in the previous year. While the mentor was able to assist the groups in any area deemed necessary, his efforts were primarily focused on enhancing teamwork efficiency and group communication. Directly, he assisted the groups in the development of two knowledge dissemination structures. The first was a master spreadsheet used to track essential design variables. This spreadsheet, developed in a simple *Microsoft Excel* format, used different tabs to organize different variable types. For example, individual tabs may refer to material properties, equipment characteristics, pit dimensions, or costs. As pertinent chapters were completed, additional tabs were added to the document.

The second communication strategy implemented by the groups was an online database used to store project documents. At Virginia Tech, students are given a 30 megabyte filebox free of charge; however, similar devices may be found online for little or no cost. One alternative option is simply a free email account. While the specific method or software is irrelevant, all students must be given read and write access to the online storage system. Using the university provided filebox, both groups were easily able to adjust the settings to allow these preferences while maintaining password protection. Both groups used the filebox to store weekly documents pertaining to the most current chapter as well as the aforementioned master spreadsheet.

Due to the timeframe in coordinating the mentor and mentee groups, neither design team was able to implement the communication structures at the beginning of the semester. Group A employed both the spreadsheet and the filebox shortly after Chapter 2, approximately 3 weeks into the semester. Since Chapters 1 and 2 feature introduction information, rather than rigorous design, the group was able to easily congregate the data needed for the spreadsheet. Conversely, Group B was not able to implement either device until after Chapter 5, approximately 8 weeks into the semester. At this point, several chapters had been oriented in rigorous design. Consequently, Group B realized some difficulty in implementing the devices but still reconciled their potential advantage.

RESULTS AND ANALYSIS

To assess the effectiveness of the knowledge dissemination structures, personal communication and interviews with the two groups were conducted. The interviews focused on two topics: (1) time and difficulty of implementation and (2) efficiencies gained from usage.

TIME AND DIFFICULTY OF IMPLEMENTATION

The two groups using the knowledge dissemination structures were asked to comment on the difficulty and time requirements needed to implement the devices. Both groups indicated that the master spreadsheet entailed a surprising degree of haste, as relatively short timeframes were needed for development and maintenance. Specifically, Group A cited almost no initial work, since they were able to create the spreadsheet early in the design process. Alternatively, Group B claimed that approximately one hour was needed to search the early chapters and design work in order to find the data needed for the spreadsheet. Both groups indicated that weekly updates of the spreadsheet were easily accommodated. Typically, the groups were able to simply copy the summary tabs from their individual design spreadsheets into their master sheet. After minimal culling and formatting, the master was finalized for the week. When questioned about the difficulty of development, both groups suggested that their experience in the file format (*Microsoft Excel*) eased the deployment of the device.

In implementing the online filebox, both groups suggested a slightly heightened degree of difficulty. While the timeframes for development were once again minimal (less than one hour), neither group was extensively familiar with the filebox software. Consequently, assistance from the graduate student mentor was needed to explain the procedures for starting the filebox and allowing password-protected read and write access. Albeit initially unfamiliar to the groups, both indicated that the tool was relatively easy to set-up, after the original advice. Even without the graduate mentor, the groups believed that the online instructions were thorough and possibly sufficient. Additionally, a different or more commercial tool (such as *Microsoft Groove*) may be even easier to employ.

EFFICIENCIES GAINED FROM USAGE

Once implemented, the knowledge dissemination structures provided increased efficiency to both groups. Specifically, the master spreadsheet eliminated the need to manually search previous chapters. Since Group A deployed the spreadsheet early in their project, they did not have any means to compare the manual search to the spreadsheet usage. However, in the interview, they qualitatively justified the spreadsheet usage by citing the presumed inefficiencies of manual look-up. Contrastingly, Group B was able to provide a quantitative comparison between the two methods. The group claimed that prior to spreadsheet implementation, up to half an hour was needed to find critical data in the text of the previous chapters. Once the spreadsheet was in use, this process was reduced to merely a couple minutes. Since the latter parts of the report may require several searches from as many as five to seven prior chapters, the overall quantitative benefit for Group B is evident.

Similarly, both groups claimed significantly increased efficiencies from the online filebox. Prior to implementing this tool, Group A saved all of their files onto an external hard drive that was passed between group members. This method required extensive planning in order to collaborate meeting times, work division, and hand-off strategies.

After deploying the filebox, the group cited a noticed increase in productivity. The degree of preliminary planning was significantly reduced, as group members were free to work on the project in their own time. Additionally, since independent work was possible, edits and corrections were more easily completed.

Group B noted similar increases in productivity after establishing the filebox. Prior to implementation, data files were stored personally by the group member using them. Consequently, members were constantly trying to find the latest version of crucial files and reports. This process frequently required unnecessary communication and lost time, as opposing group members would have different versions of the same file. The search for the latest file versions became increasingly more inefficient as the report progressed. Group B claimed that implementation of the filebox corrected all of these problems as the latest file version was always available online.

ANALYSIS

While the information gathered from the interviews provides a considerably restricted data set, the groups' claims do confirm initial hypotheses: the knowledge dissemination structures are easy to implement and may increase efficiencies in small groups. Albeit not rigorously quantitative, both groups experienced increased productivity after implementation of the knowledge structures. Citing the anecdotal evidence from the groups, the cost-benefit comparison also appears to be extremely favorable, as implementation required nominal effort in all cases. To further promote the usage of these devices, both groups highly recommended that others use a similar process.

In analyzing the devices individually, the information gathered in the interviews suggests that the master spreadsheet is easier to implement but has only limited value without the online filebox. Although the project data may be gathered in one place, the spreadsheet is not effective if it is not openly available to all group members in real-time. Conversely, while more difficult to implement, the filebox imparts a significant degree of value without the spreadsheet. By simply having up-to-date file versions, group members are able to work independently, reducing the time and effort required to organize formal meeting and work sessions. However, as indicated by the groups, the optimal solution utilizes both tools simultaneously.

LIMITATIONS AND FUTURE OPPORTUNITIES

The primary limitations of this research are the restricted sample size and the use of anecdotal information. Since only two groups were used to assess implementation ease and efficiency gain, the results cannot be considered deterministic or universal. Other small groups, working on other design projects, may not experience the same benefits from such a system. Also, the "information" gathered from the interviews should not be confused with rigorously-tested, statistically relevant "data."

These limitations present opportunities for future research. A well-planned, simple research study could produce results to test the true efficiency of the knowledge dissemination structures in small groups. Prior to introducing the tools, a professor in a small-team oriented design course could ask students to track the time spent weekly on various tasks, such as group meetings, independent design, group design, report writing, editing, correcting, etc. The professor should indicate that these statistics will not influence grades but will only be used for research. At a predetermined point in the semester, the professor could then present the tools to the students, even providing a means of online collaboration. Once again, the professor can ask the students to track the time needed to set up these tools and to continue tracking the time in the aforementioned areas. From this time-study data, the professor should be able to determine if efficiencies are gained and if productivity is increased. The accuracy of the study can be increased by repeating the test in multiple courses in multiple years. After compiling data for several years, anomalies, such as a particularly difficult design element or chapter, can be identified and normalized out of the data set. Also, personal interviews and surveys can continue to provide anecdotal evidence from the students' perspective.

While the results of this potential study are expected to show that the knowledge structures help, the ultimate conclusion of this research will quantitatively demonstrate the true cost-benefit ratio of effective, formal communication. Such research will provide a means of teaching beneficial group practices to young engineering students. By presenting tested data, instructors should be able to overcome the cynical attitude most students have toward perceived unnecessary work.

CONCLUSIONS

This paper has presented research pertaining to the effectiveness of information sharing processes in small engineering design teams. Through the assistance of a graduate student mentor, two groups in the senior mining engineering capstone design course were selected to implement two tools to help in team communication and knowledge tracking. These tools included a master spreadsheet which contained essential design variables that are defined, determined, and changed continuously throughout the design project along with an online filebox used to store various group files and documents. Assessment of the groups was conducted by personal interviews, producing anecdotal results. The three most significant conclusions from these interviews include:

- Both devices are highly effective and easy to implement;
- Owing to software familiarity, the master spreadsheet is easier to implement;
- Independently, the online filebox is the more effective tool, as it allows group members to work separately.

Due to the restricted sample size and relaxed, qualitative nature of the investigation, the results are not considered deterministic or universal. Future efforts should utilize a rigorous, quantitative research plan which will produce more accurate and mechanical results. If optimistic, these results may be used to promote teamwork building and formal communication in engineering education.

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