# Team Performance Factors in Distributed Collaborative Software Development

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## Abstract

This paper investigates the interactions of high and low performing distributed student teams using a set of categories to examine their written communication. The teams were involved in a software development project involving two universities located in different countries. This study tracks the progression and changes in the categories coded for each team's communication throughout the project's time line to determine characteristics of high and low performing teams.

## Introduction

Throughout the years, technology has developed such that it allows for effective communication between groups of individuals to be conducted remotely. Groups are usually formed with a common goal or purpose towards which all group members work together. Communication and interaction among group members is both inevitable and necessary if they are to be successful in achieving this goal or the purpose. Studies have shown that a group's performance can be affected by one or more factors. One of these is a group's interaction and behaviour (Mills, 1967). In order to identify team interaction and behaviour in problem solving and in managing and co-ordinating their activities, many studies have developed and used categories to analyse a group's communication (Bales, 1951; Danziger, 1976; Olson, *et al*, 1992). There are many problems that can occur in teamwork that would endanger its success. This is especially true in the area of software development where approximately two-thirds of software projects are late (Teasley, *et al*, 2000). Team success can range from the timely completion of a project in industry to a result of high performance in an educational project. Many studies have looked at different factors, which affect high and low performance in different types of projects (Belbin, 1996; Taplin, *et al*, 1999; Teasley, *et al*, 2000).

The study this paper is concerned with looks into understanding what makes good team building of software and what characterises high and low performance teams in terms of software development in distributed student teams in Computer Science. In order to find cues that would identify factors in software development performance, the study used discourse analysis to examine the communication and interactions produced by each team.

This paper encompasses a part of the study by comparing the interactions of a high performing team with a low performing team using a set of categories to examine the written communication of distributed student teams. The distributed student teams are involved in a software development project that is part of Computer Science courses at two universities.

This study tracks the progression and changes of the categories coded onto each team's communication throughout the project's timeline most especially during key decision periods in the software development cycle. Along with the categorisation coding, the comparison incorporates a team profile developed with information gathered from questionnaires, journals, logs and interviews.

## The Runestone Project

The case study used in this investigation is the Runestone Project. The Runestone Project is a three-year project sponsored by the Swedish Council for Renewal of Undergraduate Education and is an international collaboration between Uppsala University (UU) in Sweden and Grand Valley State

University (GVSU) in Michigan, USA. A pilot study was conducted in 1998, which involved a group of eight student volunteers: four from UU and four from GVSU. The students involved in the pilot study were in their third or fourth year of university studies. Overall, the pilot study was qualified as successful. (Last, *et al*, 2000)

The primary aim for the Runestone Project is to introduce actual 'international experience into undergraduate Computer Science education in a way that has value for all participants' (Daniels, et al, 1998). Students are required to work in groups of 5-6 people. Each group contains members from each university. Students collaborate closely with their foreign counterparts using appropriate technology to communicate solutions to a set task. This remote communication encompasses Runestone's secondary aim that is to 'identify effective support structures for remote international collaboration, encompassing strategies for communication, management and technology use' (Daniels, et al, 1998).

## Runestone project year 2000

One aspect of the course that was changed in the year 2000 was that more frequent deadlines with smaller deliverables were set. It was hoped that this would allow dysfunctional teams to be recognised more quickly and that the process of conflict and co-operation within teams would be resolved in the early stages of the project. The addition of more frequent deadlines added more clarity to what was required from the students.

This investigation will focus on the communication and interactions of the Runestone 2000 teams. Any reference to assessment, data collection, team formation or technology will be related to Runestone 2000.

## Student demographics

The year 2000 Runestone project involved ninety-three students, 47 from UU and 46 from GVSU. There were sixteen teams in total, thirteen teams of six students (three from each university) and three teams of five students in each team. US students were in their third or fourth year of university study and Swedish students were in their third year of university study.

## The task

The task set for the course, called the Brio Project, was to design and implement a distributed, real-time system to navigate a steel ball through a pre-determined path by tilting the surface of the game board in two-dimensions with stepper motors

## University courses

The Runestone Project encompasses the whole of the Brio project which is itself incorporated as part of each university course. In Sweden, the Brio project is a portion of a larger course and in the US, it comprises the entire course. The Brio project was designed to meet the Computer Science University requirements for each course.

A mismatch between the beginning and ending of the two university semesters has meant a compromise of an eight-week duration for the project.

## Team formation and procedures

Local sub-groups of two or three students were formed with the advice of the local instructors who had previous knowledge of some of the students' backgrounds. The aim was to form well-balanced

teams. Half of the local sub-groups in each university chose a team leader. Sub-groups with team leaders were arbitrarily matched with foreign sub-groups that did not have a team leader. This then formed international teams with half the team leaders in each of the universities.

Presentations were required at the completion of each set milestone. Team members were required to take turns leading a presentation. All team members had to present at least once. Normally, the student who presented was also the student who had the main responsibility for the task that was being presented.

All team members were required to take on the role of developers. The role of leader was clearly defined as an extended role where the person taking on that role would need to co-ordinate work as it progressed while still contributing work as a developer.

## Technology used for collaboration

Students were required to have weekly meetings and encouraged to keep regular contact with their instructors and other team members, both local and remote. For regular team meetings, students used Internet Relay Chat (IRC). Other types of correspondence with instructors or either local or remote team members were carried out via email. Web pages were used initially for introductions and to share personal information. They were later used to publish and make project documents available to the rest of the team.

In general, communication was mostly email correspondence however, they were kept short and to the point. IRC correspondence was much lengthier and seems to have provided a venue for discussion and interaction. Web pages were used more for sharing information that did not require an immediate response.

## Data collected

The Runestone Project has generated a great deal of interest for researchers and faculty members in both the process and the product. Data was collected in a variety of forms and was carried out throughout the project. Data collection covered all types of interaction between team members except for informal face-to-face meetings. The collection of data included background questionnaires, project logs, journals, student email and IRC archives, web pages, peer evaluation and instructor interviews. The students were made aware that the information was not shared with the course instructors, therefore allowing the students freedom for expression without any repercussions.

## High and low performing teams

As this is a work in progress, the communication of only two teams (high and low performing) has been investigated in this paper. For this study, ranking all the teams according to their team average mark identifies team performance. The top 25% were considered high performing and the low 25% were considered low performing. The high performing team discussed in this paper will be identified as Team A (one of the top 25% in ranking) and the low performing team will be identified as Team B (one of the low 25% in ranking).

## Team profiles

Team A (high performing) was composed of 6 students (5 males and 1 female) - 3 from the US and 3 from Sweden. Team B (low performing) comprised of 5 students (3males and 2 females) - 3 from Sweden and 2 from the US.

The age range for Team A was between 21 and 29. Four of the students in Team B had an age range of 21 and 29 and one student was older than 40. Major grade point averages (GPA on a 4.0 scale) are only available for the US students. The GPA for students in Team A ranged from 3.3 to 3.9 and for

students in Team B ranged from 3.1 to 3.7. Each student was given an individual mark for the course. All final marks for the course are given using the US alphabetical grading scale of A+ (highest) to F (lowest). Team A's marks ranged from A+ to B- whereas Team B's marks ranged from B to D+.

## Method

The overall study encompasses the team communication (Email and IRC). Using discourse analysis, which focuses on the ways people construct individual versions of events through their conversation (Coolican, 1999), a set of categories has previously been developed and tested. The team's communication is coded by giving phrases relevant categories. The phrases along with the categories are electronically logged. Analysis of the frequency of categories against time is carried out and a comparison can be made of the two team's frequency of categories throughout the project timeline. Along with the categorisation coding, the comparison incorporates a team profile developed with information gathered from questionnaires, journals, logs and interviews.

## Category framework

Using data driven analysis initially, it was recognised that the data could be organised into specific categories, which would help in the identification of both the software and group development processes, and in the classification of interaction types.

The top category levels were identified while examining the correspondence created by the students in emails and IRC. Twelve categories were used to classify the content of the communication of the two teams. The top-level categories are shown in Table 1 below.

| | |
|---|---|
| C1 - Planning Work | C7 - Humour |
| C2 - Planning Admin | C8 - Graphical Expressions |
| C3 - Decisions | C9 - Ideas |
| C4 - Roles | C10 - Identification |
| C5 - Conflict | C11 - Task/Work Specific |
| C6 - Social/Get to know | C12 - Goals |

*Table 1 - Top Level Categories*

It was recognised that a finer granularity of categories was necessary and sub-categories were developed. For example, a particular phrase was given the general category of planning work (C1). However, aspects of the phrase showed that it could be identifying tasks or requesting update of work or a number of other actions. As the categories and sub-categories were being developed, a meaning and example was added to each sub-category to enable the same interpretation. Disputes about the interpretation or understanding of the meanings were discussed between the researcher and an independent coder until a satisfactory meaning was reached.

## Coding process

The coding process began by identifying phrases in the individual team emails and IRC communications. These phrases were classified under one or more sub-categories. Although sub-categories were assigned to individual phrases, it was recognised that the phrases were context dependent. Otherwise they would have been meaningless and would not have matched the assigned categories. Once a piece of communication was coded, it was logged electronically so that analysis could be more easily conducted.

## Preliminary findings

Both the volume and content of each team's communication were analysed. Team A produced 93 emails which made up 12% of the lines of coded phrases and 68 IRC which produced 88% of the lines of coded phrases. Team B produced 115 emails that contained 35% of the lines of coded phrases and 4 IRC with 65% of lines of coded phrases. It was interesting to see that there is a higher ratio of IRC vs. Email usage in Team A's communication than in Team B's communication. This finding seems significant enough that further investigation with other teams may identify the amount of communication in each medium as a factor in a team's performance.

A comparison of the overall frequency of categories between Team A and Team B was done in order to see if there was any significant difference in the occurrence of any particular category (i.e. the amount of social interaction - C6 between the teams) (Hause, *et al*, 2001). As figure 1 shows, there was very little difference in the frequency of categories between Team A and Team B for the 12 categories.

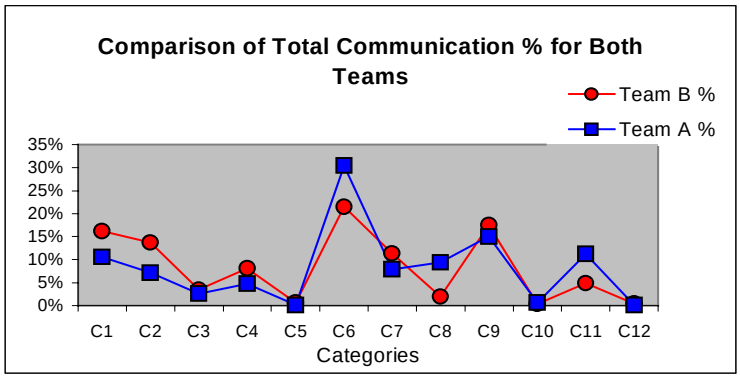


*Figure 1 - Comparison of overall category frequency*

Figure 1 also shows the category of social interaction (C6) as having the highest frequency with more than 20% of the phrases for both teams.

As there was no significant difference in the frequency of categories between the two teams, an investigation was done on the relationship between the categories and the project time line. Because the timing of each individual communication varied for each team, the timing period of 8 weeks (the course duration) was broken up into three specific time periods. Each time period encompasses the communication of each team for that specified duration therefore giving this a clearer comparison. Time Period 1 = First 3 weeks, Period 2 = weeks 4, 5, 6, Period 3 = weeks 7 and 8. These time periods correspond to deadlines for 3 major deliverables. (Hause, et al, 2001).

Figure 2 shows each team's relationship between category 1 (planning work) and the three time periods.

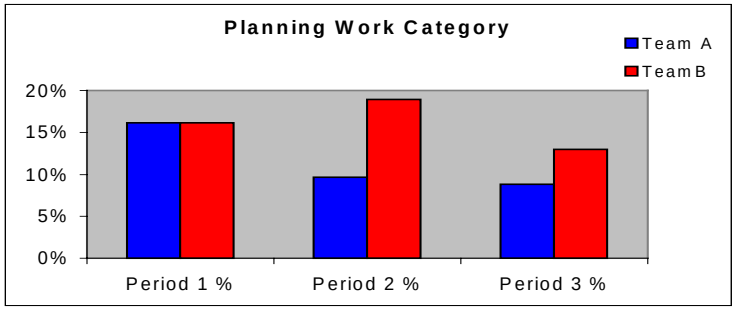


*Figure 2 Planning Work Category*

In Period 1, there is an equal percentage of planning work (C1) communication over all categories for each team. However, Periods 2 & 3 show a clear difference in the percentage of the two teams. Further investigation on the planning work (C1) sub-categories will give a clearer insight into more specific planning actions. However, the significant difference in planning work (C1) interaction for Periods 2 & 3 between both teams indicate the timing of planning has an impact on a team's performance.

Another interesting fact, which became evident, was that the most frequent communicator in Team A contributed 36% of all communication. The next highest communicator was the leader who contributed 19%. In Team B, the highest communicator was the team leader who contributed 38% of all communication with the next highest contribution of 23%.

## Conclusion

As this is a work in progress and further investigation on other high and low performing teams will be conducted, only preliminary conclusions can be drawn.

From the analysis based on the communication (IRC and email) of the two teams studied here, it can be concluded that communication between all team members in collaborative software development is crucial. This can be drawn from the fact that the individual with the highest amount of communication in each team was also the individual who received the highest individual mark in the team.

More importantly, the timing of different types of interaction such as planning work has an impact on a team's performance. The difference in the timing of the planning interaction between the two teams showed that planning work in the early stages of software development is important. Team B's planning work communication in the latter stages of the project showed a lack of direction. This was evident by comments such as one that was made by one of Team B's members a few weeks after the project started.

> *I guess I am still slightly confused about this whole class and how everything is supposed to go. Are you all just as confused or am I the only one?* *(Team B member)*

A conclusion that will be cautiously drawn is that the ratio of IRC vs. Email usage has an impact on how the team members communicate and therefore an impact on the team's performance. Although as stated previously, further investigation is required, there was a significant difference between the ratio of IRC vs. Email usage in the two teams. Team A (high performing) had a higher ratio of IRC 88%: Email 12% than Team B (low-performance) with IRC 65%: Email 35%. This seems to show that higher use of IRC for communication has an impact on a team's performance.

The electronic communication used by the distributed teams in this project allowed this study to log, quantify and analyse communications by category and over time. This has provided the researchers an insight into the student's actions and timing of those actions, which enables a more objective way of identifying factors that influence team performance.

## Further work

The work done to date on this project has already shown some interesting results. It is recognised however that it is currently limited because only two teams have been investigated to date. Further work in this study will investigate more teams of both high and low performance.

The investigations on more teams will not only deal with what has been covered in this paper but will expand so that not only categories but also sub-categories will be compared against the project time line for all teams.

The impact of Email vs. IRC usage will also be analysed against performance and specific categories. It will be interesting to see if either medium is best used for a specific type of category such as socialising or planning.

This project has proved to be extremely interesting and rich in information. Part of further work will be to keep an open mind on other factors that may become evident in influencing team performance in collaborative software development.

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## References

Bales, R.F. & Strodtbeck, F.L. (1951). Phases in Group Problem-Solving. *Journal of Abnormal and Social Psychology*, 46, 485-495.

Belbin, R.M. (1996). *Management Teams: Why they succeed or fail*. Oxford: Butterworth-Heinemann.

Coolican, H (1999). *Research Methods and Statistics in Psychology*. Second Edition. London:Hodder & Stoughton.

Daniels, M., Petre, M., Almstrum, V., Asplund, L., Bjorkman, C., Erickson, C., Klein, B., Last, M. (1998). RUNESTONE, an International Student Collaboration Project. *In Proceedings of IEEE Frontiers in Education Conference*. Tempe, AZ .

Danziger, K. (1976). *Interpersonal Communication*. Exeter: Pergamon Press Inc.

Hause, M.L., Last, M.Z., Alstrum, V.L. Woodroffe, M.R. "Interaction Factors in Software Development Performance in Distributed Student Groups in Computer Science" to be published in *Proceedings of ITiCSE 01*, Canterbury.

Last, M.Z., Alstrum, V.L., Daniels, M., Erickson, C., Klein, B., An International Student/Faculty Collaboration: The Runestone Project, in *Proceedings of ITiCSE '00*, Helsinki.

Mills, T.M. (1967). The Sociology of Small Groups. New Jersey: Prentice-Hall.

Olson, G.M., Olson, J.S., Carter, M.R., Storrosten, M. (1992). Small Group Design Meetings: An Analysis of Collaboration. *Human-Computer Interaction*, 7, 347-374.

Taplin, M., Yum, J.C.K., Jegede, O., Fan, R.Y.K., Chan, M.S. (1999). Help-seeking Strategies Used by High-Achieving and Low-Achieving Distance Education Students. Pater presented at *13th Annual Conference of the Asian Association of Open Universities*, Beijing.

Teasley, S., Covi, L., Krishnan, M.S., Olson, J.S. (2000). How does radical collocation help a team succeed? *CHI 2000 Proceedings*.