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Collaborative Learning in Software Development Teams

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ABSTRACT

Recently Web 2.0 has emerged as a framework to study collaborative learning. Assessing learning in team projects is one mechanism used to improve teaching methodologies and tool support. Web 2.0 technologies enable automated assessment capabilities, leading to both rapid and incremental feedback. Such feedback can catch problems in time for pedagogic adjustment, to better guide students toward reaching learning objectives. Our courseware, SEREBRO, couples a social, tagging enabled, idea network with a range of modular toolkits, such as wikis, feeds and project management tools into a Web 2.0 environment for collaborating teams. In this paper, we first refine a set of published learning indicators into communication patterns that are facilitated in SEREBRO. We apply these indicators to student software development team discussions regarding their collaborative activities. We show how the refined patterns, captured by SEREBRO's Web 2.0 modules, are catalysts to the learning process involved in software development.

Keywords (Required)

Collaborative learning indicators, Software development teams, Web 2.0

INTRODUCTION

Learning is defined as a process that combines observation, experience and cognition with social factors such as team dynamics and cultural influences to form meaning [1]. Computer Supported Collaborative Learning (CSCL) is a pedagogical paradigm where collaborative learning is mediated through the use of online tools for communication, documentation and/or domain specific task performance [2]. In contrast to prior CSCL studies, a sample of students in an academic setting of software development provides new avenues for research.

The term "Web 2.0" is often tossed about to describe various applications in social media and blogging. More formally, Web 2.0 can be understood as a shift from a static "read-web" [3], involving simple html display and minimal intractability via forms, to a dynamic "read-write-web" [3] that provides a platform for application development, social interaction, and rich user functionality not present in the earlier Web. Web 2.0 tools, such as wikis, social networks and blogs facilitate the study of CSCL in software development environments by capturing communication and task related event data involved in the collaboration process. Another quality that makes Web 2.0 technology amenable to collaborative learning is that analysis tools can be built in or mashed up with existing frameworks to alleviate some of the manual effort associated with collecting and presenting consolidated data.

For the past two years, we have developed and used Web 2.0 courseware, called SEREBRO, for undergraduate software projects classes in the Computer Science Department at the University of Tulsa [4-6]. Recently, SEREBRO has also been used in psychology courses that require team projects. Built on the Django framework, SEREBRO integrates a communication forum, known as an idea network, with project support tools, capturing posts and tool usage events. The tools are built following a modular Web 2.0 architecture which allows SEREBRO to be tailored to best support collaboration given the class objectives. From the student perspective, SEREBRO's Web 2.0 toolset offers collaborative mechanisms to transfer the results of their discussion and feedback into associated work products since teamwork and taskwork are closely coupled. Instructors benefit from the Web 2.0 framework, because analysis tools can be quickly integrated for organizing captured data and assessing input for further study. Though we have studied SEREBRO's use for analyzing performance [6], we have not examined it with respect to CSCL.

Meta-analysis of CSCL research shows it has been applied to a variety of educational domains [3, 7], but only recently has Web 2.0 emerged as a desired framework for deploying CSCL environments. CSCL analysis methods examine content and

system usage logs after a defined session period in terms of collaborative learning indicators and interpret the results of the examination within the given problem context of the users [8]. Multiple learning indicators exist based on a variety of measurement perspectives. When grouped together and analyzed collectively, the presence or absence of certain indicators suggest learning patterns that link team and/or individual learning to standard performance measures, such as grades [9]. Few studies target software development and IT environments; and of those that do, none attempt to form learning indicators based on the post content derived from developing a software product.

In this paper, we examine the SEREBRO courseware as a Web 2.0 CSCL environment for learning assessment. We refine an aggregated set of indicators from collaborative learning research by imposing software development concepts. The results are pattern-based learning indicators that we target for determining if specific learning objectives appear given data taken from student teams required to meet the same milestone goals over the same timeline. We examine the learning indicator patterns and correlate them with SEREBRO metrics [6].

RELATED WORK

Teaching strategies to support collaborative learning have been studied for software development and training. Community of Learners [10] follows the *inquiry learning* cycle where individuals conduct research, share the outcomes with the group, and apply the results to work tasks. Problem-based learning [11] intrinsically motivates the learner to solve real world problems due to the applicability and helpfulness the solutions may provide. When such strategies are implemented in offline project environments, directly assessing individual learning is a difficult task. There is significant variability induced by the nature of self-reporting surveys [12] and/or audit rubrics [13] which are needed to measure productivity and progress towards final product completion using offline milestone requirements. Moving these pedagogic strategies to online environments allows for better capture and assessment of learning activities. CSCL environments eliminate a large portion of self reporting by automatically capturing tracking data [2]. This online data enables a direct examination of group processes, project work products, and team communication which together provide for better learning assessment methods.

Certain performance patterns combined with the connectedness of users in a social network are interpreted as a form of learning. Dettori and Persico [8] apply a research method known as Interaction Analysis to team communication posts. They examine posts from multiple orthogonal learning indicator perspectives, which together define patterns where learning may have occurred. Daradoumis et al. [14] uses social network analysis of individual participation in project groups to define task performance learning indicators. They show that teams with users who performed less system actions, such as create and read on documents, performed worse than teams with users who performed more actions [14]. In addressing yet another measurement challenge, Winne [15] questions if and how self-report measures can be integrated with computer-based learning environment trace data (e.g., tracking the number of tags a person makes), and whether this would paint a clearer picture of self-regulated learning. More detail with respect to these indicators is found in the section titled Indicator Development.

SEREBRO COURSEWARE

SEREBRO was initially developed as part of a pilot study to foster a creative design process among software development team members and to reward those who contribute to the project's creative elements [4]. The core facility for expression and team discussion is an *idea network* that combines idea management with social networking. Because SEREBRO is a Web 2.0 online forum, asynchronous postings, along with email alerts of posts, empower students to work on the project from anywhere and at anytime. Figure 1 shows a sample idea network. Topic discussions begin when someone posts a *brainstorm* node (blue circle). A team member can *agree* (green triangle) with a post to continue the discussion, *disagree* (orange inverted triangle) and add a counter argument, or *comment* (talking bubble) with questions or neutral statements. Multiple brainstorms can be present within a single topic and started by any team member to produce independent trees. Post content appears when a user hovers over a node. Clicking on a node shows the post on the right of Figure 1 and allows the user to respond. At login, each user is presented with an RSS feed of all recent events to which they can directly navigate.

Tabs in the top left of Figure 1 show the position within SEREBRO, e.g. home page (Home), project (Titanium Team), workspace (Forum), development milestone (Challenge 1), and discussion topic (Vision and Scope). The last tab, Post View, displays the idea network as a thread with indented child nodes. Tabs on the right hand side toggle posts as meeting minutes from face-to-face communications (Flashback Mode with clock icon) and allow a search of the tagging system (Tag search) for users to semantically link entities within SEREBRO. All users have profiles with contact information and a user icon. The profile also contains current performance status based on SEREBRO's online measures and is publically displayed in each post [6]. In Figure 1, the status information about the person posting, Schmidt, is shown to the left of the post.

Figure 1: SEREBRO 3.0 Idea Network with Post

SEREBRO Score was initially developed using a reinforcement learning analogy to increase creativity by providing rewards [4]. The algorithm currently in use concentrates points on ideas that are well-received by the team and generate further discussion. It propagates points from child to parent, discounting them as the distance from the considered node increases. As reward thresholds are met, badges become publically visible in the user's profile. All posts are captured and include the date/time, topic, tags, and user. Most recently, *SEREBRO Score* has been shown to be a general performance indicator [6]. *SEREBRO Artifacts* captures and counts all created and updated activities associated with a *SEREBRO* module, such as an entry in the associated wiki, a commit to the source control (SVN), a task description entry in the Gantt chart (Tasks), file sharing (Uploaded Files) and a calendar entry for a team meeting (Schedule) that appear in the left hand side menu of Figure 1. The activity capture information includes date/time, activity, module, comments, tags, and user.

Our case study uses data from a milestone early in the software development process of a Web application in Fall 2010. Four teams with a total of 13 students were given two weeks and the same project requirements to produce a predefined set of work products. *SEREBRO* was used for project discussion, file sharing, and developing the wiki for joint documentation. Note that students voluntarily agree to the use and publication of the captured data and its analysis.

INDICATOR DEVELOPMENT

Students involved in software projects are generally tech savvy, independent problem solvers that tend to break down tasks into smaller sets of tasks that can be done concurrently by different members of the team. Communication between team members is usually task directed and knowledge is shared when a team member reports back to the group on the results of their activities or updates the group on their current progress. We use this context for our learning indicator development.

The goal of our study is to examine collaborative learning based on the *participation* and *knowledge creation metaphors* [9]. The *participation metaphor* contains a social context and is assessed in terms of how the community shares and distributes expertise among participants in the community. This metaphor fits directly with our experimental environment. The *knowledge creation metaphor* emphasizes collaborative activities with an interleaving, rather than just sharing, of interactive activities. This metaphor also fits because the students collaborate on the creation of the work products throughout the milestone. We work with two coding schemes from literature, Daradoumis, et al., [14] and Dettori and Persico [8], that are associated with these metaphors to form our indicator patterns.

Both [8, 14] describe high-level indicators with detailed layers defined on which they attribute learning. However, while their top level indicators have similarities, the lower layers are distinct with respect to their problem solving domains and system environments. Daradoumis, et al., [14] focus on defining and assessing indicators for *task performance* and *group functioning* of distance learning teams. Task performance is subdivided to map to activities of creating, reading, and manipulating a shared document. Group functioning examines participation in scheduling group events and organizing the group workspace, e.g. folder management. In *SEREBRO*, these activities are aggregated by the *SEREBRO Artifacts*. The detailed actions in

[14] performed by the group are examined in terms of the proportions of a certain activity over others and the network density of the team interactions as they perform the activities. An activities comparison is made between effective distance learning teams and ineffective teams. For example, effective teams showed more read activities on group created documents overall than ineffective teams did.

Dettori and Persico [8] focus on team discussion to assess the presence of self-regulated learning within the collaborative process. Self-regulated learning is normally assessed through questionnaires and interviews. Given their CSCL environment, Dettori and Persico devise indicators to examine the latent content of posts to represent the intent of these traditional methods for data capture. Their orthogonal approach separates a process model of learning – planning, monitoring, and evaluation – from a component model that examines behavioral, motivational, and social properties. The process model forms the high level indicators and the component model defines the underlying layers of each process. Winne [15] states that self-regulated learning can be viewed as an aptitude and an event. Aptitudes are by definition malleable, and therefore may change over the course of the learning episode, needing to be measured at multiple points in time. In contrast, an action that the learner performs is an event, which can be tallied (i.e., occurrence), described in terms of context (i.e., contingency), or recorded according to common patterns (i.e., patterned contingency). For this type of assessment, SEREBRO captures post content for analysis, while SEREBRO Score serves as a metric for post content acceptance overall by other team members. SEREBRO Artifacts supplies the activities tracking. Henceforth, we refer to them as Score and Artifacts.

Because of the homogeneity among the students and their independent problem solving trait, less explanation of complex topics is needed in the posts to get a point across. Being technology savvy, students have few inhibitions in using the courseware and making it work for them. Their busy schedules force online meetings. Thus, their discussion is tightly coupled to the project. Since the Web 2.0 framework couples discourse (teamwork) with work product tools (taskwork), students transfer problem solutions to activities, while documenting activities through tagging or commenting. Thus, communication, research, coding, and documentation are required for milestone completion. In addition, working as a team is heavily stressed as part of the class goals. Therefore, sharing individually acquired knowledge, gained during completion of these tasks, with the team is a key factor in successful collaboration.

Two kinds of knowledge sharing (KS) are part of the learning paradigm [16]. Tacit knowledge – “knowing how” – is personal and context specific. Its appearance is usually based on prior application or experience. Explicit knowledge – “knowing what” – is declarative and can be directly described or interpreted. In a CSCL environment, students express both tacit knowledge gained through their work related experiences and explicit fact-based knowledge gained through research. Both types of idea sharing can lead to knowledge being transferred to teammates, which eventually becomes part of their tacit or explicit knowledge, denoting learning. Both knowledge related behaviors are found in the discourse among student software developers, indicating the extent to which collaborative learning is occurring [17].

Figure 2 shows our structure of high-level learning indicators with lower level values which we assign to posts in a tuple format. The first category, *Knowledge Sharing*, is partitioned into Tacit and Explicit knowledge. The *Task Directed* category combines and refines concepts from [8] and [14] with Planning related to scheduling tasks and understanding goals, Action being a stated activity toward project completion, and Monitoring evaluating discussion, team progress, and opinion requests. The *Target* category identifies explicit references to a person or group to perform some activity, examine something, or to provide ‘kudos’. This category reflects the self-regulated aspect of the indicators in [8] and the direct transfer of information. The final category, *Emotion*, includes positive, negative, and conflicted values expressed within the post. The component model in [8] directly influenced the values in this category. For each category, null values are allowed. Overall, the categories provide sufficient coverage for assessing learning in software development related post content.

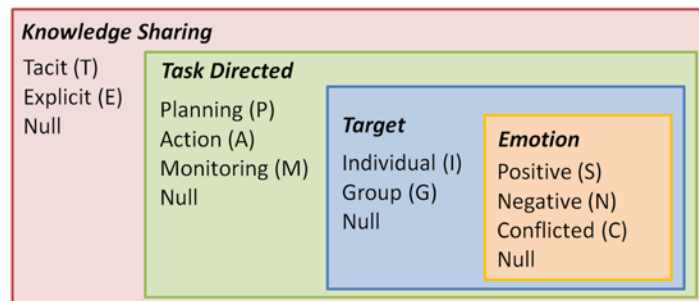


Figure 2: Refined Indicators

Patterns of Interest

Knowing the data collected by SEREBRO for correlation, we discerned specific patterns of interest for the study that also coincide with learning assessment in other CSCL research. Thus, we believe these patterns embed information critical to the software development learning process. Knowledge sharing (KS) embeds the team's rationale for design, documentation, and implementation decisions into posts and therefore we believe the presence of knowledge sharing in the tuples to be the biggest factor in CSCL in the software development context. **Table 1** shows the patterns we examine, their codes, descriptions, and examples. The implication of {X,Y} in the tuple means any one of the values in the union of X Y. The "*" symbol is a wildcard meaning "any" or "don't care". The table states our expectations for each pattern, which we hypothesized before data analysis.

PATTERN	CODE	DESCRIPTION	EXPECTATION
1. (T,*,*,*)	T	Tacit KS embeds experiential knowledge contributing to the project development direction. Ex. "From working on my grandfather's farm, I think crop rotation advice should be included."	Correlates to individual Score through team acceptance of knowledge
2. (E,*,*,*)	E	Explicit KS imparts domain knowledge and delivers facts to support or discourage team approach. Ex. "I examined this website and these features compete with our product."	Correlates to individual Score through team acceptance of knowledge
3. ({T,E}, *,*,*)	TE	General KS - Presents either form of KS.	Correlates to individual Score
4. ({T,E},M,*,*)	TEM	Active KS loosely corresponds to [8] Monitoring qualities for evaluating progress combining shared knowledge with asking opinions. Ex. "Here's how I think the problem should be solved. ... But I'm missing the user perspective if anyone can help out with this."	Correlates with both Score and Artifacts because these students likely drive the learning process, meaning they share knowledge as part of the team discourse and create artifacts towards team goals
5. ({T,E},A,*,*)	TEA	Action Oriented KS is the knowledge transition involved in task completion (action). Ex. "Given our product discussion, I wrote the Value Added section of the Vision document."	Correlates with Artifacts since if this commented action was performed, likely others were too.
6. ({T,E},P,*,*)	TEP	Plan Related KS has students sharing knowledge related to a plan of action. Ex. "Alerting the user to weather changes can help them manage the garden. Who can mash up a weather service?"	Correlates with Artifacts since these students are likely to perform the tasks planned
7. (*,P,I,*)	PL	Individual Planning corresponds to [8] indicator for setting personal goals and deadlines. Ex. "I will try to have the vision document done by tomorrow afternoon."	Correlates with Artifacts since these students are likely to perform the tasks they planned for themselves
8. (*,P, G,*)	PG	Group Planning corresponds to [8] indicator for proposing group goals and scheduling joint plans. Ex. "Do we want to split this up or work on it jointly on SEREBRO?"	No correlation with either Score or Artifacts because students with high levels of this pattern are likely pushing work on someone else
9. (*,M,*,{S,N,C})	MSNC	Emotionally Active corresponds to [8] indicator for expressing appreciation for peer's efforts, contributions and results and spotting group's malfunctioning and analyzing its causes. Ex. "I just looked at it, and it looks great."	Correlates negatively with Artifacts because the student is spending too much time emoting and not enough time working

Table 1: Learning Indicator Patterns

Data Collection

Each post as captured by SEREBRO during the milestone was examined by a subject matter expert and classed according to Figure 2. Posts addressing distinct concepts were patterned at the concept level, rather than the whole post, i.e. each concept

had its own learning indicator tuple. The post in Figure 1 had two tuples emerge: (E,M,I,P) from evaluating a positive start and referencing requirements; and (I,P,G,null) given the questions surrounding ideas and the group planning of expected answers. We totaled the counts for each of the learning indicator patterns (Table 1) for each team member across all posts as shown in Table 2 with Score and Artifacts.

User	Team	TE	T	E	TEM	TEP	TEA	PI	PG	MSNC	Score	Artifacts
1	1	13	12	1	5	1	1	2	2	2	170	17
2	1	7	4	3	3	1	1	0	2	2	159	13
3	1	4	4	0	3	0	0	2	1	1	128	4
4	2	18	13	5	7	2	0	4	3	2	460	6
5	2	10	9	1	2	0	1	0	0	1	414	5
6	2	10	7	3	4	0	0	2	0	1	460	12
7	3	7	7	0	2	1	0	4	3	1	329	4
8	3	18	12	6	8	1	2	8	2	4	538	14
9	3	9	9	0	1	1	0	1	0	0	233	3
10	3	18	15	3	8	2	1	7	2	6	330	30
11	4	11	5	6	5	3	1	3	3	2	321	20
12	4	13	11	2	6	1	1	2	3	4	398	20
13	4	8	5	3	3	0	1	1	1	1	244	15

Table 2: Raw Data Counts

ANALYSIS

We pose three research questions regarding the indicators. The first question concerns the role KS and task-related learning indicators in patterns 1-6 reflecting participation and action.

RQ1: Do KS and task-related learning indicators interact to form meaningful patterns reflective of individual participation or action as measured by SEREBRO?

Score measures individual participation and contribution and *Artifacts* measures action. Our second research question concerns the nature of planning in patterns 7 and 8. We target whether *Individual Planning (PI)* results in more Artifacts than *Group Planning (PG)*.

RQ2: Do self-targeted planning tasks result in more work actions than group-targeted planning?

Our third research question concerns the involvement of emotion, specifically what role emotion plays in artifact creation. We use the same metrics to examine research question three as the previous questions, with particular interest in the Artifacts and pattern 9.

RQ3: Does the use of emotional language result in lower levels of productivity?

In the next sections, we answer RQ1 and RQ2 using Pearson's correlation r . Correlation values were calculated between the learning indicator patterns and Score and Artifacts, respectively. Table 3 shows the average correlation for the milestone data in Table 2. Values highlighted in light blue represent the significant measures for RQ1. For RQ1, we consider a correlation $|r| > 0.44$ to be significant ($df=13$, $p \leq 0.10$) to say a particular learning indicator pattern is reflective of individual participation, when compared to Score, or action, when compared to Artifacts.

Values in orange show the significant measures for RQ2. For RQ2, we consider correlations $|r| > 0.40$ to be significant ($df=13$, $p \leq 0.15$) to say a learning indicator pattern is reflective of individual action, when compared to Artifacts.

The purple highlighted cell is significant to RQ3. For RQ3 we consider a correlation $|r| > 0.44$, specifically $r < -0.44$, to be significant ($df=13$, $p \leq 0.10$) to say the *Emotionally Active (MSNC)* is reflective of poor artifact creation, when compared to Artifacts.

Pattern	TE	T	E	TEM	TEP	TEA	PI	PG	MSNC
Score	0.64	0.48	0.54	0.50	0.13	0.22	0.51	0.11	0.32
Artifacts	0.50	0.36	0.44	0.66	0.45	0.58	0.40	0.36	0.81

Table 3: Correlation Results

Addressing RQ1

Consistent with Table 1 expectations, the *Tacit KS (T)*, *Explicit KS (E)*, and *General KS (TE)* patterns correlated significantly with Score; all r values > 0.44 (blue highlights in Table 3). *General KS* had the highest correlation with Score ($r=0.64$). Since Score measures the participation and content of communication, correlation to this indicator lends support to our hypothesis that KS is an important part of the learning process. Examining KS in the context of task-related learning indicators provides a very different picture that is, with the exception of *Active KS (TEM)*, oriented towards the production of artifacts. The correlation values for *Plan Related KS (TEP)* and *Action Oriented KS (TEA)* show that they do not correlate to Score, but instead correlate well to Artifacts. Consistent with our expectations, this correlation highlights the role of tasks in determining the result of the learning. For planning and actions, KS is a "learn by doing" indicator. The high correlation value of *Active KS* for both metrics reveals that individuals that explicitly monitored activities occurring in the idea network were most involved in generating artifacts and in contributing meaningful knowledge in posts. Overall, these results paint a picture of KS that is modulated by the task type. Coupling the relatively high correlations of values with the 90% confidence interval used in the analysis of RQ1 supports using KS and task-related indicators in concert as specific patterns of learning.

Addressing RQ2

For RQ2 we specifically investigated the planning and target indicators, expecting that *Individual Planning (PI)* posts that target the individual (e.g. "Tomorrow, I will do ...") would correlate to Artifacts. We also hypothesized that *Group Planning (PG)* would not correlate with either Score or Artifacts. Team observations from previous projects classes have shown anecdotally that group targeted planning is often the result of "leaders" who contribute less actions overall. It follows that students with high amounts of *Group Planning* patterns in their posts would have less actions. Both results are supported by our analysis. *Group Planning* showed no statistically significant correlation with either metric while *Individual Planning* was correlated with both. To our surprise, we saw an unexpected dynamic emerge here. *Group Planning* had no correlation to Score while *Individual Planning* showed that students who planned for themselves had more participation and meaningful content (achieving higher Scores) than those that planned but targeted the group. Goal setting is an important self-regulated learning strategy that has been shown to predict individual learning and performance [18]. Our results provide initial evidence to support that setting goals for the entire group (i.e., assigning a goal to others) may not be related to the goal setter's individual performance indicators. Overall for RQ2, we saw that the target of the planning task is critically important to the generation of artifacts, participation and content. Our RQ2 results are predicated on an 85% confidence interval.

Addressing RQ3

For RQ3, we investigated emotion because previous learning research highlighted its importance. Given prior class observations, we expected that higher levels of posts containing emotion would correlate to lower amounts of artifact production, that is we expected $r < -0.44$ for Artifacts in Table 3. For the *Emotionally Active (MSNC)* pattern, not only did we not see the expected result, but the higher levels of monitoring posts containing emotion actually resulted in the single highest correlation to Artifacts. Correlating highly ($r > 0.80$) using the r critical value of 0.64 yields a 99% confidence interval for the correlation between the *Emotionally Active* pattern and Artifacts. This result contradicts our original hypothesis, instead indicating that an emotional connection may be an important aspect of task performance. Though, *Emotionally Active* posts contain more than raw emotion; there appears to be a problem-solving component such that group malfunctioning is analyzed, and feedback is provided to contributing team members on their work. In this way, teamwork facilitates taskwork production. We will explore this in future experiments to assess the generalization of this finding across other data sets including other milestones for Fall 2010 and previous datasets.

DISCUSSION AND CONCLUSION

From our study, SEREBRO offers a Web 2.0 CSCL environment conducive to assessing learning. We developed a refined set of learning indicator patterns to examine learning from multiple distinct perspectives and posed research questions relevant to learning in an undergraduate software projects course. We hypothesized about how the learning indicator patterns would compare to SERBRO metrics that capture the participation, content and contribution of users to their team projects. After testing our research questions using correlation values, we showed how several patterns, primarily KS and task planning, are important to the learning process. Because SEREBRO has been used over the past two academic years and has now been transitioned, for wider use, into psychology classes, additional data will be coded with the patterns to determine if the findings are generalizable to larger, diverse data sets.

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