Effects of Sequences of Socially Regulated Learning on Group Performance

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ABSTRACT
Past research shows that regulative activities (metacognitive or relational) can aid learning and that sequences of cognitive, metacognitive and relational activities affect subsequent cognition. Extending this research, this study examines whether sequences of socially regulated learning differ across low, medium or high performing groups. Scaffolded by a computer avatar, 54 primary school students (working in 18 groups of 3) discussed writing a report about a foreign country for 51,338 turns. Statistical discourse analysis (SDA) of these sequences of talk showed that in high performing groups, high cognition was preceded more often by high cognition and less often by denials or low cognition. In medium performing groups, high cognition was preceded more often by high cognition or planning. As these results indicate that different sequences among students' cognitive, metacognitive and relational activities are linked to levels of performance, they can inform a micro-temporal theory of socially shared regulation.

Categories and Subject Descriptors
K.3 computers and education; K.3.1 Computer Uses in Education; Collaborative learning

General Terms
Measurement, Performance, Design, Reliability, Experimentation, Theory.

Keywords
Metacognition, Temporal Analysis, Collaborative Learning, Scaffolding, Elementary Education, Discourse analysis.

1. INTRODUCTION
Students who orchestrate their individual self-regulation and collective socially shared regulation during group activities often learn more than other students [1]. This socially regulated learning is a dynamic process; group members adjust the level of control and monitoring to the learning context, the learning task, knowledge and skills of the other group members. Yet, there are few studies of socially regulated learning dynamics [2].

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During collaborative learning, students support one another's learning as they discuss, elaborate, argue, confirm and regulate one another's activities. Regulative activities such as metacognitive (i.e., planning, monitoring) and relational activities (i.e., confirming, engaging) aid students' learning [3]. Moreover, sequences among cognitive, metacognitive and relational activities link them to one another [4]. Yet, researchers have not systematically examined the relationships between these sequences of learning activities and group performance. In this study of 54 primary school students (18 triads), we test whether sequences of students' cognitive, metacognitive and relational activities are related to group performance. Our results can help us build a micro-temporal theory of socially regulated learning and inform our instructional practices [5].

2. THEORETICAL FRAMEWORK
We begin by discussing the need for understanding micro-temporal characteristics of socially regulated learning. Then, we consider the transitions between cognitive, metacognitive and relational activities and the relation with learning performance.

2.1 Micro-temporal, socially regulated learning
A micro-temporal theory of socially regulated learning explains how cognition, regulation and motivation interact over time during collaborative learning, specifically how students regulate their learning differently across various situations [1, 5]. Thus, to understand socially regulated learning, we examine learning context, task, support and other group members' attributes, in addition to individual characteristics [6].

Accordingly, we conceptualize socially regulated learning as a series of processes that unfolds over time [5, 7, 8], explicating its sequential and temporal characteristics. The *sequential characteristics* of SocRL reflect which actions typically follow each other; in Molenaar and Chiu [4] for example, confirmation of a group member's idea was more often followed by reading and processing of information, whereas denial of a group member's idea was more often followed by elaboration and questioning. The *temporal characteristics* of these actions indicate when they occur and how they influence each other over time [7]. In Azevedo et al. [9] for example, students planned more at the start than at the end. As most studies of SocRL's temporal and sequential characteristics have been exploratory [2], our next step is to statistically model characteristics that contribute to group performance [3].

2.2 Sequences of cognitive, metacognitive and relational activities and group performance

Sequences of cognitive, metacognitive and relational activities might influence group performance. When students go beyond the information provided to create new ideas, elaborate them, or connect different ideas (*high cognition* [10]), they are more likely than reading or processing information (*low cognition*) to contribute high quality parts to the final group paper. Thus, we expect high performance to be linked more closely to both instances and sequences of higher cognition rather than that of cognition. Furthermore, metacognition (planning, monitoring,) can facilitate subsequent high cognitions and reduce distractions, both of which might improve group performance. Lastly, positive relational activities can encourage desirable activities that enhance group performance, while negative relational activities can have the opposite effect.

Metacognitive activities monitor, control and align other activities to the groups' learning goals [11]. We view planning as an important mediator between low and high cognition, consistent with the positive feedback loop in self-regulated learning theory [12]. The positive feedback loop specifies that control actions, such as planning, initiate cognitive activities in line with the task goals. For example, when the task goal is to compare the climate of two countries, students plan to list characteristics of both countries' climates in a table to discuss similarities and differences. After the group has acquired enough information about the individual climates (low cognition), the controlling activity planning helps the group to compare the two countries (high cognition). When cognition is well aligned with the task goals, this process supports the groups' learning performance. Therefore we expect the sequence planning - high cognition to support group performance.

Finally, relational activities can engage group members or confirm the proposed direction both of which support a positive group climate, which fosters cognition and better group performance [13]. For example, agreement can encourages a group mate to elaborate his or her idea. On the other hand, negative relational activities, such as denial, can discourage consequent high cognition which might hinder group performance [14]. For example, after a disagreement, a student is less likely to continue to elaborate on the previously mentioned topic.

3. THIS STUDY

This study tests whether sequences of socially regulated learning are related to group performance. We expect that instances and sequences of high cognition; planning activities (the positive feedback loop) and monitoring (via the negative feedback loop) support performance.

3.1 Method

54 primary school students (18 triads) engaged in 51.338 face-to-face turns of talk while working in a computer learning environment for 6 hours (see detailed description in Molenaar et al. [3]). Conversations were audio-taped with voice-recorders. We analyzed their learning activities with content analysis and statistical discourse analysis (SDA; [14]).

3.2 Participants

Teachers rated students as low, middle or high achievers based on their reading, writing and computer abilities. Then, they created triads with one low-, one middle- and one high-achiever, with at least one boy and one girl.

As coding all students' turns of talk requires enormous time and labor, we randomly drew a smaller sample of 18 triads (one in each of 3 conditions from each class) for this study. The 23 boys and 31 girls were from six classes in three elementary schools – all in outer city, suburban areas with white, middle-class populations. The students in this sample consisted of 9 fourth graders, 27 fifth graders, and 18 sixth graders.

3.3 Procedure

The teacher gave the triads of students the assignment below and monitored their progress. Each triad worked together face-to-face in small groups on one computer. The study consisted of eight lessons, each lasting one hour. In the first lesson, the students completed a pre-test (about the country to be studied, Cronbach's alpha was 0.88 for the Iceland test and 0.92 for the New Zealand test). Then, they received instructions about the assignment and the virtual environment. In the last lesson, the students completed two post-tests, a metacognitive test and the country knowledge test (same as the pre-test).

During the middle 6 lessons, the triads worked on an assignment called "Would you like to live abroad?" Its goal was to explore a country of choice (New Zealand or Iceland), write a paper on their findings and decide whether to live in this country. Before writing a paper about the selected country, the students completed four sub-tasks: (a) introduce themselves to the expert, (b) write a goal statement, (c) select a country and (d) specify topics of interest in a concept map. In this study's e-learning environment Ontdeknet, each country expert shared information on these topics and answered student questions on a webpage, edited by the Ontdeknet editor [15].

All tasks, including writing of the paper, were integrated into each triad's virtual workspace. The e-learning environment stored all clicks and edits. All lessons were supervised by one of the authors, who did not participate in the lessons.

To control for classroom effects, we randomly assigned triads in each class to one of the three scaffold conditions: (a) none (control), (b) structuring, or (c) problematizing. In a computer environment, scaffolds are messages that support a student on a task that he or she cannot accomplish alone [16]. For students in the structuring scaffold or problematizing scaffold conditions, the computer environment analyzed the students' attention focus, behavior and progress on the task [17]. Using this information, the system dynamically determined when metacognitive activities should occur during each group's discussion and showed at least 12 scaffolds to the students [17]. In the control group, the avatar David occasionally asked how they were feeling, but did not show any metacognitive scaffolds.

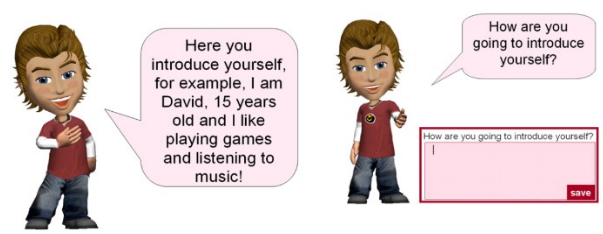

Figure 1. Example of structuring (left) and problematizing (right) scaffolds for the task introduction.

In the structuring condition, triads received direct metacognitive support; for example, the avatar David showed an exemplary plan of a task "The expert would like to know what you want to learn. Please write all the topics about New Zealand that you would like to learn more about in this mind map" (see figure 1). In the problematizing condition, scaffolds elicited students' metacognitive activities and explanations; for example, the avatar David asks, "How are you going to make a mind map?" These students could write their answers in a text box on the screen.

3.4 Analysis

We analyzed the learning activities with content analysis and statistical discourse analysis (SDA, [14]). Content analysis yielded codes for each turn of talk. Then, we used SDA to model how earlier activities and their interactions with group performance were related to high cognition.

3.4.1 Content analysis

The unit of analysis was a speaker's turn of talk. Each turn of talk was coded with one main category code (cognitive, metacognitive, relational, procedural; see table 1 based on Veldhuis-Diermanse, [18]). All categories and their subcategories were mutually exclusive and exhaustive. The first author and a research assistant independently coded two randomly selected protocols (2500 turns), with high inter-rater reliability for the main categories [19] (Cohen's kappa k = 0.92; lowest k = 0.82 for the non-codable category and highest k = 0.94 for the metacognitive activities).

Table 1. Main coding categories for each turn of talk.

Main category	Description
Cognitive activity	About task content (e.g., elaboration)
Summarizing	Recapture previous contributions
Metacognitive activity	Monitor or control cognitive activities
Relational activity	Social interactions among students
Procedural activity	Regarding procedures for using the learning environment
Teacher / Researcher	Turns by the teacher or the researcher.
Off task	Unrelated to the task.
Not codable	Too unclear to interpret

The cognitive activity category contains turns about the task content (e.g., reading the material, asking a question about the domain, discussing the learning task, elaborating specific issues and summarizing previous contributions). Low cognition includes reading and processing. High cognition includes asking questions and elaborating [10]. As researchers have debated whether summarizing is a cognitive or a metacognitive activity [20], we kept summarizing as a separate category. Metacognitive activity includes turns that monitor or control cognitive activities (orientation, planning, monitoring, evaluation and reflection, [21]). Relational activity includes turns regarding students' social interactions (engaging other group members, denying or conforming to one another's ideas).

3.4.2 Group performance

Each triad's final paper score (ranging from 0 to 6) was the scaled sum of two scores: (a) number of different topics about the country and (b) the percentage of student's formulated text (excluding text provided by the country expert). The latter was computed using Wincopyfind 2.6. Two independent researchers counted the number of topics covered in the paper. 28% of the papers were scored by two independent researchers (Cohen's kappa = 0.75). The groups were divided in low, medium and high. Low scoring groups scored below 3 (mean = 1.2), medium scoring groups scored between 3 and 4 points (mean = 3.4) and high scoring groups scored above 4 points (mean = 5.6).

3.4.3 Statistical Discourse Analysis

We modeled students' high cognition with statistical discourse analysis [14].

$$\begin{aligned}\textbf{High\_cognition}_{ijk} = F(&\beta_{000} + f_{0jk} + g_{00k} \\ &+\beta_{00s}\textbf{Performance}_{00k} + \beta_{00t}\textbf{School}_{00k} + \beta_{00u}\textbf{Scaffold}_{00k} \\ &+\beta_{00v}\textbf{Group}_{00k} + \beta_{0wk}\textbf{Student}_{0jk} \\ &+\beta_{xjk}\textbf{Previous\_Speaker}_{(i-1)jk} + \varphi_{xjk}\textbf{Earlier\_Speaker}_{(i-2)jk} \\ &+\beta_{zjk}\textbf{School\_interactions}_{ijk})\end{aligned}$$

The probability of high cognition at turn *i* by student *j* in group *k* is modeled via the Logit or Probit link function (F) of the overall mean β_{000}, and the unexplained student- and group-components f_{0jk} and g_{00k} (*residuals*). Wald tests identify significant effects (likelihood ratio tests are not reliable for multilevel analysis of binary data). An alpha level of .05 was used. To control for false positives, the two-stage linear step-up procedure was used. Non-significant variables were removed. The marginal effect of each variable's total effect (direct plus indirect) was reported as the increase or decrease (+X% or –X%) in the outcome variable.

First, we entered a vector of *s* performance levels: high achieving group and medium achieving group (against the baseline of the low achieving group) (**Performance**).

Next, we entered *t* school variables: grade and school (**School**). Then we added the interactions of the above variables with high achieving group and medium achieving group (**Interaction**).

Then, we applied the procedure for **School** to *u* scaffolding conditions: structuring scaffold and problematizing scaffold (**Scaffold**). Next, we applied these procedures to *v* group variables: group size, ratio of girls, group mean of pretest scores, and group SD of pretest scores (**Group**). Afterwards, we applied these procedures to *w* student variables: age, gender, pretest score, and study country (New Zealand vs. Iceland) (**Student**).

Next, we applied these procedures to previous speaker variables (*vector autoregression*, VAR). More recent actions might have stronger effects [31], so previous speaker variables were added in reverse order, first at lag 1 (previous turn or –1): high cognition (–1), low cognition (–1), summarize (–1), evaluation (–1), deny (–1), monitoring (–1), confirm (–1), planning (–1), reflection (–1), motivation (–1), engage (–1), and orientation (–1) (**Previous_Speaker**). Then, *x* variables at lag 2 were added (**Earlier_Speaker**), and so on until lag 6.

4. RESULTS

4.1 Summary statistics

The 54 students (in 18 groups of 3) spoke for 51,338 turns. 33 students studied New Zealand and 21 students studied Iceland. Students showed low cognition in 25% of the turns and high cognition in only 2% of the turns.

4.2 Explanatory model

About 10% of the differences in likelihood of high cognition occurred across groups, and 90% occurred across turns of talk – differences across students were not significant. All results discussed below focus on differences in group performance and describe first entry into the regression, controlling for all previously included variables.

Group performance, school variables, and attributes of prior conversation turns were all significantly linked to students' high cognition (see Figure 2). High-achieving groups showed 1% more high cognition compared to low- or medium- achieving groups. Meanwhile, medium- or high-achieving groups in school 3 showed slightly more high cognition than those in other schools did (by 1% or 0.01%, respectively). In contrast, low achieving groups in school 3 had 1% less high cognition compared to other schools. Together, group performance and school variables accounted for 31% of the differences in high cognition across groups and 7% of the total variance in high cognition.

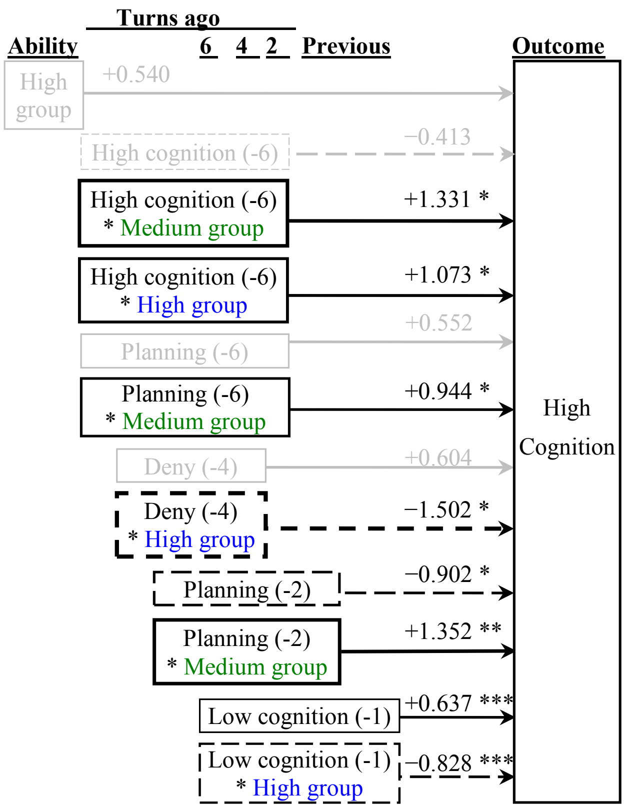

Figure 2. Path diagram of final 3-level model predicting high cognition. Solid lines indicate positive effects. Dashed lines indicate negative effects. Thicker lines indicate larger effect sizes. *p < .05, **p < .01, ***p < .001.

Attributes of the previous turn were also linked to students' high cognition. In low and medium achieving groups, low cognition was 1% more likely to be followed by high cognition. In contrast, low cognition in high achieving groups was 0.01% less likely to be followed by high cognition.

The impact of the characteristics of conversation turns was not limited to only the next conversation turn. After students in low or high achieving groups planned, the speaker two turns later was 1% less likely to express high cognition (Table 3, panel A, model 4). In contrast, after students in medium achieving groups planned the learning process, the speaker two turns later was 1% more likely to express high cognition.

After a student in high achieving groups denied others' ideas, the speaker four turns later was 0.5% less likely to express high cognition.

After a student in medium or high achieving groups expressed a high cognition, the speaker six turns later was 2% or 1% more likely to express high cognition, respectively. Moreover, after a student in a medium achieving group planned, the speaker six turns later was 1% more likely to express high cognition.

5. DISCUSSION

Past research has shown that scaffolding, cognition, metacognition and relational activities can support cognition during collaborative learning and showed statistically significant micro-level relationships among sequences of these activities [3]. However the relationships between these sequences and group performance have not yet been examined. The results of this study showed how low, medium and high performing groups are associated with different sequences among students' cognitive, metacognitive and relational activities. The remainder of this section considers the implications of the primary results, how different sequences of cognition, metacognition, relational activities influence group performance.

High performing groups show greater likelihoods of not only high cognition but sequences of high cognition. As expected, high performing groups were more likely to produce high cognition at each turn of talk, which in turn are more likely to contribute to the completion of the task. Moreover, medium and high performing groups show more sequences of high cognition followed by subsequent high cognition. These results are consistent with past studies showing extensive periods of meaning making in higher performing groups [10, 22].

Unlike other groups, medium performing groups showed planning (-2 and -6) before high cognitive activities (a positive feedback loop). This result suggests that planning facilitates high cognition, which improves performance but not to the highest level. Future research can examine this result further.

Finally, the high performing groups seemed more sensitive to the group climate. After a denial, high cognition was less likely.

Overall, low, medium and high performing groups of students show different sequences of cognitive, metacognitive or relational activities. The findings suggest that high and medium performing groups tend to transfer more flexibly among metacognitive, relational and cognitive activities, compared to low performing groups.

Insights into the relations between sequences of learning activities and group performance form the foundation needed for a micro-temporal theory of socially regulated learning [2, 4]. The results indicate that high cognition and sequences of high cognition support group performance. Also, metacognitive planning supports high cognition. Finally, denial as shown in previous studies can reduce high cognition. These findings show how sequential characteristics of socially regulated learning influence group performance.

This paper takes modest steps towards connecting sequences of socially regulated learning to the group performance. However, several limitations need to be addressed in future work. Currently, only group performance was connected to sequences within the groups' learning activities; a natural next step is to also include individual student performance. This paper is based on extensive and labor intensive coding of collaborative discourse. Developments in the field of learning analytics and big data might allow for less labor-intensive measures to collect future data, such as trace analysis based on students interaction with the computer based learning environments.

6. ACKNOWLEDGMENTS

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7. REFERENCES

[1] Schoor, C. & Bannert, M. 2012. Exploring Regulatory Processes during a Computer-Supported Collaborative Learning Task Using Process Mining. *Computers in Human Behavior. 28(4)*, 1321-1331.

[2] Molenaar, I. & Järvelä, S. 2014. Sequential and Temporal Characteristics of Self and Social regulated Learning. *Metacognition and Learning*, Vol 9, p. 75-85

[3] Molenaar, I., Chiu, M. M., Sleegers, P. J.C. & van Boxtel, C.A.M. 2011. Scaffolding of Small Groups' Metacognitive Activities with an Avatar. *International Journal of Computer Supported Collaborative Learning,* vol 6(4), 601 - 624

[4] Molenaar, I., & Chiu, M.M. 2014. Dissecting sequences of regulation and cognition. *Metacognition and learning,* Vol 9, p. 137-160.

[5] Greene, J. A., & Azevedo, R. 2007. A theoretical review of Winne and Hadwin's model of self-regulated learning. *Review of Educational Research*, 77(3), 334–372.

[6] Malmberg, J., Järvelä, S. & Kirchner, P. 2014. Elementary school students' strategic learning: does task-type matter? *Metacognition and learning*, Vol 9,

[7] Reimann, P. 2009. Time is precious. *International Journal of Computer-supported Collaborative Learning, 3*, 239-257.

[8] Winne, P.H. 2010. Improving measurements of self-regulated learning. *Educational psychologist, 45*, 267 – 276.

[9] Azevedo, R., Moos, C.D., Johnson, A.M. & Chauncey, A.D. 2010. Measuring Cognitive and Metacognitive Regulatory Processes During Hypermedia Learning: Issues and Challenges. *Educational psychologist, 45*, 210 – 223

[10] Volet, S. & Järvelä, S. 2001 (Eds.). Motivation in learning contexts. London: Pergamon/Elsevier.

[11] liskala, T., Vauras, M., & Lehtinen, E. 2004. Socially-shared metacognition in peer learning? *Hellenic Journal of Psychology*, 1(2), 147-178.

[12] Winne, P. H., & Hadwin, A. F. 2010. *Self-regulated learning and socio-cognitive theory*. In B. McGaw, E. Baker, & P. Peterson (Eds.), *International Encyclopedia of Education* (3rd Edition). New York.

[13] Janssen, J., Erkens, G., Kirschner, P., & Kanselaar, G. 2010. Task-related and social regulation during online collaborative learning. *Metacognition and Learning*, 1-19.

[14] Chiu, M. M. 2008. Flowing toward correct contributions during groups' mathematics problem solving. *Journal of the Learning Sciences, 17* (3), 415 - 463.

[15] Molenaar, I. 2003. Exploration-net: Online collaboration. In D. Lassner & C. McNaught (Eds.), Proceedings of World Conference on Educational Multimedia, Hypermedia and Telecommunications 2003 (pp. 398-400). Chesapeake, VA: AACE.

[16] Wood, D., Bruner, J., & Ross, G. 1976. The role of tutoring in problem solving. *Journal of child psychology and psychiatry, 17*, 89-100.

[17] Molenaar, I., & Roda, C. 2008. Attention Management for Dynamic and Adaptive Scaffolding. *Pragmatics & Cognition, 16*(2), 224-271.

[18] Veldhuis-Diermanse, A. E. 2002. CSCL-Learning? Participation, learning activities and knowledge construction in computer-supported collaborative learning in higher education. University of Wageningen.

[19] Fleiss, J. 1981. *Statistical itletlzods for Rates and Proportions*. New York: John Wiley and Sons.

[20] Veenman, M. V. J., Kok, R., & Blote, A. W. 2005. The relation between intellectual and metacognitive skills in early adolescence. *Instructional Science, 33*(3), 193-211.

[21] Meijer, J., Veenman, M. V., & van Hout-Wolters, B. H. 2006. Metacognitive Activities in Text-Studying and Problem-Solving: Development of a Taxonomy. *Educational Research and Evaluation, 12*(3), 209-237.

[22] Van Boxtel, C. 2004. Studying peer interaction from three perspectives. In *Dialogic learning* (pp. 125-143). Springer Netherlands