Process and Output: Relation Between Transactivity, Temporal Synchronicity, and Quality of Group Work During CSCL

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Abstract: Do the simultaneous alignment of student activities (temporal synchronicity) and students successively building on each other's reasoning (transactivity) predict the quality of collaborative learning products? A mixed method approach was used to study 74 first year university students who were randomly assigned to work in dyads on an ill-defined problem of biodiversity collapse in tropical forests within a CSCL setting. The study results revealed that neither temporal synchronicity nor transactivity correlated with the quality of group products. The qualitative analysis of chat transcripts showed the variability between the groups can be explained by group dynamics, students' prior knowledge, confidence in managing the learning task, collaborative strategy, and communication skills.

Introduction

Recent advances in the Computer-Supported Collaborative Learning (CSCL) literature indicate that the efficacy of collaborative learning effort is thought to be influenced by the extent to which students can ensure the consistency of the joint work product by temporally synchronizing their collaborative activities (Erkens, Jaspers, Prangsma, & Kanselaar, 2005), and by transacting on each other's ideas (Stahl, 2013). Building on previous research, this study investigates whether these two properties could predict the quality of group products.

Synchronizing collaborative activities across time and appropriate distributions of efforts and resources are of critical importance to the group's performance (Erkens, Jaspers, Prangsma, & Kanselaar, 2005; Rummel & Spada, 2005). According to Baker (2002), "the degree of alignment refers to the extent to which participants are 'in phase' with respect to different aspects of the problem-solving activity, that is, to what extent they are genuinely working together" (cited from Arvaja, Häkkinen, & Kankaanranta, 2008, p. 268). Collaborative problem solving is non-aligned or non-synchronized when, for instance, one partner focuses on individual achievement over collective teamwork or there is no mutual agreement on a chronological order of activities. Failure to maintain continuous attention and reflection on one's own understanding as well as fellow group members can negatively affect temporal synchronization and lead to process losses (Baker, 2002; Schneider & Pea, 2013; Rummel & Spada, 2005). The type of CSCL environment in terms of synchronous or asynchronous forms of working and communicating has distinct variations of temporal synchronicity and its measurement - ranging from being in the same working space at the same time to coordinated effort over time (e.g., 24-hour knowledge factory well known in CSCW).

It is assumed that students working in groups adopt shared understanding and negotiate the meaning about a topic by asking questions, discussing, explaining, and providing extra information to support their viewpoints (De Lisi & Goldbeck, 1999). This type of group discussion is known as transactive discussion, i.e. students successively build on each other's reasoning by interpreting the meaning of their logical statements on the task at hand (Teasley, 1997). The way collaborating students build on each other's contributions can be carried out at low and high levels of transactivity (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2013). At the lowest level, simple consensus occurs when group members accept what is said or done without further discussion. At the highest level of transactivity, a joint decision is made as a result of a dynamic incorporation of both agreements and disagreements between partners (Molinari, Sangin, Nüssli, & Dillenbourg, 2008). Previous research has shown that the highest level of transactive discourse increases the probability that learners trigger cognitive activity fostering individual and group performance (Stahl, 2013).

The present study was undertaken to combine the lines of research explained above into one set-up. The following research question was addressed: *To what extent do temporal synchronization of collaborative activities and the use of high levels of transactive discourse affect the quality of group products during synchronous CSCL?*

Methods

Participants

The participants in this study were 74 first year university students enrolled in an Environmental Sciences MSc program in the Netherlands. The sample comprised of 18 Dutch and 56 international students; 53% were women. The age of the respondents ranged from 19 to 37 years, with a mean age of 24 years (*SD* = 3.2); 96% of the participants were under the age of 30. The participants were randomly assigned to work in dyads. One dyad was excluded from the study as they did not use the CSCL-environment for communication, but used face-to-face communication.

Assignment and procedure

This study used an assignment that was part of an introductory course for MSc students, called Principles of Environmental Sciences. To fulfill this assignment, students had to analyze the problem of biodiversity collapse in tropical forests. While collaborating in dyads within a synchronous CSCL environment students were expected to inductively solve an environmental problem, by following three consecutive steps: (1) analyzing the problem of biodiversity loss by identifying causes and effects, (2) proposing possible Responses (solutions) to avert the biodiversity loss, and (3) selecting the most viable ways to tackle the problem of biodiversity loss by prioritizing the Responses. Students were expected to fill in a Driver–Pressure–State–Impact–Response (DPSIR) model for an ill-defined environmental problem to which several solutions could be proposed (i.e. DPSIR is a framework that helps to identify and describe processes and interactions in human–environmental systems, Fortuin, Koppen, & Leemans, 2011).

In the study, there were one introductory (plenary) and two online group work sessions over three days. The overall time required for completion of the assignment was about 8.5 hours. In the plenary meeting the DPSIR model was introduced. In the first group working session on day 2, students started by spending a few minutes getting to know each other and then they continued by studying the task materials at an individual computer. Students were then given time to post their individual thoughts, and to exchange ideas with their peers afterwards. On day 3, students continued working on the collaborative problem-solving task and a solution evaluation phase took place, which consisted of three subtasks. Namely, making a DPSIR-model, making a list of possible Responses, and reporting the overall prioritization of the Responses. The assignment ended in a finished DPSIR model, which was assessed. All online activity was automatically captured in log files, which were further analyzed for temporal synchronicity and high level transactivity (see below).

The dyads collaborated in a digital learning environment called Virtual Collaborative Research Institute (VCRI; Jaspers, Broeken, & Erkens, 2004). The VCRI groupware program incorporated both personal tools (Sources-tool and Notes-tool) as well as shared tools (Chat-tool, Cowriter-tool, and Diagrammer-tool) as shown in Figure 1. The Chat-tool allowed students to communicate with their collaborative partner. In the Cowriter-tool students wrote their Responses. In the Diagrammer-tool students edited elements of the DPSIR model.

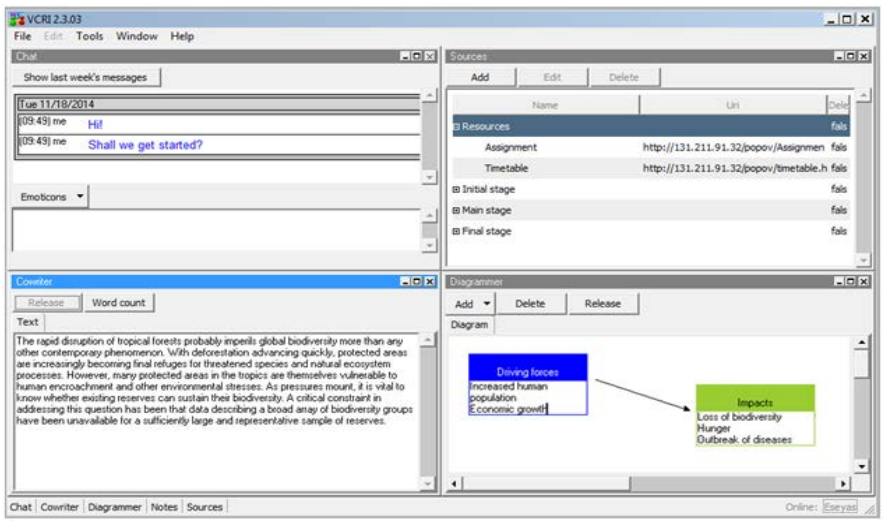

Figure 1. Screenshot of the VCRI environment, with Chat-tool (upper left), Sources-tool (upper right), Cowriter-tool (bottom left) and Diagrammer-tool (bottom right).

Instruments

Temporal synchronicity

Log files were automatically generated of each dyad's activities in VCRI, including which tools were opened and what actions were performed within the tools. It was quantified whether the members of a dyad mirrored each other's activity by opening and working in the same tool. An automatic coding mechanism, using Multi Episode Protocol Analysis (Erkens, 2005), was developed which coded at each time point whether or not the two members of the dyad were temporally synchronized, and if so, in which tool. The following two conditions had to be met in order for a dyad to be coded as temporally synchronized in a particular tool:

1) The dyad performed at least five consecutive actions within one specific tool, with the inclusion of Chat-messages. Because the Chat-tool was the primary medium for communication, the consecutive actions in a tool still count if an action in the Chat-tool occurs within this row of five activities.

2) The row of (at least five) consecutive activities includes activities produced by both members of the dyad. For example, five activities by member 1 in the diagrammer do not count as the dyad being temporally synchronized.

Thus, when a sequence of activities met the criteria, all activities in those sequences were coded as temporally synchronized. The percentage of the total number of activities that was coded temporally synchronized was used as the measure of temporal synchronicity for each dyad.

Transactivity

Student chats were analyzed for the occurrence of high levels of transactivity, namely *Integration* according to Noroozi's hierarchy (Noroozi et al., 2013; table 2), which means that learners adopt the perspective of their peers and build syntheses of the (counter) arguments uttered by their peers. A randomly selected third of all chats were coded by the three researchers and the outcomes were discussed until consensus about the coding was reached. After that the rest of the chats were divided between the researchers for coding all the remaining chats. In chat episodes where disagreement about the correctness of coding as high level of transactivity in the integration category occurred, consensus was reached through discussion by all three researchers. For all dyads the percentage of chat utterances that were coded as integration was then calculated by dividing the number of utterances in all integrative episodes by the total number of utterances in the chat conversation. Also, for each episode of high level transactivity discourse in the integrative category, it was checked whether the students transferred the discussed concept to the DPSIR diagrammer. The percentage of concepts in the diagrammer that was discussed on a high level of transactivity was then calculated.

Quality of students' group work

The assessment of the quality of the students' constructed DPSIR diagrams (obtained from the Diagrammer-tool) was made on a 5-step rating scale (5 being the best score) for three assessment criteria: width (the number of concepts in the diagrammer), correctness (the amount of concepts that is correct), and structure (the way concepts are grouped and related within the diagrammer). Two teachers coded all students' DPSIR diagrams independently and all disagreement and discrepancies were discussed until they reached an agreement. Both inter-rater agreement between two expert coders (Cohen's k= 0.82) (Landis & Koch, 1977) and intra-coder test-retest reliability for each coder for 15% of the data (90 % identical scores) were sufficiently high. Subsequently, all points assigned to each student dyad per criterion were added together and then divided by 3 (i.e. the total number of criteria). Each group of students could get a mean quality score of between one and five, which was converted to the Dutch 10 point grading scale. Scores below 5.5 were regarded insufficient to pass the course.

Analyses

A multiple regression analysis was performed to investigate whether temporal synchronicity and high level of transactivity predicted the grade that the dyads received for their diagrammer final product. The quantitative results were extended by adding qualitative descriptions of the dyads' collaborative processes.

For the qualitative analysis all dyads were categorized and placed in a table based on their qualitative characteristics. Dyads were categorized as having either high or low occurrences of high level transactivity (more or less than 33.3%), high or low temporal synchronicity (more or less than 33.3%), or an sufficient or insufficient grade (higher than or equal to or lower than 5.5). The collaboration of all dyads within each cell of the table was thematically analyzed by looking at the chat conversation as well as the ordering of events within the log files.

To analyze the chat conversations, an open coding approach was used to identify meaningful events such as the occurrence of disagreement between group members or reaching a shared solution to a question (cf., Barron, 2003; Rummel and Spada, 2005). Each event consisted of an episode in which each student had more than one

chat utterance. Using an iterative process, all chat transcripts were analyzed based on the emerged themes. Then, the three researchers wrote brief summaries of the way students collaborated. When there was doubt about the accuracy of a summary, a second researcher analyzed that dyad. From the summaries of all dyads per type, a characterization for each dyad type was composed.

Findings

Relation between high level transactivity, temporal synchronicity, and quality of group product

Table 1 displays the descriptive statistics for percentage of activities that was temporally synchronized, percentage of high level transactive utterances in the chat conversation, number of concepts in the diagrammer that was discussed transactively on a high level, and final grade for the diagrammer. As can be seen, on average the dyads achieved a relatively high level of temporal synchronicity, meaning that almost half of the time collaborating partners were using the same tools at the same time, including direct communication through the chat. The percentage of high level transactivity in the chat was relatively low (on average 15.09%), while about a third of the concepts in the final diagrammer product were discussed on a high level of transactivity. The average grade was 6.42, and out of 36 dyads, only five dyads did not achieve a sufficient grade.

Multiple regression analysis showed that neither temporal synchronicity ($t(35) = -.451$, $p = .655$) nor high level transactivity ($t(35) = .177$, $p = .861$) was a significant predictor of the grade that the dyads received for their diagrammer final product.

Table 1: Descriptive statistics for main variables

	M (%)	SD (%)	Min	Max
Temporal synchronicity	40.81	8.71	24.99	62.28
High level transactivity in chat	15.09	10.87	0.0	45.95
Number of Diagrammer concepts discussed transactively in chat	39.50	23.07	0.0	85.71
Grade	6.42	0.97	3.82	8.36

Qualitative description of dyads

No significant relationship between grades, high level transactivity and temporal synchronicity was found. In fact, both relatively low and high scores on high level transactivity lead to sufficient grades in this study. To explain these findings, qualitative descriptions of collaboration types that occurred in the dyads are provided in Table 2. These qualitative descriptions shed some light on the variability in outcomes between dyads. It also shows contrasts between groups with different characteristics and similar outcomes in grade, as well as groups with similar characteristics but different outcomes in grade.

A categorization of dyads was made based on three dimensions: synchronicity (low versus high), high level transactivity in discourse (low versus high), and grade (insufficient versus sufficient), leading to eight categories. Table 2 displays the distribution of dyads among these categories. As can be seen, one type of dyad did not exist in our dataset, namely the combination of low synchronicity, low occurrence of high level transactivity and an insufficient grade (Cell A).

In the sections below, we illustrate and contrast the types of dyads that showed similar process characteristics, yet differed in the grade they received. For example, dyad types A and C both show low temporal synchronicity and a low number of concepts discussed on high level transactivity, yet type A achieves an insufficient grade and type C a sufficient grade.

Dyad type A and C

Contrary to our expectations all dyads with lack of temporal synchronicity and a low number of concepts discussed on high level transactivity fell into dyad type C (sufficient grade) in our study. Further analyses of dyads type C revealed that in some cases the dyads consisted of two strong students that could manage their own tasks by distributing the workload and coordinating their actions, instead of trying to collaborate and learn from each other. In other cases, some of the students took almost full control of the task and finished the whole assignment on their

own. As an example, we consider one dyad from type C (see excerpt below), where one student is responsible for 98% for all activity in the Diagrammer-tool and as a group they had only 2.8% of the high level transactive discussions. Still, in contrast to dyad type A, this dyad achieved a high grade (8.4 out of 10 points). Student 2 gives Student 1 barely a chance to participate, as evidenced by the use of the phrase "my diagram". As a result of this disproportional cooperation dynamic, the dyad achieves little high level transactivity and little temporal synchronicity.

Student 1:	Wow, you have finished the whole assignment.
Student 2:	I already made something but don't know if its correct
Student 2:	Do we need to put all driving forces, for instance, in 1 box or in seperate [separate] boxes?
Student 1:	I'm thinking about it now...I think we should ask someone else or the teather [teacher]
Student 2:	You're messing up my diagram :P
Student 1:	I'm trying to find out if I can add a box..
Student 2:	I can do it if you want
Student 2:	and you can chat me if you agree with what I add

Table 2. Summary of types of dyads, sorted according to temporal synchronicity, number of Diagrammer concepts discussed on high level transactivity in chat, and grade.

		Low occurrence of high level transactivity (number of concepts discussed on high level transactivity < 33.3%)	High occurrence of high level transactivity (number of concepts discussed on high level transactivity > 33.3%)
Synchronicity 0.0% - 33.3%	Grade < 5.5 Insufficient	A n = 0	B n = 1 SUMMARY: This particular dyad collaborated but was not critical of each other's work. They regularly wanted to show their work to the teacher, possibly because they were insecure.
	Grade > 5.5 Sufficient	C n = 5 SUMMARY: The dyads all divide the tasks between them, leading to cooperation instead of collaboration, and little temporal synchronization.	D n = 3 SUMMARY: The dyads all divide the tasks between them, leading to cooperation instead of collaboration, and no temporal synchronization. The dyads have some moments where their activities intersect and at those points they discuss the task material on high level transactivity.
Synchronicity 33.3% - 66.6%	Grade < 5.5 Insufficient	E n = 2 SUMMARY: The dyads have a lack of high level transactivity, in one case because the dyads divide the tasks and cooperate; in the second case because the students are too insecure to move beyond merely exchanging information.	F n = 2 SUMMARY: The dyads showed collaboration, including high level transactivity in discourse, and often challenged each other. The low grade may be explained in one case because the dyad based their discussion on incorrect information, and in the other case because the dyad spent too much time on figuring out the DPSIR model they had to construct.
	Grade > 5.5 Sufficient	G n = 10 SUMMARY: The dyads collaborated efficiently but showed no high levels of transactivity. There was a lack of challenging each other, instead quickly agreeing when the other proposed a solution. The dyads consist of motivated students with a focus on completing the assignment	H n = 13 SUMMARY: The dyads collaborated efficiently and with regular occurrence of high level transactivity. Ideas are constantly challenged in a friendly way, and the students regularly check whether they are still on the same page. Input from both students is combined into a co-constructed solution. The dyads consist of motivated students.

Dyad type B and D

Dyad type B occurred only once in our data set, whereas dyad type D had three instances. Both types of dyads, B and D, demonstrated similar style of working together. Namely, they discussed most subject matters in an open and constructive way. These dyads discussed their plans/activities verbally, agreed on what needed to be done, and then proceeded individually, without temporal coordination. Qualitative analysis of chat transcripts revealed that dyad type B had to ask the teacher for help over 10 times, partly because they thought they had to, and partly because they felt insecure about what they had produced (see excerpt below). In contrast, dyads type D managed their collaborative work without teacher's help and all content-related questions were discussed between the participants themselves.

Student 1:	so the diagrammer doesn't need to be modified .every item of response should be more specific
Student 2:	i don't know
Student 2:	maybe we could ask to a teacher isn't it?
Student 2:	did you saw what I posted about the 2 last points/
Student 1:	Yes
Student 1:	and i post the 1
Student 2:	it seems to be good
Student 2:	we should show the complete work to the teachers

Dyad type E and G

From the dyads that achieved a high level of temporal synchronicity in their collaboration and discussed a low percentage of their concepts of high level transactivity, 2 dyads scored an insufficient grade (dyad type E) and 10 dyads scored a sufficient grade (dyad type G). Overall, the dynamic of these two types of dyads was set on completing the DPSRI assignment, but not on learning from each other and understanding more about the subject matter. In situations when one student would pose a question or a suggestion, the other student would usually respond very briefly or agree very easily. The difference in grades may be explained by the dynamics of collaboration that these two types of dyads demonstrated. Collaborating students in both types of dyads, E and G, worked very closely with each other in terms of space/tools use, but dyads in type E spent more time figuring out the assignment and doubting actions (i.e., one dyad in type E used the word "Maybe" 42 times throughout their entire chat conversation) compared to dyads in type G. This is shown in the excerpt below.

Student 1:	but the problem is that I don't know if we have to focus on the case described in the article or if we can find another impacts that are not in the text
Student 1:	but I think you are right actually
Student 1:	and you speak about 50% forest loss but maybe we should put that in the pressues [pressures], as an explanation and proof of deforestation
Student 2:	maybe you are right
Student 1:	and the other ones, maybe we can develop a few by sentences from the text
Student 2:	I don't know if we can find some impacts that are not in the text, too. so, maybe now we can just use the things given in the article or in the film

Dyad type F and H

From the dyads with both high occurrence of high level transactivity and temporal synchronicity, only two dyads scored an insufficient grade (dyad type F), and 13 dyads scored a sufficient grade (dyad type H). This supports our expectation that high occurrence of high levels of transactivity and temporal synchronicity may lead to quality of group work. Further analyses of dyad type F shows that both dyad types are very polite, constructive and friendly in their chat. However, one of these two dyads had a low score (2 out of 5) on the correctness criterion, possibly indicating that they based the concepts in their diagrammer on misconceptions. The other dyad spent a lot of time figuring out what the assignment was about and what the idea behind a DPSIR model was, these difficulties in understanding the assignment seemed to be increased by language barriers between the two students in the dyad.

Twelve of the 13 dyads in dyad type H are characterized by challenging each other in a friendly and motivating way, showing patience and checking each other's ideas to come to co-constructed refined solutions

(see excerpt below). One dyad however, started working on the diagrammer very early on in the assignment, but then had an argument the students themselves called a 'serious situation'. When the students realized the argument lasted for too long and they had to hurry to complete the assignment, they stopped arguing in the chat and were able to finish the assignment.

Student 1:	Ah it belongs to air pollution
Student 1:	or climate change
Student 2:	true, but emissions is a pressure and it pollutes the air. Shall I add it to the pressures?
Student 2:	and air pollutions keeps standing there as a state
Student 1:	yes! perfect!

To summarize, the qualitative descriptions showed the variability between the groups in terms of characteristics such as group dynamic, students' content knowledge, confidence in managing the learning task, collaborative strategy (cooperation versus collaboration), and communication skills.

Discussion

Findings and implications

In contrast to expectations, neither temporal synchronicity nor high level transactivity correlated with the quality of group products. Sufficient grades were achieved with only a high occurrence of high level transactivity, only a high level of temporal synchronicity, and even with low levels of both high level transactivity and temporal synchronicity. This suggests that none of these variables is vital for collaboration to lead to sufficient final product. The qualitative analysis of collaborating dyads showed that there were a number of variables, besides the two under direct investigation, that influenced whether a dyad would succeed or not. The clearest finding was that by discussing their activities and agreeing on a clear task division, two students with strong content knowledge can work independently from each other and still achieve a good grade.

The most surprising type of dyad we encountered was the type that scored an insufficient grade even though they had high levels of temporal synchronicity and high level transactivity. A possible explanation is that they reasoned on false beliefs, meaning that their misconceptions about the task material remained undetected by the students themselves. This finding shows the importance of both social aspects as well as cognitive/task-related aspects of collaboration. Perfect socio-collaborative skills are only beneficial when students challenge each other's statements continuously and keep checking their output for correctness. Since it is a demanding task for teachers to monitor and regulate multiple collaborating groups at the same time (Van Leeuwen, Janssen, Erkens, & Brekelmans, 2015), automated moderation of discussions on both socio-collaborative and cognitive dimensions of collaboration could be beneficial. Some of the processes we observed in the dyads, such as the 'overruling' behavior when a dominant student was coupled to an insecure student, could be prevented with adequate moderation of discussions. Thus, there is a challenge here to take into account not only differences *between* dyads, but also differences *within* dyads.

Limitations and directions for future research

This study was carried out in an authentic learning environment, but the results of this study should be interpreted in light of some limitations. First of all, the task students worked on did not include an incentive to share knowledge - there was no dependency between the students within dyads. For example, if students had been given differing task materials, they would have had to share and discuss, and high level transactive discourse may have been more likely to occur. Another limitation of the study design is that we did not measure individual knowledge gains. It could be that although the investigated variables did not predict quality of the group product, the students in various types of dyads may have differed on individual knowledge gains.

Concerning temporal synchronicity, we checked whether both students had the same workspace activated, but not whether both students were actively contributing nor whether they actually acknowledged each other's presence. It could be argued that the two students need to demonstrate awareness that "they are attending to something in common" (Tomasello, 1995, pp. 106). However, research on temporal synchronicity in the field of CSCL is relatively scarce (Rummel & Spada, 2005). It is not yet clear to what extent implicit coordination such as temporal synchronicity differs or correlates to explicit types of coordination (in which students openly discuss

coordination of activities), which is a much more common area of research (Järvelä & Hadwin, 2013). In this respect, we hope to have given input for future research.

Finally, in our analysis we did not take into account the role of students' cultural background. Students may have had communicative barriers that hindered high level transactive and synchronized collaboration (Popov, Biemans, Brinkman, Kuznetsov & Mulder, 2013). Indeed, our results pointed out the importance of group dynamics for dyads to succeed on the task. This could be a relevant direction for future research, also given the increasing numbers of massive open online courses (MOOCs) in which students from different countries and cultures participate. The observed differences, and different combinations of dyad characteristics, show the need for personalized support.

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