The Mediating Role of Interactive Learning Activities in CSCL: An INPUT-PROCESS-OUTCOME Model

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Abstract: Computer-support for collaborative learning has been shown to be most effective if it is designed to foster productive social interactions. In this conceptual paper, we propose an INPUT-PROCESS-OUTCOME model to guide research on the defining features, and on the conditions and effects of such productive interactions in CSCL. The model builds upon the recently proposed *interactive-constructive-active-passive*-framework of overt learning activities (ICAP; Chi, 2009). We propose that the *interactive* mode of learning is a fruitful concept for specifying what constitutes productive social interaction in CSCL, given several conceptual and methodological clarifications. The mediating role of *interactive* learning activities in CSCL is highlighted by the proposed INPUT-PROCESS-OUTCOME model, and supported by recent empirical findings. Building on a brief review of exemplary findings, we discuss challenges and opportunities for future research in CSCL.

Keywords: input-process-output model, interactive learning activities, process analysis, mediation

Introduction

Computer-support for collaborative learning has been shown to be most effective if it is designed to foster productive social interactions, such as mutual explanation, shared regulation, or argumentation (Dillenbourg, Järvelä, & Fischer, 2009). In order to identify such productive interactions, CSCL researchers typically analyze process data, for instance from automatically generated log files or from audio-video-recordings (Rummel, Deiglmayr, Spada, Karimanis, & Avouris, 2011). However, it still remains unclear what exactly constitutes productive social interaction in CSCL. This is true even when restricting this question to the socio-cognitive perspective of learning, as adopted by the authors of this paper. The socio-cognitive perspective views individual knowledge and skill acquisition as the most relevant outcomes of CSCL, and productive interaction as a means of fostering individual learning. In this paper, we propose an INPUT-PROCESS-OUTCOME model designed to guide research on three questions that are at the heart of CSCL research (cf. Dillenbourg et al., 2009): What constitutes productive social interactions in CSCL? Under what conditions do such productive social interactions occur? What effects do they have on learning?

To address the first question, we build on the recently proposed interactive-constructive-active-passive-framework (ICAP; Chi, 2009). We propose that the *interactive* mode of learning is a fruitful concept for specifying what constitutes productive social interaction in CSCL. We briefly introduce the framework and add necessary conceptual and methodological clarifications. To address the second and third question, we introduce an INPUT-PROCESS-OUTCOME model and provide some exemplary empirical evidence which demonstrates the mediating role of interactive learning activities in CSCL. Note that we do not claim to be answering the second and third question yet. The model is designed to guide research efforts targeting these questions.

Productive interactions in CSCL

The ICAP framework

According to the ICAP-framework educators achieve the highest learning gains in their students if they succeed in facilitating so-called *interactive* learning activities. In line with previous research on productive social interactions in CSCL, being interactive in ICAP entails the co-construction of novel ideas in dialogue in which "both partners [are] taking turns mutually creating" (Chi & Wylie, 2014, p. 228). For instance, both students might give and incorporate feedback, compare and integrate alternative perspectives, or challenge one another's ideas. Such interactive learning activities are differentiated from three lower levels of overt learning activities: *Constructive* learning activities comprise processes of inferring new information and integrating new information with existing prior knowledge, through learning activities such as self-explaining, constructing concept maps or otherwise making sense of learning materials. *Active* learning activities include activities such as selecting and summarizing new information, without going beyond the information presented in the learning materials. *Passive* learning activities denote attending to information, without actively engaging with the learning materials. Higher levels of learning activities subsume all lower levels. In consequence, being *interactive* (e.g. replying to a peer`s argument with a counterargument) requires also being *constructive* (e.g. constructing one`s argument), *active* (e.g., selecting which aspect of the peer`s argument to address), and *passive* (e.g. reading the peer`s argument). In terms of their effectiveness for learning, the framework hypothesizes the following sequence: interactive > constructive > active > passive learning activities.

In summary, the specification of productive learning activities, in particular *interactive* ones, within the ICAP-framework is in line with existing research on productive social interaction in CSCL (Dillenbourg et al., 2009). However, ICAP adds the benefits of a systematic taxonomy, and yields fruitful hypotheses for the differential effectiveness of different kinds of observable activities (e.g., *interactive* versus *constructive*). Recent research has yielded coding schemes for classifying observable learning activities (e.g. from log files, discourse, collaboratively and individually produced texts) according to the levels of the ICAP taxonomy (Deiglmayr & Schalk, 2013, submitted; Olsen, Rummel, & Aleven, 2015; Vogel, Kollar, Reichersdorfer, Ufer, Reiss, & Fischer, 2013, submitted). This line of research also proposes to further differentiate interactive learning activities, for example according to the level of symmetry of the collaborative relationship (instructive vs. joint dialogues; Chi, 2009), according to the function of the interactive activity (argumentation vs. co-construction; Vogel et al, submitted), or according to the relevance with regard to domain principles (principle-based interactive turns; Deiglmayr & Schalk, submitted).

Limitations of the ICAP framework

The ICAP framework has received initial support from empirical studies (for an overview, see Chi & Wylie, 2014), and we will provide further data supporting it in this paper. Nevertheless, important conceptual and empirical questions remain yet to be answered.

As we know from a rich base of studies in CSCL, a collaborative learning setting does not automatically entail productive social interactions, that is, *interactive* learning activities (Dillenbourg et al., 2009). For example, a student might merely read messages, explanations, and arguments posted in a chat-based learning environment, thus demonstrating only *passive* learning activities. Other students might work towards quick consensus building by copying solutions from a worked example and signaling agreement, thus engaging in only *active* learning activities. Other students might construct elaborated arguments in a form of "individual dialogue" (Chi, 2009), that is, without taking up a partner`s feedback or contributions, thus being *constructive*, but not interactive. Only once students build upon each other's contributions they would be said to engage in *interactive* learning activities. Similarly, Chi and Wylie (2014) state that it is the enacted learning activities that count (i.e., the activities actually shown by the learners) and not the intended learning activities (i.e., the ones the instruction was designed to trigger). Yet, the exemplary studies cited by the authors of ICAP in favor of the hypothesized benefit of interactive over constructive learning activities (Chi, 2009; Chi & Wylie, 2014) operationalize this contrast as a comparison between an individual learning condition (e.g., individual concept mapping or individual note taking) and a collaborative learning condition (e.g., collaborative concept mapping or collaborative note taking). While these conditions were designed to trigger either constructive or interactive learning activities, Chi and Wylie (2014) do not present data on how the learners actually engaged with the learning materials. Therefore, additional research is needed, which addresses the effectiveness of interactive learning activities by looking at process data (i.e., actually enacted learning activities), and which also compares the effectiveness of different kinds of enacted learning activities within collaborative settings. The studies employing coding schemes for assessing interactive learning activities, as summarized above (Deiglmayr & Schalk, submitted; Olsen et al., 2015; Vogel et al., submitted), are among the first to test the validity of the ICAP framework based on actual process data. These studies show that a collaborative setting – even if designed to facilitate interactive learning activities – does not guarantee that all students engage in interactive learning activities. The extent to which students do participate in interactive learning activities at critical moments of the collaborative process, however, appears to be positively correlated with their learning outcomes (see below for details).

Conditions and effects of interactive learning activities in CSCL

To guide further research efforts, we propose an INPUT-PROCESS-OUTCOME model highlighting the mediating effect of interactive learning activities in CSCL (Figure 1). Learning activities, and in particular interactive learning activities, are deemed to be the most important PROCESSES that mediate between design decisions and outcomes in CSCL. The occurrence of productive social interactions, that is, *interactive* learning activities, are dependent on the INPUT conditions, such as specific features of CSCL environments (e.g., the presence of a collaboration script), or individual learner characteristics (e.g., prior knowledge). Further, context features such as the learning setting, teacher variables, or characteristics of the learner group, play important roles. OUTCOMES can be described on different levels and dimensions (e.g. group vs. individual; cognitive, metacognitive, affective, motivational); it is important to note that we focus on individual, cognitive learning outcomes here (i.e., individual knowledge and skill acquisition).

Introducing a formal taxonomy of learning activities, such as ICAP, allows for testable predictions about the causal mechanism by which given INPUTS (e.g., the presence of a collaboration script or the feedback from an adaptive CSCL system) have effects on selected OUTCOMES (e.g., individual acquisition of content knowledge and/or collaboration skills). The model is adapted from models of statistical mediation (e.g., Hayes, 2013), and allows the specification of both direct effects (INPUT-OUTCOME LINK) and indirect, that is, mediated, effects (INPUT-PROCESS-OUTCOME link). INPUT-PROCESS-OUTCOME models are also popular in the literature on teamwork (e.g., vanKnippenberg, de Dreu, & Homan, 2004). However, in that literature, the OUTCOME of interest is typically some measure of team performance (e.g., quality of group products; team creativity). Individual learning and transfer is of interest only as far as it contributes to team performance; that is, individual learning is a PROCESS feature rather than an OUTCOME in models of effective teamwork (e.g., Ilgen, Hollenbeck, Johnson, & Jundt, 2005). Further, PROCESSES such as specialization and division of labor, are often conducive to team performance, but may actually hinder individual learning (Deiglmayr & Schalk, 2013, submitted). Therefore, it is important that CSCL research continues to develop its own theories of what constitutes effective interaction. We propose that integrating the ICAP framework in an INPUT-PROCESS-OUTCOME model is one useful starting point. In the following we will provide examples of recent studies that yielded first evidence for the presumed causal links in the model.

Evidence for the direct INPUT-OUTCOME link

As already mentioned, Chi and Wylie (2014) cite several studies which demonstrate that collaborative learning settings designed to facilitate *interactive* learning activities (INPUT) led to higher individual learning OUTCOMES, compared to structurally similar individual learning settings designed to facilitate *constructive* learning activities. While we can take these studies as support for the direct INPUT-OUTCOME link, process data are needed to show that the benefits really are mediated by higher levels of enacted interactive learning activities.

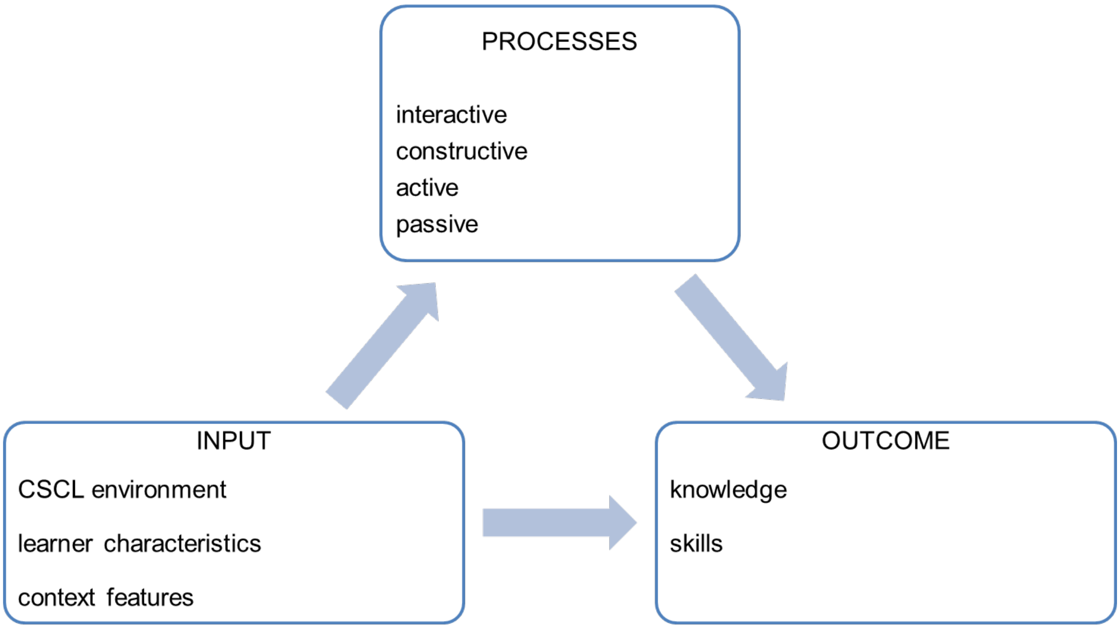

Figure 1. The mediating role of interactive learning activities in CSCL

Evidence for the INPUT-PROCESS link

Evidence for the INPUT-PROCESS link is provided by studies which show that specific features of a CSCL environment (INPUT) actually lead to higher (or lower) levels of *constructive* or *interactive* learning activities (PROCESS).

Vogel et al.(2013, submitted) assessed students' argumentation and knowledge co-construction in mathematical proof tasks. They differentiated between *constructive* learning activities and two types of *interactive* learning activities: *interactive* argumentation and *interactive* co-construction (PROCESS). In line with the authors' hypothesis, introducing a collaboration script (INPUT) led to higher levels of *interactive* argumentation and of *constructive* learning activities, but did not influence *interactive* co-construction.

Olsen et al. (2015) assessed the proportion of *interactive* dialogue, as compared to other types of talk (PROCESS), which resulted from three design features implemented in their CSCL environment. These INPUT features were the presence/absence of a role script, of cognitive group awareness features, and of the distribution of information across partners. The results show that the three design features led to different proportions of *interactive* dialogue vs. other talk. The highest proportion was obtained for distribution of information, while the two other INPUT features yielded smaller amounts of *interactive* dialogue.

Evidence for the PROCESS-OUTCOME link

Evidence for the PROCESS-OUTCOME link is provided by studies which show that higher levels of *interactive* learning activities in students` dialogues (PROCESS) lead to higher levels of individual learning (OUTCOMES). The findings obtained by Vogel et al. (submitted) show that students` participation in *interactive* argumentation with their partner (but neither *interactive* co-construction nor *constructive* activities) was a significant predictor for their acquisition of argumentation knowledge, thus yielding evidence of the PROCESS-OUTCOME link in addition to their evidence for the INPUT-PROCESS link (see above). However, evidence for the INPUT-PROCESS link does not automatically entail evidence for the PROCESS-OUTCOME link. For example, Olsen et al. (2015) did not find a positive correlation between the amount of interactive dialogue (PROCESS) and indicators of individual learning (OUTCOME).

Evidence for the indirect INPUT-PROCESS-OUTCOME link

To demonstrate the indirect INPUT-PROCESS-OUTCOME link, evidence for the two partial links is not sufficient. Rather, evidence for the mediating role of PROCESS features needs to be established, for example employing the statistical techniques of path analysis, regression-based mediation, or structural equation modelling (Hayes, 2013). One example of evidence for the indirect link is a recent study by Deiglmayr and Schalk (2013, submitted). These authors showed that two different ways of distributing learning resources among learners in a jigsaw-type collaboration script (INPUT) led to different levels of interactive and constructive learning activities during a subsequent collaborative problem solving phase (PROCESS). In particular, learners with low prior knowledge participated much more frequently in interactive learning activities (operationalized as the co-construction of principle-based explanations) if the distribution of learning materials created weak rather than strong knowledge interdependence between learners. Further, higher engagement in interactive (but not constructive) learning activities (PROCESS) was positively related to individual learning (OUTCOME). A series of regression analyses showed that the effect of experimental condition (INPUT) on individual learning (OUTCOME) was partially mediated by the level of participation in interactive knowledge construction (PROCESS), yielding evidence for the indirect INPUT-PROCESS-OUTCOME link.

Challenges and opportunities for future research

As demonstrated by the cited studies, varying the INPUT does not automatically lead to the intended PROCESSES or OUTCOMES. There are several explanations for a lacking effect, which each yield hypotheses for future research, conceptual refinements of the proposed model, and the development of improved methods:

1. *Interactive learning in CSCL needs to be defined and analysed more carefully.* The study by Vogel et al. (submitted) indicates that not all interactive learning activities may be equally affected by INPUT variables (such as a collaboration script) and, more importantly, that these different interactive learning activities do not seem to be equally effective for learning. Thus, CSCL research needs to carefully differentiate between different kinds of interactive learning activities.
2. *Methods for measuring the degrees to which learning is passive, active, constructive, or interactive need to be refined.* The studies summarized in this paper all used different, study-specific coding and rating schemes for assessing the degree to which learners` contribution in CSCL were constructive or interactive. Conceptual clarifications of what constitute effective interactive learning activities in CSCL (see bullet point above) will also allow for more refined methods of analysing process data, and for greater comparability across studies.
3. *There might be an optimal degree of interactivity*, beyond which no increase (or even a decrease) in intended outcomes might be observed. Rather than the total amount of interactive learning activities,

their proportion in relation to other activities, their timing, or possibly their number in comparison to some threshold might be most relevant measure for predicting OUTCOMES.

4. *INPUT features affect OUTCOME through other PROCESSES than interactive learning activities.* While interactive learning activities, such as the co-construction of knowledge, are the main goal of many CSCL designers and educators, they are not the only processes that may lead to learning. Thus, even within a collaborative setting, CSCL research needs to also pay attention to other productive activities, such as constructive or active learning activities that occur at an individual level rather than in learners` interaction.
5. *Third variables moderate the effects.* As the findings by Olsen et al. (2015) demonstrate, some INPUT variables may affect PROCESSES in the intended way, but without affecting the intended OUTCOMES. Potential explanations include third variables, such as learner characteristics (cf. Deiglmayr & Schalk, submitted), the specified learning goals, or the type of assessment. For example, third factors, such as prior knowledge, may lead to higher learning gains as well as higher engagement in interactive learning activities. Thus, CSCL research should carefully consider possible moderators (cf. Hayes, 2013).

To conclude, the proposed INPUT-PROCESS-OUTCOME model which incorporates the ICAP-framework as PROCESS component can guide future research efforts. While the model has already been supported by some findings, future work is needed to address the open questions highlighted above.

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