

# New challenges in CSCL: Towards adaptive script support

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**Abstract:** Scaffolding learners, i.e. helping learners to attain tasks they could not accomplish without support, entails the notion of fading, i.e. reducing the scaffolding for learners to become more and more self-regulated. Fading implies to tailor support for collaboration, such as collaboration scripts, to the particular needs of the specific collaborators. In computer supported collaborative learning (CSCL) settings, support can be designed in a very restrictive and inflexible fashion; at the same time computerized settings open new possibilities for the realization of adaptive support as they enable automation of analysis and feedback mechanisms. In this symposium we present new technical approaches and latest empirical research on possibilities and limitations of adaptive support for learners in CSCL settings.

Much research has demonstrated the potential effectiveness of collaboration for improving students' problem solving and learning (e.g., Slavin, 1996). Collaborative learners have the possibility to receive help from their partner, and can engage in elaborated discussions (Teasley, 1995). Unfortunately, research has also shown that effective collaboration does not happen spontaneously (e.g. Dillenbourg, Baker, Blaye, & O'Malley, 1995; Rummel & Spada, 2005). Collaborative learners often do not engage in productive interactions and thus miss collaborative learning opportunities. Hence, in order to ensure that students can benefit from learning collaboratively, it is important that collaborative partners learn how to work together in productive ways. Particularly at the beginning, some degree of other-regulation, e.g., through guidance, instruction, and training, is required before learners are enabled to engage in self-regulated effective processes of collaborative learning (Kollar & Fischer, 2007; Slavin, 1996). One approach that has shown its effectiveness in a variety of contexts is guiding students' interaction by a collaboration script (e.g. Kollar, Fischer & Hesse, 2006; O'Donnell, 1999). To improve students' interaction, scripts prompt students to engage in cognitive, meta-cognitive, and social processes that might otherwise not occur. However, concern has been expressed that there may be a danger in "overscripting" collaborative interaction, i.e., providing too much structure and support for collaboration – especially for advanced students who are capable of self-regulating their learning activities (Cohen, 1994; Dillenbourg, 2002). This reproach is particularly true for script approaches that have been developed for computer-mediated collaboration (e.g., Pfister & Mühlfordt, 2002). Scripting collaboration inflexibly might prevent the independent, exploratory thinking required for generative learning or problem-solving, and consequently decrease students' motivation. Moreover, following script prescriptions may impose considerable cognitive load upon learners and thus hamper problem-solving and learning. Taken together, there is reason to believe that it might be best to scaffold collaboration in an adaptive fashion, providing and fading structured support for collaboration based on the particular needs of the specific collaborators. Further evidence for the assumption that adaptive support of collaboration will be most effective for learning comes from research on cognitive tutors (e.g. Anderson, Corbett, Koedinger, & Pelletier, 1995). A key strength of cognitive tutors is that they provide just-in-time support, tailored to the needs of the individual student in a particular moment. As soon as the student makes an error, he or she receives feedback from the system and usually is given some advice about how to overcome the impasse.

In the long run, this is what an adaptive collaboration approach aims at: a collaboration tutor. However, this is obviously a highly ambitious goal to achieve. Defining all possible interaction patterns and decisions collaborative learners could make ahead of time and defining a "best path" or "buggy paths" through the collaboration space seems to be difficult and perhaps impossible. So far, it is only possible to define positive and negative collaborative behaviors in general terms. The challenge is to find ways to monitor those behaviors based on real-time data collected during student collaboration and have the system respond to the collaborating partners accordingly. While interest in adaptive collaborative learning systems is on the rise in the computer-supported collaborative learning (CSCL) community (Soller, Jermann, Muehlenbrock, & Martinez, 2005), little progress has yet been made on the implementation of adaptive support. In this symposium we present latest results from projects concerned with developing adaptive support for CSCL environments. Wecker and Fischer have taken a first step towards adaptiveness by comparing traditional script support to faded scripting in a CSCL setting under the condition of distributed monitoring. Meier and colleagues conducted a study in which they compared the effects of adaptive feedback vs. generic feedback vs. no feedback on students' subsequent collaboration. Walker, Rummel & Koedinger tackled the challenge of providing intelligent domain support to the peer tutor in a computer-mediated peer tutoring setting. Against the background of a number of empirical

studies with varying degrees of automation, Rose, Kumar, Gweon, Wang, and Joshi discuss the possibilities of providing adaptive support on the basis of automated analysis of conversational data. The former three contributions present experimental studies and exemplify the challenges, but also the gains, of conducting empirical research on adaptive support. Then the contribution by Rose et al. takes a broader view and opens up the stage for a discussion of the possibilities and limitations of achieving adaptive collaboration support.

## Fading of collaboration scripts: Does it foster the acquisition of application-oriented knowledge?

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To foster the acquisition of knowledge that learners can apply easily to solve problems of fields of practice, learners are often required to discuss authentic problems in problem-oriented environments for computer-supported collaborative learning. For example, students of education are asked to analyze cases in which learners face motivational problems by means of psychological theories such as Weiner's attribution theory. This application of theories to solve practical problems requires knowledge of heuristics for applying theories to cases. For example, learners need to derive *diagnoses* of problematic traits of behaviour on the basis of case information and relevant definitions of theoretical concepts. They also need to derive *consequences* such as predictions of future developments or suggestions for interventions from these diagnoses based on general regularities. One approach to foster this kind of reasoning during problem-based learning is collaborative argumentation. However, the quality of argumentation in these contexts is typically low (Stegmann et al., 2007). The instructional approach of collaboration scripts (Kollar, Fischer & Hesse, 2006) was developed as a kind of socio-cognitive scaffolding to overcome these problems and has proven rather successful in increasing the quality of argumentation (e. g. Stegmann et al., 2007). The fading of these scaffolds has been suggested as an important means to enable learners to internalize the information contained in them (e. g. Pea, 2004). It could be demonstrated that distributed monitoring of a learner's steps by a learning partner can increase the effectiveness of fading with respect to the internalization of the target skill (here: argumentation; Wecker & Fischer, 2007). It is still an open question, however, how the fading of such scripts affects the acquisition of more domain-specific application-oriented knowledge and whether distributed monitoring interferes with these effects. These questions were investigated in the present study.

## Methods

The participants were 143 students of education in two designs: One was a group design with "no script", "script" and "script with fading" conditions. Furthermore, a 2x2-factorial design with the factors "fading" (no/yes) and "distributed monitoring" (no/yes) was implemented. In discussion boards for dyads, learners wrote counterarguments to case analyses based on attribution theory. Beforehand, they read texts on the theory and on argumentation. The *script* was implemented in the user interface of the discussion board as text boxes, instructions and explanatory examples. *Distributed monitoring* was implemented by prompting one of the two learners to provide feedback to his or her learning partner's steps in formulating each counterargument. Per dyad one person who had not provided feedback was included in the analysis. *Fading* was implemented mainly by gradually replacing the specific instructions in the script with unspecific ones. First the learners filled in questionnaires and read the texts on attribution theory and argumentation. Then they collaborated for 80 minutes in the learning environment. Finally, they completed the post-tests. *Application-oriented knowledge* was measured based on the learners' own case analyses from the post-test, operationalized as the number of segments containing components necessary for complete case analyses (i. e. proportion of correct diagnoses and number consequences drawn per diagnosis).

## Results

*Effects of script and fading on knowledge on application-oriented knowledge.* The null hypothesis of identical means could not be rejected with respect to the proportion of correct diagnoses ( $F(2; 35) = 2.18; p = .13; \eta^2 = .11$ ), with a lower mean in the script condition. Yet a significant difference was found with respect to the number of consequences drawn per diagnosis, with the highest levels in the script and fading condition, followed by the script condition ( $F(2; 35) = 3.56; p < .05; \eta^2 = .17$ ).

*Effects of fading and distributed monitoring on application-oriented knowledge.* For the proportion of correct diagnoses, a significant main effect fading was found for fading ( $F(1; 57) = 8.66; p < .01; \eta^2 = .13$ ), with higher numbers of consequences in the fading conditions. No main effect for distributed monitoring ( $F(1; 57) = 1.10; n. s.; \eta^2 = .02$ ) and no interaction effect ( $F(1; 57) < 1; n. s.; \eta^2 = .01$ ) could be detected. No effect whatsoever was found for the number of consequences drawn per diagnosis (all  $F(1; 57) < 1; n. s.; \eta^2 = .01$ ).

## Discussion

These results indicate that the effects of a script targeted at a specific skill such as argumentation on application-oriented knowledge can be increased by the fading of the script: In the faded script condition, the balance of diagnoses and consequences in case analyses was more even, thereby yielding more systematic case analyses. Distributed monitoring does not appear to interfere with the positive effects of fading. This finding might be explained by the increased availability of cognitive resources for schema induction through the fading of scripts (cf. Renkl & Atkinson, 2003). Therefore, the fading of scripts in collaborative problem-based learning seems to be an appropriate means to foster multiple instructional goals related to the acquisition of application-oriented knowledge.

## Teaching students how to improve their collaboration: Assessing collaboration quality and providing adaptive feedback in a CSCL setting

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In the present study, we explored the possibility of giving adaptive feedback to students based on an offline assessment of their collaboration on a joint CSCL task with the help of a multi-dimensional rating scheme. The rating scheme is based on the one proposed by Meier, Rummel, & Spada (2007). One goal of our experiment was to test whether the theoretical model underlying our assessment tool would be able to capture the relevant aspects of students' collaboration in a CSCL setting that differs strongly from the one in which the rating scheme had originally been developed (communication channel: chat vs. videoconferencing; task domain: programming vs. medical decision making; group composition: dyads with homogenous prior knowledge vs. interdisciplinary dyads). Most importantly, however, we wanted to use this theoretical model to teach students how to improve their collaboration. This was done by integrating an innovative instructional unit in a regular computer-science class at the University of Patras, Greece. The core of this instructional unit was an adaptive feedback component in a sequence of CSCL activities: Students collaborated on two subsequent tasks in the domain of programming. In between, they received adaptive feedback about their collaboration on the first, based on a feedback scheme that corresponds to the assessment tool's dimensions. Effects of two different kinds of feedback, either generic or adaptive, were assessed in students' collaboration on the second task in a between-subjects design. We expected that giving feedback that is adapted to an assessment of students' collaboration quality would help students to focus on those aspects of their collaboration that need the most attention, and thus would be more effective than information about what constitutes successful collaboration in general. Thus, even though giving adaptive feedback requires instructors to invest more time and effort, we hope to show that it will also lead to better teaching results. Data analysis in this experiment is still under way, but the first observations made during its implementation are promising.

## Method

46 first-year computer science students of the University of Patras, Greece, participated on a voluntary basis. 23 homogenous dyads were formed based on the prior knowledge. The same student dyads collaborated on two tasks, in two consecutive weeks, as part of an introductory programming course. All students interacted through Synergo (Avouris, Margaritis, Komis, 2004), a network-based, synchronous, collaborative drawing tool including a shared whiteboard for building the algorithm flow-chart, and a chat for exchanging short messages. Synergo includes a playback tool which allows a reliable reproduction of the activity using sequential event logfiles. In that way, evaluators can review the whole activity, navigate through different episodes, and assess the quality of students' collaboration. The experiment lasted four weekly lab sessions; the two CSCL tasks were given two students in the second and third week, respectively. In both tasks, students were asked to collaboratively build a diagrammatic representation (flow-chart) of an algorithm in Synergo, based on a written description of its properties and behavior. The first task introduced the loop structure as a new concept. The second task used the same algorithmic structures, but was more difficult to implement.

The quality of students' collaboration on the first CSCL task was assessed on the six dimensions of the adapted rating scheme: *collaboration flow* (i.e. the degree to which students actions and/or utterances build upon each other), *sustaining mutual understanding* (i.e. working towards "common ground"), *giving explanations* (i.e. self- and other-directed explanations), *argumentation* (i.e. engaging in a critical discussion), *structuring the problem solving process* (i.e. coordination of activities, including time management), and *cooperative orientation* (e.g., constructive handling of disagreements). These dimensions were similar in their purpose and

scope to a subset of the original nine dimensions of the rating scheme by Meier et al. (2007), but had been defined and illustrated with examples to fit the new CSCL setting.

The corresponding *feedback scheme* contained a generic description, a positive feedback module and a negative feedback module for each of the six dimensions. For example, the generic module for “giving explanation” read: “It is important for you to learn from your partner’s knowledge, and let him learn from you. Therefore, ask for explanation if you have not completely understood what your partner is doing, and be sure that you explain understandably your own actions and reasoning.” The positive feedback for the same dimension was: “Your activities show that you are putting effort into explaining to each other what you are doing. Keep up with this good practice!”; and the negative feedback was: “Your activities show that you need to give more explanations of what you are doing in order to improve the quality of your collaboration and your joint solution.” Prior to their collaboration on the second task, students received domain specific feedback on typical mistakes, and feedback on their collaboration according to experimental condition: Dyads in the *generic feedback* condition received only the generic feedback for each dimension, in the form of a short instructional text. They were told that this was general advice on how to collaborate well. Dyads in the *adaptive feedback* condition received adaptive feedback in addition to the generic feedback. Adaptive feedback was selected by determining the two dimensions with the highest ratings and the two dimensions with the lowest ratings. Ambiguities were resolved by a set of rules and a hierarchy of dimensions. The positive feedback modules were added to the generic feedback for the two “best” dimensions and the negative feedback modules were added to the generic feedback for the two “worst” dimensions. Dyads in the *control condition* received no feedback on their collaboration, only task-specific feedback. However, they were encouraged to discuss their collaboration on the first task with each other. Students in all conditions were informed that the feedback was based on careful observation of their collaboration on the first task. Dyads in all conditions were given 20 minutes to read the feedback and to discuss what they could do to improve their collaboration in the upcoming task.

## First Results and Outlook

Data analysis in this experiment is still under way, so only some preliminary observations can be reported. First of all, the adaptation of the rating scheme to the new CSCL setting was successful: The two raters involved in assessing students’ collaboration on the first task report that the dimensions were able to capture the most important aspects of students’ collaboration, and that it was helpful in selecting the adaptive feedback. Measures of inter-rater reliability for the rating scheme are currently being obtained in a sample of logfiles from both tasks and all three conditions. Students accepted the adaptive feedback given to them based on these ratings as genuine, and discussed it actively. On the other hand, students in the remaining conditions, in particular the control condition, reported that they found it difficult to think of ways in which they might improve their collaboration on the second task. Therefore, we are optimistic that our analysis of students’ collaboration on the second task will confirm our expectations that feedback, in particular of the adaptive kind, was effective in helping students to collaborate better. We will look in detail into the effects of generic versus adaptive feedback on students’ discussion of their past and upcoming collaboration, and their actual interaction during the second task. We see further potential use of our rating and feedback schemes in teaching students how to improve their collaboration as part of their general curriculum, but also in training teachers to provide adaptive feedback on students’ collaboration.

## Adaptive Domain Support for Computer-Mediated Peer Tutoring

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Reciprocal peer tutoring, where two students of similar abilities take turns tutoring each other, has been shown to promote the domain learning of students involved (Fantuzzo, Riggio, Connelly & Dimeff, 1989). For tutoring to be effective, the peer tutor must provide conceptual, elaborated help (Fuchs et al., 1997) that addresses tutee misconceptions (VanLehn, Siler, Murray, Yamauchi, & Bagget, 2003) and ultimately guides the tutee to a correct solution. Previous efforts at assisting peer tutoring have focused on training peer tutors or structuring the tutoring process; for example, King, Staffieri, and Adelgais (1998) found that having students ask each other a series of questions at different levels of depth had a significantly positive effect on tutor learning. Adaptive support for the peer tutor may be an improvement over these fixed approaches, as it would provide help tailored to individual peer tutors at the moments when it is most needed. We have been taking steps in this direction by augmenting the Cognitive Tutor Algebra (Koedinger, Anderson, Hadley, & Mark, 1997), a successful intelligent tutoring system, with peer tutoring activities. The domain models of the tutoring system,

which typically provide algebraic help, can then be leveraged in order to provide adaptive domain support to the student collaboration. The following paragraphs describe the design and effects of this adaptive domain support.

## Design of Adaptive Domain Support

During typical classroom use of the Cognitive Tutor Algebra, students can ask for a hint from the intelligent tutoring system at any time, and receive immediate feedback on errors as they solve problems. In the design of domain support for collaboration, we balanced two competing concerns: students should have similar access to domain help as in individual use of the intelligent tutor, but the interaction between collaborators should be encouraged by the tutoring system, not constrained or disrupted. Therefore, just like in individual use, domain hints are available on demand. However, unlike individual use of the tutor, hints are requested by and given to the peer *tutor*, and the person solving the problem (the peer *tutee*) must interact with the peer tutor via chat in order to receive the help. In the process of communicating the hint to the peer tutee, the peer tutor could learn by interpreting the hint and explaining it in a way that addresses the peer tutee's impasse. Similarly, system feedback is given based on peer tutor responses rather than tutee problem-solving actions, and is displayed only to the peer tutor (e.g., when a peer tutor marks a step correct when it is wrong, as in Figure 1). Both hints and error feedback consist of a prompt for students to interact, followed by the domain help individual learners would ordinarily receive. This collaborative feedback was implemented through the development of a separate *collaborative tutor* module to augment the cognitive tutor module. Every time that the peer tutee takes an action in the interface, the response by the cognitive tutor is stored in the collaborative tutor, rather than presented as feedback to the peer tutee. Then, when the peer tutor takes an action in the interface by marking a step right or wrong, the collaborative tutor compares the peer tutor's action on that particular widget to the stored cognitive tutor's response for the widget. If the two actions fail to match, then the collaborative tutor sends the peer tutor the feedback shown in Figure 1. Similarly, the collaborative tutor module stores the hint that the cognitive tutor would have sent for each step, and presents it to the peer tutor on demand, along with a prompt to collaborate.

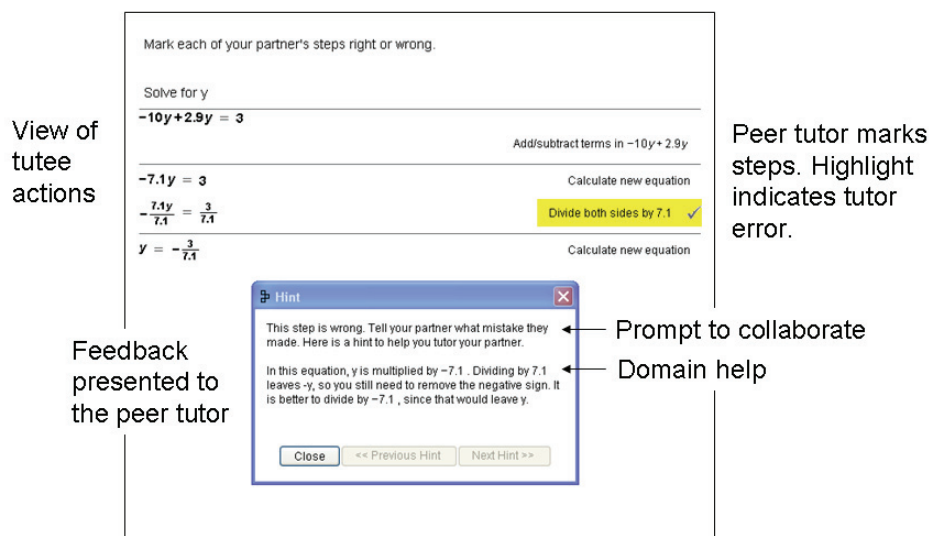


Figure 1. Equation solver subsection of peer tutor interface. Full interface also contains chat window.

## Method

We conducted a classroom study in five second-year algebra classes in which we compared three conditions: In the *adaptive condition* students tutored each other with adaptive support and problem answers available (17 participants), In the *non-adaptive condition* students tutored each other simply with problem answers available (14 participants), and in the *individual condition* students used the cognitive tutor individually (20 participants). To evaluate the effects of the adaptive domain support, we examined how student learning and progression through the intervention problems was affected by student collaboration and type of support. We hypothesized that collaborating students would solve fewer problems successfully than students working alone, potentially due to the increased interaction between the peer tutor and the tutee. However, the number of attempts made per problem should be similar for collaborating students given adaptive support and individual learners, as both conditions would have access to the same cognitive tutor help. Attempts per problem should be greater for collaborating students without adaptive support, as those students would not have as much access to help. The adaptive condition should have a greater effect on learning than the non-adaptive and individual conditions because it provides the advantages of both collaboration and of domain feedback.

## Results and Discussion

In line with our hypotheses, our analyses indicate that number of problems solved per hour in the individual condition was greater than the number of problems solved per hour by dyads in the non-adaptive support condition and adaptive support condition ( $M_s = 47.04, 13.33, 17.65$ ;  $SD_s = 30.24, 7.71, 5.69$ ;  $F(2,34) = 8.64$ ;  $p < .01$ ), but surprisingly, the total number of incorrect attempts per problem made by each student over the intervention was not significantly different between conditions when pretest was considered as a covariate ( $M_s = 1.46, 1.81, 2.46$ ;  $SD_s = 1.26, 1.04, 1.87$ ;  $F(2, 47) = 2.480$ ;  $p = .1$ ). Although all students learned from pretest to posttest, there were no significant differences in learning gains between conditions.

The results indicate that students progressed similarly through the problems in all conditions, and therefore that the domain support given to peer tutors was sufficient for facilitating the tutoring interaction. However, it is surprising that the attempts per problem in the non-adaptive and adaptive conditions were equivalent. Further analysis is necessary to look both at problem-solving behaviors at different intervention phases, and at how students used the help that was provided. In summary, we have leveraged existing domain models to develop a collaborative tutor that provides adaptive domain support for peer tutoring. This technology will serve as a promising basis for the development of more sophisticated adaptive scripting.

## Open Problems in Dynamic Collaborative Learning Support

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State-of-the-art forms of collaboration support play a role similar to training wheels on bicycles. As is well known, however, training wheels must eventually come off. And typically, they are removed by a watchful parent, who may decide after watching their child fall a few times, to put them back on for a time until the child has developed further in their own coordination and balance. In a similar vein, the learning sciences literature tells us that scaffolding should be faded over time (Collins, Brown, & Newman, 1989), and that over-scripting or unnecessary support may be detrimental to collaboration or demotivating (Dillenbourg, 2002).

This model of a watchful parent requires that the collaborative learning environment is able to track what is happening in the collaboration between students. Thus, a major goal of our research is to support collaboration in a way that is responsive to what is happening in the collaboration rather than behaving in a “one size fits all” fashion. For example, rather than providing prompts to elicit reflection from students whether or not they have already shown evidence of doing so spontaneously, we aim to monitor the behavior of students, and prompt positive behaviors that are lacking or discourage negative behaviors we detect. To this end, we have made substantial progress towards automatically replicating multi-dimensional process analyses of collaborative learning discussions (Wang, Joshi, & Rosé, 2007; Rosé et al., in press), towards tracking topics discussed in collaborative discussions (Wang & Rosé, 2007; Kumar, Rosé, Wang, Joshi, & Robinson, 2007), and estimating level of learning during conversations (Joshi & Rosé, 2007). A running theme through this work has been the development of a methodology for creatively encoding the raw conversational data in such a way that enables state-of-the-art machine learning technology to identify consistent and generalizable patterns in the data. In addition to developing basic technology to support our own work, we have also worked towards providing resources to other researchers interested in the problem of dynamic collaborative learning support by developing the publicly available TagHelper tool set (<http://www.cs.cmu.edu/~cprose/TagHelper.html>) as well as a distance course called Machine Learning in Practice (<http://www.cs.cmu.edu/~cprose/MachineLearningInPractice.html>).

With this technology in hand, we have begun to move past the traditional one-size-fits-all non-adaptive approaches to collaboration support. As part of our experimental approach, we have typically contrasted individuals and pairs, with and without support, where students communicated with each other and with the interactive support within a typed chat interface. Our purpose for doing so was to separate the direct effect of the support on learning from the indirect effect it has on learning by improving collaboration. We have conducted a series of studies in which we experimentally investigated foundational issues related to the design of dynamic support for on-line collaborative learning (Gweon, Rosé, Zaiss, & Carey, 2006). One question we started with was whether the context sensitive support, because it would be offered much less frequently than “one-size-fits-all” support that is administered whether it is needed or not, would result in any significant effect on the learners’ experience whatsoever. Fortunately, these initial investigations demonstrated that explanation elicitation prompts delivered strategically, on an as needed basis, were effective for eliciting explanation attempts as well as increasing learning in a collaborative learning setting. Moving beyond simple prompts to interactive instructional agents that can engage students in reflective dialogues, we have also run two successful pilot studies in which we used these dialogue agents to deliver interactive support to collaborative learners when triggered by an automatic analysis of the collaborative learning discussions as they unfolded (Wang & Rosé,

2007; Kumar et al., 2007). In both of these successful studies, the fully automatic interactive support lead to significant increases in learning in comparison to a control condition where students worked individually and did not have the interactive support, in one case achieving an increase in learning gains of 1.24 standard deviations above that of the control condition.

While our results with dynamic collaborative learning support to date have been encouraging, close inspection of the conversational data from our recent investigations with that technology indicate that we have far to go to reach our ultimate goal. For example, although in one study we determined that students with dynamic support were more likely to engage in transactive forms of conversation (Wang & Rosé, 2007), in another study (Kumar et al., 2007) we noticed that although the degree to which students engaged in transactive patterns of discussion correlated with their learning, the condition where students received the dynamic support for collaborative learning showed marginally lower levels of transactive discussion although the students in that condition learned significantly more than in the control condition. Furthermore, although the conversational agents that delivered the support were effective for increasing reflection and learning with students whether or not they were working collaboratively, students who worked individually appeared to engage more deeply in their interaction with the agents, whereas students who worked in pairs tended to “talk around” the agents rather than treating them as participants in the conversation the way the individual students did, although positive effects of the agents on learning demonstrate that the students are not ignoring the content of the agent’s utterances. Thus, we see that the three way interaction between pairs of students and the collaborative support agents is not as effective as it could be. Overall, students benefit most from working together with the support of the agents, although the agents somewhat degrade the quality of the interaction between students in some cases, and similarly the collaboration sometimes interferes with the interaction the students have with the agents. Furthermore, evidence from questionnaire data and informal discussions with students indicate that students perceive the conversational support agents as an interruption. We suspect that the fact that the support we are offering is seen as an active part of the interaction rather than a passive part of the environment in which the interaction takes place changes the way it affects the conversational behavior of the students. While much valuable work investigating the design space for static forms of support for collaborative learning provides a valuable starting place for our investigation, a continued effort is needed. Thus, a major focus of our current work is on investigating the design space for interactive agents for supporting collaborative learning processes, and more recent results offer evidence that agents with richer conversational behaviors are more effective for engaging student attention in a collaborative learning context.

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