Learning to Collaborate in a Computer-Mediated Setting: Observing a Model Beats Learning from Being Scripted

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Abstract: In an earlier study we had tested if observing a model collaboration or following a collaboration script could improve students' subsequent collaboration in a computer-mediated setting and promote their knowledge of what makes good collaboration. Both model and script showed positive effects. The current study was designed to further probe the effects of model and script by comparing them to conditions (model-plus, script-plus) in which the learning was further supported by providing elaboration support (instructional prompts and guided self-explanation). 40 dyads were tested, 8 in each of the following conditions: model plus elaboration, model, script plus elaboration, script, control. Observing a model collaboration with elaboration support yielded the best results over all other conditions on several measures of the quality of collaborative process and on outcome variables. Model without elaboration was second best. The results for the script conditions were mixed; on some variables even below those of the control condition.

Introduction

In the face of a growing specialization of knowledge, collaboration of specialists from different disciplines is required in many learning and working contexts. And often these people will be spatially distributed, making it necessary for them to use modern communication technologies to collaborate at the distance. Take the following example: Some symptoms can indicate both a physical as well as a mental diagnosis, making it difficult for an individual psychologist or physician to devise the correct diagnosis and, in consequence, a suitable treatment. Hence, the collaboration of psychologists and physicians is increasingly regarded to be of importance for the well-being of patients. Then, a relevant question is how to encourage and support collaboration among locally distributed medical and psychological practices. In this context video conference systems have been advocated as a particularly suitable solution (Köhler & Trimpop, 2004). Video-mediated communication systems support complex synchronous interactions (Finn, Sellen, & Wilbur, 1997). Participants in different locations can communicate via audio-video connection. In addition, application sharing technologies add the possibility to not only view, but also jointly edit text or visual material.

Ample research has demonstrated that collaboration can be effective for improving problem-solving and learning (Dillenbourg, Baker, Blaye, & O'Malley, 1995, Slavin, 1992). However, this research has also made it clear that not all collaboration is effective, but that the fruitfulness of collaboration depends on characteristics of the interaction (Dillenbourg et al., 1995). Effective collaboration must be learned and requires guidance, instruction, and training (Slavin, 1992). And this is even more so when the challenges of a computer-mediated and interdisciplinary interaction are added to those of collaboration as such (Rummel & Spada, 2005).

Over the past years, numerous research projects in CSCL and CSCW have investigated ways to provide support for computer-mediated collaboration. In this context, our research focuses in particular on pedagogic support measures, i.e. measures that aim at instructing collaborators in ways that enable them to collaborate well and with success subsequently. In a first experimental study (Rummel & Spada, 2005) we tested providing a collaboration model or a collaboration script as instructional methods to promote graduate students ability to collaborate well and with good results in a complex computer-mediated setting and their knowledge of what makes good collaboration. Compared to two control conditions (one with the possibility to learn from prior unsupported practice, and one without any prior learning experiences) both model and script showed positive effects on three levels: (a) the collaborative process (i.e. the way dyads collaborated), (b) the outcomes they obtained, and (c) their individual knowledge about characteristic features of a good collaboration assessed in a posttest. The current study was designed to probe the learning effect of model and script further by supporting elaborative/ meta-cognitive processing of the relevant, instructional elements.

Two Pedagogic Approaches to Instructing Collaboration: Model and Script

One pedagogic approach to instructing people about how to best collaborate, is to provide them with a model of a successful computer-mediated collaboration. The idea behind this approach is that, as they observe the solution steps and the behavior of the model partners, collaborators may learn what aspects to pay attention to during their own future collaboration. Evidence from different strands of research supports this assumption (observational learning: Bandura, 1977; learning from worked out examples: Renkl, 1997; learning from exemplary dialogs: Cox, McKendree, Tobin, Lee, & Mayes, 1999). We refer to the model collaboration as "worked-out collaboration example". This indicates that it was specifically designed to exemplify aspects deemed constitutive of a good collaboration. Such aspects were identified by means of a review of research on collaborative problem-solving and learning (Rummel & Spada, 2005). An "exemplary collaboration" was derived from the literature review and, consequently, a screenplay was written incorporating the relevant theoretical aspects. When writing the screenplay for the current study, we also made use of excerpts of collaboration recordings from our earlier study (Rummel & Spada. 2005). The screenplay was then executed as a dialog by professional actors, and recorded. The recorded model dialog was integrated with text animations illustrating the development of the joint (model) solution. A multimedia presentation resulted, similar to a video, however divided in a number of discrete scenes (i.e. phases of the collaboration). Throughout the scenes, the model presentation illustrated how the model collaborators went about coordinating their collaboration, how they managed their time, and how they made use of their complementary domain knowledge in the problem-solving process. An important feature of our model collaboration was the alternation between individual and collaborative work, which had proven to be a determining factor for a successful collaboration, particularly in the case of complementary expertise of the partners (Rummel & Spada, 2005).

The second pedagogic approach we have taken relates to a well-researched measure to support collaboration: collaboration scripts (face-to-face collaboration: O'Donnell, 1999; computer-mediated settings: Fischer, Mandl, Haake, & Kollar, in press). The main idea of collaboration scripts is to prompt cognitive and social processes by participants that might otherwise not occur, thus enforcing a fruitfully structured interaction, and consequently improving the joint problem-solving and knowledge acquisition. However, collaboration scripts have also been criticized (Dillenbourg, 2002) for dictating interaction in a coercive way. Negative motivational effects may be expected in particular if collaboration is scripted over an extended period of time and over many collaborative sessions (Rummel & Spada, in press). Against this background we have raised the question if the central elements of a collaboration script could be learned from a scripted session. Such sustainable learning effects would make it unnecessary to continue the scripting and risk motivational drawbacks, but collaborators could themselves maintain a fruitful collaboration following the internalized script rules. The results of our first study (Rummel & Spada, 2005) supported our hypothesis that collaboration scripts can trigger learning about collaboration and thus improve subsequent collaboration. Our script was designed to be structurally equivalent to the model collaboration, that is, it instructed participants to engage in the same activities that were demonstrated by the model collaborators. For example, while participants observing the model collaboration would listen to the model collaborators clarifying questions about the patient case at the beginning of their collaboration, participants in the script condition were instructed to do this together with their partner.

Promoting Elaboration during Learning from Model and Script

To summarize: we had established that observing a collaboration model or alternatively following a collaboration script during an initial collaboration can be effective in improving a subsequent unsupported collaboration (Rummel & Spada, 2005). However, there was reason to believe that learning from both model and script could be further improved by providing elaboration support. As Bandura (1977) pointed out, observational learning depends to a great extent on paying attention to the relevant model stimuli, cognitively organizing and rehearsing what has been observed. Also, in research on learning from worked-out examples, self-explanations and instructional explanations have been shown to improve the processing of the examples and, consequently, learning of the demonstrated problem-solving strategies (e.g., Renkl, 2002). For the script side, the cognitive apprenticeship approach (e.g. Collins, Brown, & Newman, 1989) indicates that reflective elaboration of relevant script features might be a promising measure to promote its internalization and acquisition as a standard of subsequent collaboration. In this research, open verbalization and reflection about one's own behavior have proven to be important scaffolding strategies to support the acquisition of complex cognitive skills.

Providing specifically targeted support in order to promote learning from instructional material has been shown to be of great value in a variety of instructional contexts. Of major relevance for the research presented here are findings concerning two means to promote elaboration and learning in particular, and on the way these two should be combined: (1) instructional prompts, and (2) guided self-explanations. *Instructional prompts* are short, attention-guiding explanations provided immediately before or after content is presented. They can be either descriptive, i.e. giving a short summary or paraphrase, or principle-based, i.e. pointing to the core elements or principles underlying the learning contents. Decker (1984) has shown the effectiveness of instructional prompts – he calls them "learning points" – for learning complex social skills, such as conflict management skills, from observing model videos. Renkl (2002) provided evidence for the relevance of instructional prompts in learning from worked-out examples. Secondly, a great number of studies have demonstrated the effectiveness of *self-explanations* in supporting learning (e.g. Chi, Bassok, Lewis, Reimann, & Glaser, 1989). However, it has also become clear that self-explaining activities do not occur naturally, but that they have to be prompted and guided (Renkl, Stark, Gruber, & Mandl, 1998). Recently, collaborative self-explanations have been shown to be a particularly powerful way of supporting learning (Chi & Roy, 2006). In their study, students who collaboratively self-explained while observing recordings of a tutor tutee interaction learned more than individuals. Finally, Renkl and his research group (e.g. Hilbert, Schworm, & Renkl, 2004) demonstrated that for best learning results a transition should be made from providing instructional prompts to prompting self-explanations.

In accordance with the above findings, in the current study we implemented elaboration support for learning from model or script in the following way. *Instructional prompts* directing the learners' attention to the relevant underlying principles were provided preceding each model scene and each script phase. More specifically, participants in the model conditions were advised what they were going to *observe next*, whereas participants in the script conditions were pointed to the relevance of what they were going *do next*. Then, following the model presentation or the scripted collaboration, a *collaborative self-explanation* phase took place in which dyads were encouraged to recapitulate the model collaboration or alternatively their scripted interaction and reflect on what aspects had been important for a successful collaboration.

Method

Collaborative Scenario and Computer-Mediated Setting

Dyads comprised of one medical student and one psychology student were asked to collaborate in a computer-mediated setting and to jointly develop a diagnosis for complicated psychiatric cases. Two patient cases were designed to require medical *and* psychological domain knowledge in order to arrive at the correct diagnosis (i.e. the complementary domain knowledge represented in each dyad). For example, in case 1 the patient suffered from cardiac dysrhythmia, but also showed symptoms of a panic disorder. The contents of the two cases did not overlap so that no transfer of content knowledge was possible from case 1 to case 2. The dyads collaborated via a desktop videoconferencing system including personal text-editors and a shared text-editor.

Experimental Design

The experiment was composed of two phases. During the *learning phase* the experimental variation was implemented. Five conditions were realized: model-plus, model, script-plus, script, control. Participants in the *model-plus* and the *script-plus* condition received additional elaboration support during the learning phase: in addition to the model or the script they were provided with instructional prompts and were guided to engage in self-explaining activities. In the second phase of the experiment, i.e. the *test phase*, dyads in all conditions collaborated without further support. In this phase dependent measures were assessed on three levels: (a) the collaborative process, (b) the outcome of the collaboration, and (c) the individuals' knowledge of important aspects of a good collaboration.

Participants

The sample consisted of 40 dyads in total, specifically 8 dyads in each condition. Dyads were randomly assigned to one of the five conditions. Each dyad was composed of one student of psychology and one medical student. Students were recruited during lectures and seminars; they received a financial compensation for their voluntary participation. All students were at an advanced level of proficiency in their studies.

Procedure

After an initial introduction, all participants received training with the computer-mediated setting. Next the learning phase was administered. Participants in the *model condition* observed worked-out scenes of the collaboration between a psychology student and a medical student on diagnosing case 1. The model collaboration was delivered as a multimedia presentation on the computer screen. Dyads in the *script condition* were guided through their collaboration on case 1 by a collaboration script giving them instructions for their interaction. Each phase of the script was allotted a particular time frame. The script was provided on a second computer screen located next to the one that participants used for their collaboration (i.e., the videoconference and the text editors). The *model-plus* and the *script-plus* conditions were implemented correspondingly. In addition to the instruction provided by observing the model or alternatively working with the script, the participants in these conditions were provided with elaboration support as described above. Dyads in the *control condition* collaborated without further instructional support during both the learning and the test phase. The participants returned one day later for the test phase and the post test. During the test phase, all dyads collaborated on case 2 without further instruction. Finally, each individual filled out the posttest and a questionnaire. During both learning and test phase, the two partners of each dyad were seated in different rooms and collaborated via the desktop videoconference.

Dependent Variables

The *collaborative process* during the test phase was assessed employing a rating scheme that had been developed in the course of the process analyses for the first study (for more details, see Meier, Spada, & Rummel, submitted). It allows to assess collaborative process in an economic fashion from the video recordings and combines a qualitative with a quantitative approach. When looking at the video recording of a dyad's collaboration, process quality was assessed on nine dimensions: sustaining mutual understanding, dialog management, information pooling, reaching consensus, task division, time management, technical coordination, reciprocal interaction, and individual task orientation (assessed for both partners individually). The dyads collaboration was rated for each dimension on a five-point rating scale ranging from 0 (very bad) to 4 (very good).

The *outcome* of the collaboration, that is, the joint diagnosis for case 2, was blind-rated by an expert who had no knowledge of the study's rationale and experimental design. The expert graded the diagnoses of all dyads on a scale from 5 (highest grade) to 1 (lowest grade) with intermediate steps at x.3 and x.7 (this partition is common in the German grading system).

The *posttest* was filled out by each participant individually. It included an open-format question asking participants to describe to colleagues who were going to collaborate on a similar task how they should proceed in order to collaborate successfully. Participants' answers to this question were assessed by applying a checklist; a maximum of 16 points could be achieved.

Finally, each student filled out a *questionnaire* including a translated and adapted version of the Intrinsic Motivation Inventory (IMI; http://www.psych.rochester.edu/SDT/measures/intrins.html) based on the motivation theory by Deci and Ryan (1985), and a number of items to evaluate participants' experiences with the experimental setting. The IMI is composed of six subscales: interest/enjoyment, perceived competence, effort, value/usefulness, felt pressure and tension, and perceived choice. Each subscale consisted of four items, which were rated by participants on a six-point rating scale (ranging from 1 = not at all true to 6 = very true). The reliability of all scales proved to be satisfactory (Cronbach's alpha ranging from $\alpha = 0.75$ to $\alpha = 0.90$).

Results

Table 1 gives an overview of the results that yielded significance ($\alpha = .05$) or showed a clear trend. Compared to the control condition, the model and the script conditions showed positive effects on dyads' collaboration during the test phase. Particularly clear effects were found on process variables concerning the planning and coordination of the collaboration (task division, time management). The dimensions "information pooling" and "technical coordination" revealed the same result pattern, but did not reach statistical significance. On the other hand, the script conditions performed lower than the model conditions, and partly even lower than the control condition, on several variables. Their collaborations were rated lowest on one particular process dimension: individual task orientation (both for the psychology student, P, and the medical student, M). This process dimension aims at shedding light on a motivational aspect, the individual persons' task alignment:

> Last but not least the collaborative process will reflect participants' individual motivation and their commitment to their collaborative task.…, individual collaborators may employ volitional strategies in order to keep up a high level of expended effort in their contribution toward the joint task, including focusing one's attention on solution relevant information, keeping one's environment free of distractions, or nurturing positive expectations regarding the collaborative outcome (Heckhausen, 1989)." (Meier, Spada, & Rummel, submitted).

The result may thus indicate that dyads in the script conditions experienced motivational problems during their collaboration in the test phase. Interestingly, the self-report of motivation assessed by the IMI did not reveal such effects. We will come back to this result in the discussion. Yet another result points in the same direction: on the questionnaire items asking how useful participants' had found the learning phase (=phase 1) for their collaboration in the test phase (=phase 2) and if they had tried to transfer experiences from the learning phase to the test phase (see bottom of Table 1), script participants gave the lowest ratings. The script conditions also performed lowest on the individual knowledge posttest, and with regard to the quality of their joint diagnosis evaluated by the expert rating (see Table 1). The latter result did, however, not reach statistical significance. A different result pattern was found on the "pressure/tension" subscale of the IMI. Participants in the script conditions expressed they had felt less pressure/tension during their collaboration in the test phase, that is, their second – but first unscripted – collaboration. On the contrary, model condition participants expressed the highest amount of felt pressure/tension during their collaboration in the test phase, which in fact was their first collaboration. Overall, the ratings on this variable were relatively low (max possible was 6). We will discuss this result below. The model-plus condition showed better performances than the model condition on all variables listed in Table 1, with exception of the quality of the joint solution. A similar effect of the elaboration support could not be shown for the script-plus condition.

Table 1. Overview of results

	Model-plus	**Model**	**Script-plus**	**Script**	**Control**		
Collaborative process (N=40)	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**M (SD)**	**F (p)**	**η²**
Information pooling	2.75 (0.71)	2.69 (0.74)	2.25 (0.61)	2.52 (0.72)	1.88 (0.73)	2.09 (.10)	.19
Task division	3.13 (0.56)	2.58 (0.85)	2.13 (1.00)	2.08 (0.87)	1.29 (0.49)	6.04 (<.001)	.41
Time management	3.04 (0.86)	2.25 (0.98)	2.00 (0.84)	1.71 (0.68)	0.83 (0.56)	8.10 (<.001)	.48
Technical coordination	3.33 (0.31)	2.83 (0.69)	2.83 (0.67)	2.83 (0.59)	2.42 (0.58)	2.47 (.06)	.22
Individual task orientation (P)	3.08 (0.24)	2.92 (0.53)	2.38 (0.55)	2.38 (0.60)	2.50 (0.25)	4.08 (.01)	.32
Individual task orientation (M)	2.96 (0.45)	2.88 (0.59)	2.08 (0.79)	2.38 (0.68)	2.54 (0.50)	2.75 (.04)	.24
Collaborative outcome (N=40) Quality of joint diagnosis	3.40 (0.90)	3.96 (0.68)	3.09 (0.99)	2.76 (0.96)	3.26 (0.99)	1.89 (.13)	.18
Individual posttest (N=80) Knowledge about good collaboration	8.63 (1.32)	6.75 (1.97)	6.09 (1.46)	6.09 (1.99)	6.47 (1.42)	6.46 (<.001)	.26
Questionnaire (N=80)							
IMI scale "Felt Pressure/Tension"	3.38 (1.43)	3.15 (1.29)	2.21 (1.00)	1.88 (0.64)	2.44 (1.06)	5.13 (.001)	.22
Items assessing experience with setting Phase 1 useful for phase 2	5.38 (0.50)	4.69 (1.25)	4.60 (1.24)	4.00 (1.54)	4.73 (0.96)	2.62 (.04)	.13
Tried to transfer phase1 to phase 2	5.00 (0.63)	3.75 (1.24)	3.20 (1.08)	3.17 (1.27)	4.40 (1.30)	7.39 (<.001)	.30

Discussion

Learning from observing a *model* once again was demonstrated to be a powerful pedagogic approach when trying to promote good collaboration in a computer-mediated setting. Dyads in the model conditions showed good collaborative behaviors and were able to put what they had learned about collaboration into words in the posttest. They also yielded the best results with regard to the quality of the joint solution; however, this result did not become statistically significant. It is noteworthy that the model conditions achieved these results against the background of a highly complex (computer-mediated and interdisciplinary) collaborative setting, and despite having observed only one single model collaboration. In fact, model participants experienced a relatively high amount of pressure compared to the other conditions when trying to put into practice what they had learned during collaboration in the test phase. This is illustrated by the only significant effect found on the Intrinsic Motivation Inventory (IMI): the one for the pressure/tension subscale. The results of the current study have also provided some evidence that elaboration support can further improve learning from a collaboration model.

In contrast, the learning effects that had been demonstrated for the *script* condition in our first study could not be replicated to the same extent. While script condition dyads did show indications of having benefited from their first, scripted interaction in their collaborative behaviors in the test phase, these effects were not reflected in the quality of their joint solution. Nor were participants able to make their tacit knowledge about good collaboration explicit very well in the posttest. So what have they learned during their scripted interaction on case 1? Possibly the concurrent demands of collaborating on the case, following the script instructions, and trying to reflect on the scripting on a meta-level in order to learn, were too high. Then, the additional elaboration support in the script-plus condition obviously could not aid here as it added another layer to the already high demands. The result that students expressed having felt little pressure during their collaboration in the test phase, might thus be an indication of the relief they *experienced* when allowed to collaborate freely in the test phase. On the other hand, dyads' *observable behavior* during their collaboration in the test phase assessed by our process dimension "individual task orientation" indicated that they were less motivated than students in the other conditions. But why did such motivational problems not reveal in the IMI? In fact, the IMI scales did not reveal much at all. Students rated positive subscales high (e.g. interest/enjoyment subscale) and negative subscales low (e.g. pressure/tension) on average. Also, no other IMI subscale but "pressure/tension" revealed any differences across conditions. Self-report scales entail the danger that individuals attempt to present themselves in certain way. The necessity to take into account psychological dynamics such as self-presentation or reactance is also mentioned explicitly by the authors of the IMI (see http://www.psych.rochester.edu/SDT/measures/intrins.html). Then, it might well be that the external rating of a person's motivation as it can be inferred from utterances or actions in the context of a given situation is more objective than the person's self-report.

In sum, the results of the current study are notable given the complexity of the setting and the relatively small number of dyads in each condition. The promising main effect that could be established in both of our studies is that collaboration can be improved through instruction. Whether the learning effects do sustain over time was not tested by our studies hitherto. We think this could be best investigated in a real-world collaboration setting. In conclusion we would like to emphasize that observing a model appears to be a very powerful pedagogic strategy even when instructing complex social skills. This may point a promising direction for research on learning from worked examples. However, a caveat: the time expenditure for developing such models is very high. Secondly we would like to plea for caution when advocating the beneficial effects of collaboration scripts. Collaboration scripts have recently become quite fashionable in CSCL research – and indeed: scripted interactions often lead to better results than unscripted ones. However, so far not many researchers have been concerned with the question of how scripting affects learners' interactions *after* the termination of the scripting. The inconsistent results with regard to learning effects of collaboration scripts that we have found in our two studies clearly call for more research on this question.

References

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, NJ: Prentice Hall.

Chi, M. T. H., Bassok, M., Lewis, M. W., Reimann, P., & Glaser, R. (1989). Self-explanations: How students study and use examples in learning to solve problems. *Cognitive Science, 13*, 145-182.

Chi, M. T. H. & Roy, M. (2006). Learning from observing tutoring collaboratively: Insights about tutoring effectiveness from vicarious learning. Manuscript submitted for publication.

Collins, A., Brown, J. S., & Newman, S. E. (1989). Cognitive apprenticeship: Teaching the crafts of reading, writing, and mathematics. In L. B. Resnick (Ed.), *Knowing, learning, and instruction* (pp. 453-494). Hillsdale, NJ: Lawrence Erlbaum Associates.
Cox, R., McKendree, J., Tobin, R., Lee, J., & Mayes, T. (1999). Vicarious learning from dialogue and discourse. *Instructional Science, 27*, 431-458.
Deci, E. L., & Ryan, R. M. (1985). Intrinsic motivation and self-determination in human behavior. New York: Plenum.
Decker, P. J. (1980). Effects of symbolic coding and rehearsal in behavior-modeling training. *Journal of Applied Psychology, 65,* 627-634.
Dillenbourg, P. (2002). Over-scripting CSCL: The risks of blending collaborative learning with instructional design. In P. A. Kirschner (Ed.), *Three worlds of CSCL. Can we support CSCL* (pp. 61-91). Heerlen: Open Universiteit Nederland.
Dillenbourg, P., Baker, M., Blaye, A., & O'Malley, C. (1995). The evolution of research on collaborative learning. In P. Reimann & H. Spada (Eds.), *Learning in humans and machines: Towards an interdisciplinary learning science* (pp. 189-211). Oxford: Elsevier/Pergamon.
Finn, K. E., Sellen, A. J., & Wilbur, S. B. E. (1997). *Video-mediated communication.* Mahwah, NJ: Lawrence Erlbaum Associates.
Fischer, F., Mandl, H., Haake, J., & Kollar, I. (Eds.) (in press). Scripting computer-supported communication of knowledge. Cognitive, computational, and educational perspectives. New York: Springer.
Hilbert, T., Schworm, S., & Renkl, A. (2004). Learning from worked-out examples: The transition from instructional explanations to self-explanation prompts. In P. Gerjets, J. Elen, R. Joiner & P. Kirschner (Eds.), *Instructional design for effective and enjoyable computer-supported learning* (pp. 184-192). Tübingen: Knowledge Media Research Center.
Köhler, T., & Trimpop, R. (2004). Sehen und gesehen werden: Teleradiologie mittels Desktop- Videoconferencing. [Seeing and being seen: Tele radiology via desktop videoconferencing]. In W. Bungard, B. Koop & C. Liebig (Eds.), *Proceedings zur 3. Tagung der Fachgruppe Arbeits- und Organisationspsychologie*. München: Rainer Hampp.
Meier, A., Spada, H., & Rummel, N. (submitted). Evaluating collaboration: A rating scheme for assessing the quality of collaborative process. Manuscript submitted for publication.
O'Donnell, A. M. (1999). Structuring dyadic interaction through scripted cooperation. In A. M. O'Donnell & A. King (Eds.), *Cognitive perspectives on peer learning* (pp. 179-196). Mahwah, NJ: Lawrence Erlbaum Associates.
Renkl, A. (1997). Learning from worked-out examples: A study on individual differences. Cognitive Science, 21, 1-29.
Renkl, A. (2002). Learning from worked-out examples: Instructional explanations supplement self-explanations. *Learning & Instruction, 12*, 529-556.
Renkl, A., Stark, R., Gruber, H., & Mandl, H. (1998). Learning from worked-out examples: The effects of example variability and elicited self-explanations. C*ontemporary Educational Psychology, 23,* 90-108.
Rummel, N., & Spada, H. (2005). Learning to collaborate: An instructional approach to promoting collaborative problem-solving in computer-mediated settings. *Journal of the Learning Sciences, 14(2)*, 201-241.
Rummel, N. & Spada, H. (in press). Can people learn computer-mediated collaboration by following a script? In F. Fischer, H. Mandl, J. Haake & I. Kollar, *Scripting computer-supported communication of knowledge. Cognitive, computational, and educational perspectives*. New York, Springer.
Slavin, R. E. (1992). When and why does cooperative learning increase achievement? Theoretical and empirical perspectives. In R. Hertz-Lazarowitz & N. Miller (Eds.), *Interaction in cooperative groups: The theoretical anatomy of group learning* (pp. 145-173). New York: Cambridge University Press.

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