Conceptual and procedural knowledge construction in computer supported collaborative learning

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Abstract: This paper focuses on learners’ knowledge construction in computer supported collaborative learning. It investigates how far individual knowledge (prior knowledge), collaborative knowledge (the quality of collaborative knowledge construction), and instructional support may contribute to the outcomes of learners’ knowledge construction. It analyzes predictors for learners’ learning outcomes with respect to procedural knowledge (successful application of rules for case-solving) and conceptual knowledge (cued answer of theory concepts) under consideration of learners’ knowledge about theory definitions. To find answers to this issue, results of two studies are presented. They show that predicting factors for learners’ construction of conceptual knowledge lie mainly in the individual while procedural knowledge benefits of collaborative knowledge construction.

Knowledge construction in computer supported collaborative learning

Computer supported collaborative learning environments can provide learning experiences which go far further than the pure acquisition of facts. Some focus, for example, on the transfer of knowledge (e.g. Renkl, Mandl & Gruber, 1996), some on learners’ knowledge about argumentation (e.g. Schwarz, Neumann, Gil & Ilya, 2003), some on their problem-solving skills (e.g. Salji, Eklund & Mäkitalo, 2006) or particular domain-specific strategies (e.g. Fischer, Mandl, Kollar & Haake, 2007). Research in these fields analyzes often how learners improve their knowledge and skills while learning in these environments and focuses thereby on aspects that the environment aims to facilitate (e.g. argumentation, problem-solving skills, and strategies). Questions about how the individuals and the collaboration contribute to the group’s and to the learners’ knowledge construction remain often unanswered. Yet, to examine the potentials of computer supported collaborative learning for collaborative knowledge construction, one has to look deeper into the collaboration scenario with respect to individual and collaborative aspects that may contribute to learners knowledge construction. Schwarz et al. (2003), e.g., found in a study about the construction of collective and individual knowledge in argumentation that there were significant differences between individual and collaborative arguments and that individual arguments improved after collaboration.

De Jong and Fergusson-Hessler (1996) present a framework to distinguish different kinds of knowledge. They present four different types of knowledge and define situational knowledge as “knowledge about situations as they typically appear in a particular domain” (p.106), conceptual knowledge as “static knowledge about facts, concepts and principles that apply within a domain” (p. 107), procedural knowledge as “actions or manipulations that are valid within a domain” (p.107), and strategic knowledge which “helps students organize their problem-solving process by directing which stages they should go through to reach a solution” (p.109). Learners may work with all of these four knowledge types in the context of a learning environment, but there may be specific gains in particular aspects, e.g. strategic and procedural knowledge in problem-solving environments (Rummel & Spada, 2006). Besides that, de Jong and Fergusson-Hessler (1996) distinguish five different qualities of knowledge with respect to each type. Combining all the types and qualities of knowledge creates a matrix with 20 dimensions of knowledge. One of these dimensions is the level of conceptual knowledge, which is an indicator for the quality of learners’ conceptual knowledge. This level may range from low (surface knowledge, e.g. symbols, formulae, definitions) to high, which means deeper knowledge and comprises concepts and relations.

Research Questions

This paper investigates two different types of knowledge during collaboration. It analyzes how they are involved in learners’ collaborative and individual knowledge construction and how much of the learning outcomes they predict. The particular research questions are:

1. What are predictors for the quality of collaborative knowledge construction?
2. What are predictors for learners’ construction of procedural knowledge?
3. What are predictors for learners’ construction of conceptual knowledge?
Method
To answer the research question, two empirical studies were conducted in the laboratory of Ludwig Maximilian University. 159 undergraduate students of social sciences took part in the first study and 171 freshmen of educational sciences in the second.

Experimental paradigm and Design
The experiment comprised an individual and a collaborative learning unit (see figure 1). During the individual learning unit, learners acquired knowledge about attribution theory on the basis of a theory text. After working on this text, the learners’ prior knowledge was assessed using an individual case solution, a short-answer test, and a multiple-choice-test. For the collaboration, three learners were connected with a desktop video-conferencing system, which included an audio- and video-connection and a shared application. Using this videoconferencing environment, learners had to collaboratively solve a learning case according to attribution theory. After the collaborative learning unit, learners’ knowledge was assessed on an individual basis by asking them to solve a case and to complete a short-answer test. These tests reflect the assessment of different types of knowledge. In particular, the cases focused on procedural knowledge to disclose, how far learners could apply specific rules that are necessary to analyze attribution patterns, the multiple choice test analyzed theory definitions and gave therefore insights in learners’ conceptual knowledge on a low level, and the short answer test asked learners to describe theory concepts on their own, which can disclose conceptual knowledge on a higher level. Due to the relatively short experimental session, situational knowledge and strategic knowledge could be not assessed.

During collaboration, groups of three learners worked in one of four conditions of a 2x2-factorial design. The support measures of both studies were either content-specific or collaboration-specific. In study 1, the factor content-specific support compared a content-scheme vs. no support; in study 2 it compared the content-scheme vs. an enhanced content-scheme. This means that all learners of study 2 worked with the content-scheme that was applied in study 1. The factor of collaboration-specific support compared a collaboration script vs. no support in study 1 and strong resource interdependence vs. light resource interdependence in study 2. The issue of the particular role of support has minor importance for this analysis. More details about the support measures and their influences can be found in former publications, e.g. Ertl, Kopp and Mandl (2005) for study 1 and Ertl and Mandl (2006) for study 2.

Data Sources
Several data sources were included to assess the individual’s prior knowledge, the quality of collaborative knowledge construction, and the individual’s learning outcome.

Prior knowledge: conceptual (definitions) was measured by a multiple-choice test, which consisted of 12 items. Learners had to find the right answer out of four choices. The reliability of this test was sufficient in both studies (Cronbach’s α > .64; 1).

Prior knowledge: conceptual (concepts). Conceptual knowledge was measured by a short-answer test for describing theory concepts. This test consisted of 8 items. The reliability of this test was sufficient in both studies (Cronbach’s α > .69).

Prior knowledge: procedural. Concerning procedural prior knowledge, learners worked on a case individually. This case solution was analyzed with respect to the application of theory concepts on case information. Items used correctly for the individual case solution were summed up as a score. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high for both studies (κw > .91).

Quality of collaborative knowledge construction. To assess the quality of the collaborative knowledge construction, the product of the collaborative knowledge construction – a collaboratively solved case – was analyzed with respect to theory concepts, which had to be applied correctly on case information. According to the different categories of the attribution theory, a coding system was developed in which all causes, information and attributions were listed in an identifiable way without any overlap. On basis of this coding scheme, a sum was defined as a measure of the quality of the collaborative knowledge construction. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high in both studies (r > .87; 2).

Learning outcomes: conceptual (concepts). Conceptual knowledge in the post-test was measured individually by a short-answer test for describing theory concepts. This test consisted of 8 items, which were similar to the items of the pre-test. The reliability of this test was sufficient for both studies (Cronbach’s α > .62).

Learning outcomes: procedural. For determining learning outcome (procedural knowledge), learners solved a case individually after collaboration. Similar to the pretest case, the posttest case was analyzed with respect to correctly used theory concepts and case information. Scores were given for case information and
theoretical concepts. For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high for both studies ($\kappa > .90$).

**Control variable.** Students’ age was used as a control variable.

**Data analysis.** Linear regressions (enter method) were computed to find predictors for the quality of collaborative knowledge construction and individual learning outcomes. The analyses were calculated on the individual’s level (except the measures with the quality of collaborative knowledge construction as outcome variable which were calculated on the group level). For testing group effects, all data was re-calculated with Hierarchical Linear Models (HLM). Yet, differences between both methods of analysis were marginal because of the small group size of triads and the short time of collaboration.

**Results**

The following section presents results of both studies with respect to the three research questions.

**Research question 1**

Research question 1 asked for indicators for the quality of collaborative knowledge construction. Regarding this measure, there are differences between study 1 and study 2 (see table 1). In study 1, 47% of the variance could be resolved. In the context of the three different measures for prior knowledge, only the content scheme proved to be a significant predictor. However, omitting the variable of conceptual knowledge (definitions) would result in a small impact of prior knowledge (see Ertl, Kopp & Mandl, 2005). With respect to study 2, 34% of the variance could be resolved. In the context of the three different measures for prior knowledge, only the conceptual knowledge (definitions) proved to be a significant predictor. Furthermore, learners’ age had a negative influence.

**Research question 2**

Looking at individual learning outcomes (procedural knowledge) the results of study 1 and 2 have some similarities. With respect to study 1, 42% of the variance was predictable. Thereby, the quality of collaborative knowledge construction and conceptual knowledge (concepts) had nearly the same impact. Procedural knowledge had a much smaller impact. Furthermore, there are indicators for a detrimental impact of students’ age. With respect to study 2, 31% of the variance was predictable. Thereby, the quality of collaborative knowledge construction, conceptual knowledge (definitions) and procedural knowledge had nearly the same impact. The content-specific support had only a smaller impact.

**Research question 3**

Regarding individual learning outcome (conceptual knowledge, concepts), both studies show similar results. In study 1, 65% of the variance could be resolved. Thereby, only the three different measures of prior knowledge were influential. Most effect had the conceptual knowledge (concepts), followed by the conceptual knowledge (definitions) and procedural knowledge. The other variables were not significant. Regarding study 2, 66% of the variance could be resolved. Thereby, the conceptual knowledge (concepts) had the highest impact. Procedural

<table>
<thead>
<tr>
<th>Quality of collaborative knowledge construction</th>
<th>Study 1</th>
<th>Study 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
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<td>-31</td>
</tr>
<tr>
<td>Prior knowledge (procedural)</td>
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<td>-n.s.</td>
</tr>
<tr>
<td>Prior kn. (conceptual, def.)</td>
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<td>.46</td>
</tr>
<tr>
<td>Prior kn. (conceptual, concepts)</td>
<td>-n.s.</td>
<td>-n.s.</td>
</tr>
<tr>
<td>Collaboration specific</td>
<td>-n.s.</td>
<td>-n.s.</td>
</tr>
<tr>
<td>Content specific</td>
<td>.62</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>$R^2$</td>
<td>.48</td>
<td>.42</td>
</tr>
<tr>
<td>Adjust. $R^2$</td>
<td>.47</td>
<td>.34</td>
</tr>
</tbody>
</table>

Figure 1: Experimental paradigm of the studies
knowledge and content-specific support had only a small influence. Furthermore, learners’ age had a slightly detrimental impact.

Table 2: Predictors for the learning outcome (procedural knowledge and conceptual knowledge, concepts) by prior knowledge, quality of collaborative knowledge construction, support and age. Predictors with standardized β-weights and significance level.

<table>
<thead>
<tr>
<th></th>
<th>Learning outcome (procedural knowledge)</th>
<th>Learning outcome (conceptual knowledge, concepts)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Study 1</td>
<td>Study 2</td>
</tr>
<tr>
<td>Age</td>
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<td>&lt; .07</td>
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<td>Prior knowledge (conc., def.)</td>
<td>.34</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Prior knowledge (conc., conc.)</td>
<td>—</td>
<td>n.s.</td>
</tr>
<tr>
<td>Quality of collaborative knowledge construction</td>
<td>.33</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Collaboration specific</td>
<td>—</td>
<td>n.s.</td>
</tr>
<tr>
<td>Content specific</td>
<td>—</td>
<td>n.s.</td>
</tr>
<tr>
<td></td>
<td>.44</td>
<td>.34</td>
</tr>
<tr>
<td>Adjust. R²</td>
<td>.42</td>
<td>.31</td>
</tr>
</tbody>
</table>

Discussion

Results show that there are different influencing factors for the quality of collaboration and for individual learning outcomes. For the quality of collaborative knowledge construction, these factors range from the conceptual support in study 1 to the individual’s prior knowledge in study 2. Keeping in mind, that all learners of study 2 worked with the conceptual support of study one (see Ersl, Kopp & Mandl, 2008; Ersl & Mandl, 2006), one can assume that the individual’s prior knowledge has a high influence on collaborative settings, but it may be overridden by methods of instructional support.

Looking at individual learning outcomes, there are differences between the different types of the conceptual and the procedural knowledge. Regarding procedural knowledge, results show that the quality of collaborative knowledge construction had a strong impact on the learning outcomes—even stronger than the procedural prior knowledge. Similar results are described by Schwarz et al. (2003), who reported in their study about individual and collaborative aspects of argumentation that learners’ individual arguments improved after collaboration. This finding indicates that the multiple perspectives incorporated by collaborative learning serve as a particular stimulus for a high quality of learning (see Ersl, Winkler & Mandl, 2007). It also supports Cohen (1994), who argues that collaboration has a value per se and creates something more than just the addition of collaboration partners’ skills (Hertz-Lazarowitz, Kirkus & Miller, 1992). Yet, another strong impact on procedural knowledge was learners’ knowledge about definitions. This means that learners need a sound theoretical base to use with their procedural knowledge.

The results are different regarding conceptual knowledge. The main predictor for conceptual knowledge was learners’ prior knowledge of concepts. Other kind of prior knowledge had much smaller weights and the quality of collaborative knowledge construction didn’t prove to have a significant influence. That may be specific to case- and problem solving scenarios, because they focus learners on finding a joint solution (applying the theory definitions and the procedures) rather than on the mutual elaboration of theory concepts, which may, e.g. take place during peer-teaching.

Furthermore, a detrimental effect was found for students’ age which indicates that younger students scored better. This effect should not be interpreted in the context of age and cognitive abilities, but rather in the context of study biographies and experiences. One could speculate that the more experienced students used less mental effort for the learning session because it was not graded.

Limitations of the study. There are some limitations for interpreting this study. For experimental purposes, it mainly focused on procedural and conceptual knowledge in case-based learning. For a better understanding of how knowledge develops in collaboration, further types of knowledge have to be investigated in more different scenarios. Furthermore, to have a better insight in the contribution of the individual and the group, a control group with only individuals should have served as baseline.

Summary and Outlook. The significance of this paper relates to several aspects:
(a) There are different predictors for the outcomes of the group and the outcomes of the individual.
(b) Collaboration in a particular learning scenario, here case-based learning, can have an impact on a specific kind of knowledge (here procedural knowledge), but not on all kinds of knowledge.
(c) Technological and instructional factors play often a minor role in comparison with individual factors like the learners’ prior knowledge.

(d) Learners’ outcomes are not only influenced by their individual prerequisites but can be improved by the quality of collaboration and instructional design.

This study is a first analysis of predictors for learners’ construction of different types of knowledge during collaboration. At the current stage, there are only regressions to support the analysis. A further step should also analyze knowledge gains to get an impression to which extent this knowledge develops during collaboration. More sophisticated methods of analysis like path analysis or mediator analysis may give further insights in the issue raised by this paper.

Endnotes
(1) Conceptual knowledge (definitions) was assessed in study 1 before and after collaboration. The results showed that learners were able to identify the right definitions to a major extent before collaboration, which left little space for improvement. Therefore, it was omitted in study 2 as measure after collaboration and can therefore not serve as outcome variable.

(2) It would have been more appropriate to present a $\kappa_w$ also for the quality of collaborative knowledge construction. However, only a $r$ coefficient can be presented because the value range in this measure exceeded features of the analysis software.

References

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