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Abstract

This paper deals with collaborative knowledge construction in videoconferencing. The main issue is about how to predict individual learning outcome, in particular how far individual prior knowledge and the collaborative knowledge construction can influence individual learning outcomes. In this context, the influence of prior knowledge and two measures of instructional support, a collaboration script and a content scheme were analyzed concerning the collaborative knowledge construction. An empirical study was conducted with 159 university students as sample. Students learned collaboratively in groups of three in a case based learning environment in videoconferencing and were supported by the instructional support measures. Results show that collaborative knowledge construction had more impact on individual learning outcome than individual prior knowledge.

Keywords: prior knowledge, factual knowledge, applicable knowledge, cooperative/collaborative learning, teaching/learning strategies, video-conferencing, collaboration script, content scheme, collaborative knowledge construction, shared application

Zusammenfassung

Diese Studie beschäftigt sich mit der gemeinsamen Wissenskonstruktion in Videokonferenzen. Die Hauptfragestellung befasst sich mit Prädiktoren für den individuellen Lernerfolg, insbesondere inwieweit dieser vom individuellen Vorwissen der Lernenden und der gemeinsamen Wissenskonstruktion beeinflusst wird. In diesem Kontext wird analysiert, inwiefern das individuelle Vorwissen und zwei Unterstützungsmaßnahmen – Wissensschema und Kooperationsskript – Einfluss auf die gemeinsame Wissenskonstruktion nehmen. An der empirischen Studie nahmen 159 Universitätsstudierende teil. Diese lernten kooperativ in Dreiergruppen in einer fallbasierten Lernumgebung in Videokonferenzen und erhielten dabei instruktionale Unterstützung. Die Ergebnisse zeigen, dass die gemeinsame Wissenskonstruktion einen größeren Einfluss auf die individuellen Lernerfolge hatte, als individuelles Vorwissen.

Schlüsselwörter: Vorwissen, Faktenwissen, Anwendungswissen, Kooperatives Lernen, Lehr-/Lernstrategien, Videokonferenz, Kooperationsskript, Wissensschema, gemeinsame Wissenskonstruktion, geteilte Applikation

EFFECTS OF INDIVIDUAL PRIOR KNOWLEDGE ON COLLABORATIVE KNOWLEDGE CONSTRUCTION AND INDIVIDUAL LEARNING OUTCOME IN VIDEOCONFERENCING

Introduction

Recently, quite a lot of research is done about collaborative learning in computer supported learning environments (cf. Andriessen, Baker & Suthers, 2003; Bromme, Hesse & Spada, in print; Dillenbourg, Eurelings & Hakkarainen, 2001; Kirschner, 2002; Koschmann, Hall & Miyake, 2002; Stahl, 2002). In this context, most researchers focus on how learners use the learning environment, on the support of collaborative learning or on which processes take part during collaborative learning. The issue about sustaining effects of the collaborative learning environment is mostly neglected. This means that – even if researchers study the increase in the knowledge of the learners – questions about predictors for individual knowledge acquisition cannot be answered. However, the issue of predictors is crucial for the research in computer supported learning environments as many studies can show effects of support measures during process, but none or only few effects regarding individual learning outcome (cf. Baker & Lund, 1997; Fischer, Bruhn, Gräsel & Mandl, 2002; Pfister & Mühlpfordt, 2002; Weinberger, 2003). One reason for such results may be the influence of individual prior knowledge, which may negate effects of collaborative knowledge construction (cf. Dochy, 1992; Kalyuga, Chandler & Sweller, 1998, 2000, 2001; O'Donnell & Dansereau, 2000; Renkl, Stark, Gruber & Mandl, 1998; Stark & Mandl, 2002). Thus, finding predictors for individual learning outcome can help to improve support measures for collaborative learning in the way of focusing on relevant criteria.

This paper focuses on predictors for individual learning outcome in collaborative net-based learning scenarios. Based on an empirical study, the influence of prior knowledge and collaborative knowledge construction is investigated. For deeper insights, also the effects of support on the collaborative knowledge construction, in particular effects of a collaboration script and a content scheme are researched.

Collaborative learning in videoconferencing

Collaborative learning in small groups means that groups act relatively independent of a teacher with the goal of acquiring knowledge or skills (cf. Cohen, 1994; Dillenbourg, 1999). One major goal of collaborative learning is to support social interaction and encourage the learners' cognitive processes. In this context, learners' elaborations are seen to play a crucial role (cf. Webb, 1989; Webb & Palincsar, 1996) for expressing their knowledge, ideas and beliefs to their partners (cf. O'Donnell & King, 1999; Palincsar & Brown, 1984; Rosenshine & Meister, 1994). In this way, learners work to co-construct knowledge collaboratively (cf. Bruhn, 2000; Fischer, Bruhn, Gräsel & Mandl 2000; Roschelle & Teasley, 1995). Furthermore, learners also externalize and elaborate on learning material when taking notes (cf. Gould, 1980; Molitor-Lübbert, 1989), e.g. in a shared computer application. In collaborative learning environments, learners often create such written representations collaboratively (cf. Baker & Lund, 1997; Dillenbourg & Traum, 1999; Klein, 1999; Suthers, 2001). During this process, they create a shared external representation of the subject matter, which can be helpful for collaborative knowledge construction (Ertl, 2003; Fischer et al., 2002). When constructing a shared external representation, learners must externalize their knowledge, that is, they must elaborate on and comprehensibly explain their knowledge to the learning partner (cf. Hayes & Flower, 1980; Peper & Mayer, 1986). Furthermore, creating shared external representations can encourage learners to solve conceptual or structural problems they may have with the subject matter (cf. Fischer & Mandl, 2002; Gould, 1980; Molitor-Lübbert, 1989) and influence the co-construction of knowledge (cf. Eigler, Jechle, Merziger & Winter, 1990; Fischer & Mandl, 2002). In videoconferencing, shared applications play a prominent role in such externalization processes: The shared applications offer a shared externalization forum, which is common to all the dispersed learning partners (Dillenbourg & Traum, 1999). In computer-supported learning environments, shared applications are often built as tools for the learners (cf. Spitulnik, Bouillion, Rummel, Clark & Fischer, 2003; Suthers & Hundhausen, 2001). Such tools support the active representation of knowledge and can support learners domain-specifically (cf. Dillenbourg & Traum, 1999; Roschelle & Pea, 1997), reduce consensus illusions and foster the integration of prior knowledge (cf. Fischer et al., 2002). However, studies show that it is not enough to simply provide a collaborative learning environment (cf. Johnson & Johnson, 1992; Lou, Abrami & d'Apollonia, 2001; Rosenshine & Meister, 1994; Salomon & Globerson, 1989; Slavin, 1995). The collaborative learning process and outcomes can be improved greatly when appropriate additional support is provided.

Outcomes of collaborative learning

In this context, it is necessary to have a view on the conceptualization of learning outcomes. There are mainly two possibilities for assessing the benefits of a collaborative learning scenario, either individually on the learner level or collaboratively on a group level. However, there are differences about the interpretation of such learning outcomes (cf. Anderson, Reder & Simon, 1996; Greeno, 1997; Hertz-Lazarowitz, Kirkus & Miller, 1992; Salomon & Perkins, 1998; Slavin, 1995; Webb, 1989). The issue arises, how far individual knowledge assessment is able to evaluate effects of collaborative knowledge construction and how far a group assessment can give a hint about individuals' learning progress. Regarding individual learning outcomes, one can distinguish between conceptual knowledge and applicable knowledge (cf. De Jong & Fergusson-Hessler, 1996). Thereby, the term conceptual knowledge is used if learners can appropriately rehearse facts about the subject learned, while applicable knowledge means that learners can also apply their knowledge, e.g. in problem solving. In contrast to the clear conceptualization of individual learning outcomes, it is rather vague how to measure the effects of collaborative knowledge construction on a collaborative level. In this context, Hertz-Lazarowitz et al. (1992) suggest the product of this collaborative construction process, e.g. the final collaborative problem solution, to be considered as "group knowledge" or as a collaborative learning outcome. Other approaches stress the importance of learners' convergence in knowledge construction (cf. Fischer & Mandl, in press; Jeong & Chi, 1999).

Even if differences between individual and collaborative measures for learning outcomes may be attributed to characteristics of different learning tasks, the issue of individual and social aspects of learning outcomes gets a particular importance for cooperative learning in computer supported learning environments. In such environments, groups can compose and decompose quite quickly (cf. Walther, 1994; Walther & Burgoon, 1992). Therefore, the individual profit of the collaboration can become more important for the collaborating partners than social aspects of groups or the quality of collaboration (cf. Kerr, 1983). Thus, learners in such scenarios may desire maximal individual profit instead of a high quality of collaborative knowledge construction. As a consequence, dysfunctional group phenomena may occur (cf. Salomon & Globerson, 1989). On the other hand, when just focusing on high outcomes on a collaborative level, groups may apply strategies for maximizing group performance on the cost of neglecting group members with less knowledge. In such cases, the skilled learners would benefit quite a lot from collaboration while less skilled learners would not have any benefits (cf. Dembo & McAuliffe, 1987; Salomon & Globerson, 1989; Webb, 1989). Thus, it is important to analyze both collaborative and individual learning outcomes when dealing with group learning (cf. Salomon & Perkins, 1998).

Support measures for collaborative learning

Collaborative learning in computer supported learning environments is often supported to avoid dysfunctional group phenomena, to improve the learning process and to foster knowledge acquisition. Well-known examples for such support are cooperation scripts (cf. Baker & Lund, 1997; O'Donnell & King, 1999; Pfister & Mühlpfordt, 2002; Rummel, Ertl, Härder & Spada, 2003; Weinberger, Fischer & Mandl, 2003) or conceptual support like content schemes (cf. Brooks & Dansereau, 1983; Dobson, 1999; Ertl, Reiserer & Mandl, 2002; Fischer et al., 2002; Löhner & Van Joulingen, 2001). In the context of CSCL, cooperation scripts aim mainly at the support of collaboration strategies with assigning different roles to the learners and with sequencing or structuring the work on the task. In contrast, conceptual support aims particularly at improving the comprehension of the structure of the subject matter.

Such support measures are mainly directed at the collaborative knowledge construction and are thought to improve the process of collaborative knowledge construction substantially. This is reflected by many studies (e.g. Baker & Lund, 1997; Ertl et al., 2002; Fischer et al., 2002; Rummel et al., 2003; Weinberger et al., 2003). However, even if many of these studies were able to show effects regarding the quality of collaborative knowledge construction, there were often mixed effects regarding individual learning outcomes (cf. Baker & Lund, 1997; Fischer et al., 2002; Pfister & Mühlpfordt, 2002; Weinberger, 2003). One reason for this may be the influence of individual prior knowledge.

The role of prior knowledge in collaborative learning

Individual prior knowledge is known to be an important prerequisite for *individual* knowledge construction and learning outcome. Many theoretical approaches stress the importance of learners' prior knowledge when acquiring new learning material (cf. Gerstenmaier & Mandl, 1995; Glaser, 1989) and many empirical studies show the influence of prior knowledge on individual learning outcomes (cf. Dochy, 1992; Kalyuga et al., 1998, 2000, 2001; O'Donnell & Dansereau, 2000; Renkl et al., 1998; Stark & Mandl, 2002; Weinert & Helmke, 1998). Thus, individual prior knowledge structure may negate the effects of the collaborative knowledge construction when assessing learning outcomes.

In the research of *collaborative* learning environments, individual prior knowledge is mostly neglected with respect to learning outcomes. Different levels of learners' prior knowledge are mainly used to explain group phenomena (cf. Salomon & Globerson, 1989), the quality of explanations (cf. Webb, 1989) or as a control variable for ensuring that learners do not differ significantly. In studies about the support of collaborative learning, individuals' prior knowledge plays often an important role in group composition (cf. Cohen, 1994; Slavin, 1995), while the influence of prior knowledge as a prerequisite for collaborative knowledge construction and individual learning outcomes remains often unresolved. However, studies of O'Donnell and Dansereau (2000) investigating effects of prior knowledge in collaboration indicate an influence of individual prior knowledge also on learning outcomes in the collaborative learning context. Furthermore, studies found that prior knowledge could interact with other moderators of the collaborative knowledge construction – like instructional support measures for the learners (cf. Reiserer, 2003).

To sum up, results show that prior knowledge has an influence on individual and collaborative knowledge construction. In addition, studies indicate interactions between individual prior knowledge and instructional support measures. Until now, results are missing about the role of individual prior knowledge in the context of support measures for collaborative knowledge construction and also concerning the issue, to what extent individual prior knowledge and collaborative knowledge construction may influence individual learning outcomes.

Research questions

For getting insights in these issues, we conducted an empirical study with following research questions:

Research question 1: To what extent does individual prior knowledge affect the quality of collaborative knowledge construction supported by a collaboration script and a content scheme?

Research question 2: To what extent do individual prior knowledge and quality of collaborative knowledge construction affect learners' individual learning outcome regarding conceptual and applicable knowledge?

Method

An empirical study was conducted in the laboratory of Ludwig-Maximilian-University for answering these research questions. 159 undergraduates of educational sciences took part in this experiment.

Design of the experiment

The experiment comprised an individual and a collaborative learning unit (cf. figure 1). During the individual learning unit, learners acquired knowledge about attribution theory on basis of a theory text. After working on this text, learners' individual prior knowledge was assessed by an individual case solution and a short-answer test about conceptual knowledge. For collaboration, learners were connected with a desktop videoconferencing system, which included an audio- and video-connection and a shared application. Using this videoconferencing environment, learners had to solve a learning case according to attribution theory collaboratively. During collaboration, learners worked in one of four conditions of a 2x2-factorial design. There were 13 triads in each experimental condition and 12 triads in the control condition. We varied the factors collaboration script (with vs. without) and content scheme (with vs. without). After the collaborative learning unit, learners' knowledge was assessed on an individual base by solving a case and a short-answer test.

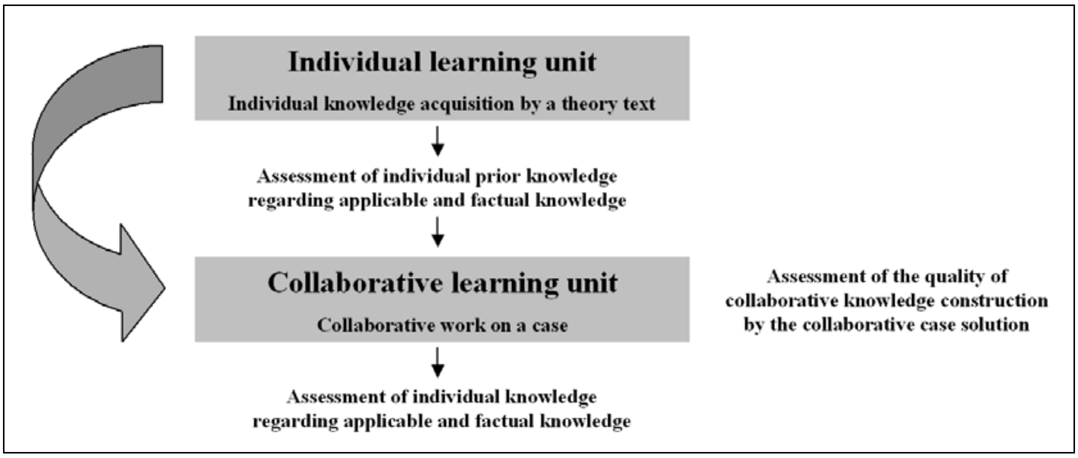

Figure 1: Design of the experiment.

Instructional support for collaborative knowledge construction

As instructional support for the collaborative knowledge construction, a collaboration script, a content scheme and the combination of both was used and compared with a control condition. Collaboration script as well as content scheme pre-structured the collaboration of the triads.

The *collaboration script* structured the collaborative unit into four phases. In the *first* phase, learners had to read case material and extract important information on an individual basis. In the *second* phase, learners had to exchange information and resolve comprehension questions collaboratively. They used the shared application for writing down concepts that were important for the case solution. In the *third* phase, learners had to reflect individually and in the *fourth* phase, learners had to develop the case solution collaboratively.

The *content scheme* pre-structured the shared application and was realized as a table, which was divided into three main categories: *Cause,* for identifying possible causes for the problem described in the case, *Information* for case information and for giving evidence for the causes and *Attribution* for identifying the correct attribution of the cause. The categories *Information* and *Attribution* each contained two subcategories: *Information* was divided in columns for *Consensus* and *Consistency* for making these two aspects of attribution theory salient. *Attribution* was divided into two sections according to the theories of Kelley (1973) and Heider (1958) to help learners attribute each cause to the relevant source. Using this content scheme, learners were guided to formulate complete attributions according to Kelley and Heider with causes and case information about consensus and consistency.

In a further condition, the content scheme and script were combined. In the *first* phase, learners had to individually complete the content scheme with a paper and pencil. In the *second* phase, the main tasks included the exchange of information and a collaborative collection of complete attributions in the shared application. In the *third* phase, learners compared their own notes with the content, which had been collected. In the *fourth* phase, learners were asked to develop the solution and to write a collaborative case solution in the shared application.

Learners of the control condition received no additional support for solving the case.

Data sources

For analysis, several data sources were included with respect to the assessment of individual prior knowledge, the quality of collaborative knowledge construction, individual learning outcome and a treatment check.

Individual prior knowledge: Conceptual knowledge

Conceptual knowledge was measured by a short-answer test. Learners had to complete sentence openers, e. g. “According to Kelley, an event can be attributed to these three causes:". This test consisted of 8 items (M = 26.3; SD = 9.51; empirical max. = 43). The consistency of this test was sufficient (α = .69).

Individual prior knowledge: Applicable knowledge

Concerning individual prior knowledge, learners worked on a case individually. For assessment, this case solution was analyzed with respect to theory concepts and case information. Items used correctly for the individual case solution were summed up to a score (M = 15.0; SD = 6.68; empirical max. = 31). For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high regarding all subscales (κ_w > .91).

Quality of collaborative knowledge construction

For assessing the quality of collaborative knowledge construction, the result of collaborative knowledge construction, which was a collaboratively solved case, was analyzed with respect to correctly used theory concepts and 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 built as measure for the quality of collaborative knowledge construction (M = 58.0; SD = 18.73; empirical max. = 92). For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high regarding all subscales (r > .87).

Individual learning outcome: Conceptual knowledge

Conceptual knowledge in the post-test was measured by a short-answer test. Learners had to complete sentence openers, e.g. "According to Kelley, an event can be attributed to these three causes:". This test consisted of 8 items (M = 29.1; SD = 7.75; empirical max. = 42), which were similar to the items of the pre-test. The consistency of this test was sufficient (α = .62).

Individual learning outcome: Applicable knowledge

For getting individual learning outcome, 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. The points for each category were summed together into a score (M = 18.58; SD = 6.88; empirical max. = 32). For ensuring inter-rater reliability of data, two evaluators marked analysis 10%. The consistency between these evaluations was high regarding all subscales (κ_w > .90).

Treatment check

A treatment check was made for ensuring that there were no differences regarding learning prerequisites within the four experimental conditions. Therefore, individual prior knowledge and motivation of the learners was controlled. Furthermore, the effects of content scheme and collaboration script were controlled regarding quality of collaborative knowledge construction and individual learning outcome.

Data analysis

For verifying the effects of content scheme and collaboration script a univariate ANOVA was calculated for the quality of collaborative knowledge construction and the individual learning outcome with content scheme and collaboration script as factors and individual prior knowledge as covariate. For finding predictors for the quality of collaborative knowledge construction and individual learning outcome, linear regressions were computed using the backward method for excluding not-significant predictors.

Results

Treatment check

The treatment check disclosed that there were no significant differences regarding prior knowledge and motivation between the four experimental conditions. Furthermore, effects of the interventions concerning collaborative knowledge construction and learning outcome were calculated (for a detailed description of the experiment see Kopp, Ertl & Mandl, 2004). With respect to the quality of collaborative knowledge construction, the content scheme had a large effect. Learners with content scheme applied nearly twice the number of concepts than learners without content scheme ($F_{(1,145)} = 163.24$; $p < .01$; $\eta^2 = .53$). This effect could also be found with respect to individual knowledge acquisition. Learners in all conditions benefited greatly from collaboration. The content scheme also proved to be effective for individual learning outcomes with respect to applicable knowledge. Learners with the content scheme scored higher ($F_{(1,154)} = 31.54$; $p < .01$; $\eta^2 = .17$). With respect to conceptual knowledge there were no significant differences. Concerning collaboration script, we got no significant effects regarding quality of collaborative knowledge construction and individual learning outcome.

Research question 1

Research question 1 was about predictors for the quality of collaborative knowledge construction. As the results in table 1 show, over 45 % of the variance regarding the collaborative knowledge construction could be predicted by prior knowledge and the support measures. The strongest predictor was the content scheme, while the individual prior knowledge (conceptual) played only a marginal role. The collaboration script and individual prior knowledge (applicable) were not significant as predictor.

Table 1: Multiple regression for predicting the quality of collaborative knowledge construction by prior knowledge, content scheme and collaboration script: Statistically significant predictors ($p < .05$) with standardized β-weights.

	Collaborative knowledge construction
Prior knowledge (conceptual)	.18
Content scheme	.68
R^2	.49
Adjust. R^2	.48

Research question 2

Regarding predictors for individual learning outcome, the results are quite different (cf. table 2 and 3). With respect to applicable knowledge, 40% of the variance could be predicted by individual prior knowledge and collaborative knowledge construction. In the context of applicable knowledge, collaborative knowledge construction had more influence than each single measure of individual prior knowledge[1]. The content scheme did not prove to be a significant predictor. However, content scheme may have had an indirect influence, as it is the main predictor for the collaborative knowledge construction. The collaboration script did not prove to be a predictor, again.

[1] Analyzing effects of collaborative knowledge construction and individual prior knowledge (conceptual and applicable) in separate regressions, each of them would be able to predict about 23% of variance. Thus, one could state that the quality of collaborative knowledge construction and individual prior knowledge have nearly the same influence on individual learning outcome with respect to applicable knowledge.

Table 2: Multiple regression for the prediction of individual learning (applicable knowledge) outcome by prior knowledge, content scheme, collaboration script and collaborative knowledge construction: Statistically significant predictors (p < .05) with standardized β-weights.

	Individual learning outcome (applicable knowledge)
Prior knowledge (conceptual)	.27
Prior knowledge (applicable)	.22
Collaborative knowledge construction	.40
R^2	.41
Adjust. R^2	.40

Analyzing conceptual knowledge, 60 % of total variance was predictable (cf. table 3). The main predictor was conceptual prior knowledge; applicable prior knowledge played a minor role. Neither the collaborative knowledge construction nor the interventions proved to be significant predictors. However, one has to state that both tests for conceptual knowledge comprised similar items, even if arranged differently.

Table 3: Multiple regression for the prediction of individual learning outcome (conceptual knowledge) by prior knowledge, content scheme, collaboration script and collaborative knowledge construction: Statistically significant predictors (p < .05) with standardized β-weights.

	Individual learning outcome (conceptual knowledge)
Prior knowledge (conceptual)	.68
Prior knowledge (applicable)	.16
R^2	.61
Adjust. R^2	.60

Summary and conclusion

These results show that the effects of individual prior knowledge are quite different regarding the quality of collaborative knowledge construction and individual learning outcome. For collaborative knowledge construction, the influence of individual prior knowledge is quite small compared to the influence of support measures. A further result is that conceptual knowledge proved to be a significant predictor in contrast to applicable knowledge, being not significant. This result seems to be contra-intuitive, as the collaborative knowledge construction is a task of applying knowledge and thus one would expect applicable knowledge to be a predictor. However, considering the content scheme as a strategy for applying knowledge, the presence of this “professional” strategy may have negated the influence of individuals’ naive strategies measured in the pretest. Therefore, the collaborative knowledge construction may have relied in particular on the conceptual knowledge of the individuals and the strategies offered by the support.

Regarding individual learning outcome, the impact of prior knowledge increases. However, in this context one has to distinguish between applicable and conceptual knowledge. With respect to applicable knowledge, the quality of collaborative knowledge construction has still most influence. However, looking at the values in table 2 one can assume that the influence of collaborative knowledge construction and both measures of individual prior knowledge is somehow balanced[1]. Considering conceptual knowledge, there was no influence of the collaboration. Even, if all learners improved their level of conceptual knowledge, the main predictor was individual prior knowledge. However, this effect may be attributed to the similarity of the test items between the pre- and the post-test.

These results can be able to explain differences between individual and collaborative learning outcome on base of different variables influencing both measures. One can assume that for collaborative knowledge construction, the collaboration effect, including the effect of instructional support measures is much stronger than individual learners’ prerequisites. This means that collaborative knowledge construction can be modified quite fundamentally by instructional support. In contrast, regarding individual learning outcome, individual prerequisites gain influence and may negate effects of collaborative knowledge construction. This has to be considered when designing instructional support for collaborative learning.

Implications

Based on these findings, there are several implications: First, collaborative knowledge construction can be much more influenced by a well-designed intervention than by individual prior knowledge. Secondly, individual prior knowledge gains weight regarding individual learning outcome, but collaborative knowledge construction has still a great influence in this area. Based on these results, the effects of many studies finding differences regarding collaborative knowledge construction and individual learning outcome may be explained. However, more research in this context is necessary for being able to generalize these results. Furthermore, the influence of learners with different levels of prior knowledge should be analyzed with respect to group processes and individual learning outcome.

The educational implications of these findings concern the design of collaborative learning environments. In learning environment research, interventions are often directed either to a better collaboration process or to an improved learning outcome. However, to gain sustainable learning environments, one has to consider the effect of interventions, the collaborative problem solving process and individual prior knowledge. Results of this study show that collaborative knowledge construction can have more impact than learners' individual prerequisites. This means that carefully designed learning environments may balance differences in learners' individual prerequisites. However, such mechanisms have to be verified by differentiate process analyses.

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