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Where is the evidence? A meta-analysis on the role of argumentation for the acquisition of domain-specific knowledge in computer-supported collaborative learning

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ABSTRACT

This meta-analysis investigated the role of the quality of argumentation for domain-specific knowledge gains in computer-supported collaborative learning settings. Given the scarcity of primary studies that report correlations between these two variables, a meta-regression approach was employed that uses interventions' effects on argumentation to predict their effects on domain-specific knowledge. Effect sizes for 17 comparisons extracted from 12 studies were included in the analysis using a random-effects model. Moderator analyses concerning type of argumentation measure, type of knowledge test, and type of intervention were conducted. The interventions had a statistically significant small to moderate mean effect ($d = 0.39$) on argumentation, which varied as a function of the type of argumentation measure employed. The mean effect of the interventions on domain-specific knowledge ($d = 0.22$) appeared to be non-existent ($d = 0.00$) on the basis of the whole sample of studies, and small at best after the exclusion of three outlying effect sizes from one study. With respect to the relation of the studies' effects on argumentation to their effects on domain-specific knowledge, no unequivocal picture emerges: After the exclusion of the three outliers, the regression coefficient for predicting the studies' effects on domain-specific knowledge on the basis of their effects on argumentation was $b = -0.08$ and statistically not significant. These findings constitute a challenge for the broadly shared theoretical assumption that argumentation mediates the effects of interventions on domain-specific knowledge. A set of recommendations for strengthening future research on the topic is presented.

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1. Introduction

Many CSCL researchers share the conviction that argumentation can be a powerful vehicle for fostering the acquisition of domain-specific knowledge (Andriessen, 2006, p. 445; Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012, p. 100; Osborne, 2010, pp. 464 f.). Different theoretical accounts suggesting such a beneficial impact of argumentation on learning postulate a range of mechanisms that may be elicited if learners engage in argumentative discussion:

First, developing and presenting arguments may involve the elaboration of the content to be learnt (Andriessen, 2006, p. 445; Chinn, 2006, p. 356; Chinn & Clark, 2013, p. 321), i.e. relations between prior knowledge and new information may be employed to make sense of the new material. Thereby, pre-existing knowledge may become a means to retrieve or even reconstruct more recently acquired pieces of knowledge. This may be the case if learners discuss how a theory or a scientific law or principle to be learnt can be derived from or explained by more general theories or principles and thereby subsume the former as a special case of the latter (Schwarz, 2009, p. 97).

Second, having to provide arguments for one's views in a discussion may require learners to make more explicit the inferential relations between various pieces of information such as observations on the one hand, and theories, scientific laws, or principles on the other, in order to make their argumentative force transparent and thereby more convincing for their learning partners (Schwarz, 2009, p. 98). The need to

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make underlying assumptions explicit may result in enhanced awareness of the relations between different parts of the emerging body of knowledge and thereby lead to better organization, which in turn may facilitate later recall.

Third, exchanging arguments may not only support memory for pieces of information that are easy to comprehend, but also spark off conceptual change (Andriessen, 2006, p. 445) and thereby deepen learners' understanding of complex phenomena and ideas. Such cognitive restructuring often requires abandoning unconsciously held assumptions or presuppositions that preclude proper integration of new information (cf. Vosniadou & Brewer, 1994, pp. 171, 174 f.). If the participants in a discussion tenaciously continue to back up their views with arguments, chances are that one of these statements will reveal such a misconceived implicit conviction and thereby render it accessible to discussion and, eventually, modification. This may occur, for instance, during inquiry learning if learners discuss whether certain pieces of evidence provide support for, or are compatible with, a theory or scientific principle or not (Schwarz, 2009, p. 98). Background assumptions underlying the learners' interpretation of the theory or their views of its applicability may be modified or even abandoned as a consequence of such a discussion. In this case, the theory or scientific law or principle that needs to be understood figures as a contested claim in the discussion, and deepening one's understanding of it involves modifying surrounding assumptions that play a role in its application to single pieces of evidence. In contrast, in a problem-based learning scenario learners may discuss potential consequences of a theory or scientific law or principle to be learnt for the solution of the particular problem that the learners face (cf. Chinn, 2006, p. 357). In this case, the contested claim concerns a proposed solution to a particular problem that may in principle be interchangeable, whereas the theory or scientific law or principle to be learnt figures as an argument in support of the proposed solution. In both of these cases, confronting one's views and supporting them with arguments may lead learners to make implicit assumptions explicit (Andriessen, 2006, p. 445), and thereby reveal possibilities for modification (Schwarz, 2009, p. 97).

From the perspective of the former two theoretical accounts, a beneficial impact of good argumentation would mainly be expected with respect to factual knowledge. From the perspective of the latter, good argumentation should primarily result in better understanding of the content to be learnt. Researchers often emphasize the latter perspective (Andriessen, 2006, p. 443; Chinn, 2006, p. 356). Accordingly, larger effects of argumentation would have to be expected for understanding, which is often measured by means of essay-type and other open-ended questions, than for factual knowledge, which is often measured by means of multiple-choice items.

A core issue related to the theoretical accounts of the role of argumentation for the acquisition of knowledge within domains concerns the specific aspects of argumentation that constitute high argumentative quality. Examples are the occurrence, frequency, breadth, depth, or comprehensiveness of arguments, the frequency of specific (explicitly mentioned) functional components of arguments such as data or warrants (e.g. Joung & Keller, 2004, p. 318; Seethaler & Linn, 2004, pp. 1771 f.; Stegmann, Weinberger, & Fischer, 2007, p. 432; Weinberger, Stegmann, & Fischer, 2010, p. 510), the number of arguments (van Drie, van Boxtel, Jaspers, & Kanselaar, 2005, pp. 585, 591; Janssen, Erkens, Kirschner, & Kanselaar, 2010, p. 69), the occurrence of specific types of argumentation such as use of evidence from experiments or "thought experiments" (Nussbaum, Sinatra, & Poliquin, 2008, p. 1983) or arguments based on prior knowledge vs. written sources (Wiley & Bailey, 2006, p. 309), overall formal argumentative quality (Janssen et al., 2010, p. 72; Nussbaum et al., 2008, pp. 1983 f.), or the tenability or factual correctness of statements used as arguments (Janssen et al., 2010, p. 72; Weinberger et al., 2010, p. 510; for a review of different kinds of analytical schemes for the quality of argumentation, see Clark, Sampson, Erkens, & Weinberger, 2007; Rapanta, Garcia-Mila, & Gilabert, 2013).

Based on the assumption that argumentation promotes the acquisition of domain-specific knowledge and understanding, a broad variety of tools and interventions for fostering argumentation has been developed (for a review of computer support for argumentation see Noroozi et al., 2012; Scheuer, Loll, Pinkwart, & McLaren, 2010), ranging from direct instruction about characteristics of good argumentation (e.g. Choresh, Mevarech, & Frank, 2009, p. 229; Nussbaum et al., 2008, p. 1983) to argument visualization tools or argumentation maps (e.g. van Drie, van Boxtel, Jaspers, & Kanselaar, 2005, p. 582; van Drie, van Boxtel, Erkens, & Kanselaar, 2005, pp. 27 f., 29 f.; Janssen et al., 2010, p. 64; Munneke, van Amelsvoort, & Andriessen, 2003, pp. 119 f.; Schwarz, Neumann, Gil, & Ilya, 2003, pp. 227 f.) and from different kinds of discussion seeds (Clark, D'Angelo, & Menekse, 2009, pp. 322 f.) to collaboration scripts (Kollar, Fischer, & Slotta, 2007, pp. 710 f.; Stegmann et al., 2007, pp. 426 f.; Weinberger et al., 2010, pp. 508 f.).

These tools have been used for a while now in order to elicit interactions that are characterized by high argumentative quality and to study the role of argumentation for learning domain-specific content. For argument visualization tools, however, a review of such studies concluded that the available evidence for their effectiveness with respect to argument quality, coherence, and critical discussion was not conclusive (van den Braak, van Oostendorp, Prakken, & Vreeswijk, 2006, p. 73). Given the availability of a reasonable number of quantitative studies on argument visualization tools and other kinds of support, it is possible now to apply quantitative methods of research synthesis to evaluate the evidence concerning the widespread convictions about the beneficial role of argumentation for learning.

The prototypical way of analyzing and expressing the role of argumentation for learning is by means of a correlation between some measure of argumentation quality during the learning phase and knowledge acquisition as measured in a posttest. Such correlation coefficients then have to be synthesized in a meta-analysis to estimate a mean correlation coefficient that quantifies the role of argumentation for learning (cf., e.g., Hedges & Olkin, 1985, pp. 229–231). On closer inspection, however, many of the existing studies do not report such a correlation coefficient for the association between argumentation and learning, but focus on just some of the relevant variables in isolation. For instance, sometimes only effects of an intervention on the quality of argumentation during interaction in a collaborative learning phase (e.g. Munneke et al., 2003, p. 121) or on the acquisition of argumentation skills as measured by a posttest are reported. Among the studies that measure both the quality of argumentation and domain-specific knowledge, only a small proportion either reports correlations between argumentation during learning and domain-specific knowledge acquisition (e.g. Asterhan & Schwarz, 2009, p. 392; Choresh et al., 2009, p. 232) or employs similar analytical strategies that allow for an assessment of the association between these two kinds of variables (e.g. Asterhan & Schwarz, 2009, pp. 386, 388, 392–394). Often, only correlations within some of the several experimental conditions, but not across all conditions, are reported – along with the information that no significant correlation was found in the other conditions (e.g. van Drie, van Boxtel, Jaspers, & Kanselaar, 2005, p. 597). This practice of analyzing and reporting mainly correlations within specific conditions or the effects of interventions to support argumentation on argumentation quality and knowledge acquisition makes the conventional approach of synthesizing indicators of association between the two variables of interest to estimate a mean correlation between argumentation and learning unfeasible.

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