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Weak versus strong knowledge interdependence: A comparison of two rationales for distributing information among learners in collaborative learning settings

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ABSTRACT

Traditional jigsaw-type scripts create strong knowledge interdependence by distributing information on core concepts between learners. However, previous research indicates that such knowledge interdependence may hinder interactive knowledge co-construction by reducing learners' common ground on core concepts. In an experiment with undergraduates (n = 78) in three-person-groups, we contrasted two rationales for distributing information: (1) establishing *strong knowledge interdependence* by distributing knowledge on core concepts as in a traditional jigsaw-type script, and (2) establishing *weak knowledge interdependence* by distributing only contextual information in a modified jigsaw-type script. Weak knowledge interdependence particularly benefitted low prior knowledge learners' transfer performance. Furthermore, it supported learners' interactive knowledge co-construction during collaboration, and this interactive co-construction mediated the effects of knowledge interdependence on individual learning. This study illustrates how collaborative and individual learning activities interrelate, and that a slightly modified jigsaw-type script makes a valuable addition to an instructor's toolbox.

1. Introduction

Collaborative learning is a powerful asset in an instructors' toolbox. Its overall effectiveness has been demonstrated in reviews and meta-analyses (Hattie, 2009; Johnson & Johnson, 2009; Slavin, Hurley, & Chamberlain, 2003). In effective collaborative learning, peers co-construct new knowledge that goes beyond what any of them knew before (Chi, 2009; Deiglmayr & Spada, 2010), for example by integrating diverging perspectives and ideas (Jucks & Paus, 2013; Schwartz, 1995), or resolving socio-cognitive conflicts (Buchs, Butera, & Mugny, 2004). Nevertheless, effective collaboration does not occur automatically. Instructors therefore scaffold collaboration by prescribing and sequencing learning activities, distributing roles and responsibilities, and providing coordination support in the form of collaboration scripts (Fischer, Kollar, Stegmann, & Wecker, 2013). However, when designing such scaffolding, instructors face difficult decisions.

One important decision concerns whether and how information on core concepts should be distributed between learners. We use the term *core concept* to refer to models, principles, or procedures needed for understanding and solving problems in a given domain (e.g., the principles needed to solve a specific mathematical problem; or the concepts needed to understand a class of medical diseases). On the one hand, distributing information on core concepts motivates collaboration by creating specialization, that is, by establishing strong *knowledge interdependence* among learners (Molinari, Sangin, Dillenbourg, & Nüssli, 2009). This strategy is, for example, employed in the widely-used jigsaw method (Aronson & Patnoe, 1997). On the other hand, providing information on core concepts to all learners from the start has the advantage that each learner can develop a first understanding of the to-be-learned concepts on which she can build during collaboration, and on which collaborators can ground their communication (Baker, Hansen, Joiner, & Traum, 1999).

What constitutes core concepts, and what contextual information, depends of course on the learning goals in a given learning situation. In mathematics, for example, students might learn from worked examples that embed mathematical principles (core concepts) in different story problems (context). In biology, students might learn the features distinguishing invertebrates from

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vertebrates (core concepts), exemplified by specific species (context). In educational psychology, students might study different sources of learning motivation (core concepts) by analyzing a set of authentic cases (context).

In the following, we argue that the strong knowledge interdependence that is created by traditional jigsaw-type collaboration scripts by distributing core concepts among learners might be suboptimal. We propose a modified jigsaw-type collaboration script in which weak, rather than strong, knowledge interdependence is created by distributing only contextual information. Our focal claim is that learners, in particular low prior knowledge learners, benefit more when only contextual information is distributed, while knowledge on core concepts is shared. As an important mediating mechanism, we assume that such weak knowledge interdependence will better prepare learners to participate in interactive knowledge construction during collaboration.

1.1. Interactive learning activities

In a recent review, Chi and Wylie (2014) argue that *interactive* learning activities are the most beneficial for increasing individual learning outcomes. Interactive learning activities are defined by their collaborative, co-constructive nature. Examples include the co-construction of solutions, arguments, or explanations in peer discussions. Interactive learning activities, which can only be enacted in collaboration with a learning partner, are hypothesized to be more effective for fostering individual learning than constructive learning activities, which are the most effective kinds of learning activities a learner can engage in the absence of a learning partner. Chi and Wylie define constructive learning activities as activities in which the learner goes beyond the information given, and engages deeply with core concepts of the learning domain (e.g., by self-explaining, elaborating, comparing, inferring, or integrating information). Interactive learning activities are supposed to be superior to constructive learning activities because the learner is constructive and, at the same time, takes up and builds upon contributions of collaborators. Thus, a learner benefits from learning partners because they provide additional knowledge resources, different perspectives, new ideas, or feedback (Chi & Wylie, 2014). Other researchers have likewise emphasized the crucial role of learners' participation in such co-constructive, or transactive discourse (e.g., Berkowitz & Gibbs, 1983; van Boxtel, van der Linden, & Kanselaar, 2001; Deiglmayr & Spada, 2011; Fischer et al., 2013).

The presumed benefit of interactive over constructive engagement is likely to depend on an individual's relevant prior knowledge. High prior knowledge learners benefit from a collaborative setting even if they take over the sole responsibility for the group's task (e.g., by engaging with the task, generating self-directed explanations, and producing a solution), that is, by being constructive rather than interactive. For example, high prior knowledge learners often dominate the discussion, and also show the greatest learning gains (Salomon & Globerson, 1989). At the same time, high prior knowledge learners also benefit from being interactive, either by engaging in mutual knowledge co-construction with equally capable peers, or by tutoring less knowledgeable peers (Ploetzner, Dillenbourg, Praier, & Traum, 1999). Low prior knowledge learners, on the other hand, typically lack the necessary prerequisites to solve the task on their own in a constructive fashion, but profit from the explanations of more knowledgeable peers (Webb & Palincsar, 1996), or from the opportunity to mutually co-construct new insights (Chi & Wylie, 2014). Thus, interactive engagement in collaboration may be particularly beneficial for low prior knowledge learners. They depend more than high prior knowledge learners on the scaffolding, feedback, and additional insights that they may gain from interacting with others.

1.2. Knowledge interdependence and interactive learning activities

Knowledge interdependence means that learners collaborate on the basis of complementary expertise (Molinari et al., 2009). Learners have access to information on core concepts only via their learning partners, on whom they are thus dependent for their own learning (Buchs et al., 2004). Instructors can create strong knowledge interdependence either by having learners collaborate on the basis of pre-existing, complementary fields of expertise (Noroozi, Biemans, Weinberger, Mulder, & Chizari, 2013; Rummel & Spada, 2005), or by purposefully manipulating learners expertise by training each on a specific subset of core concepts prior to collaboration (Berger & Hänze, 2009).

The jigsaw method (Aronson & Patnoe, 1997) is a typical collaboration script following the latter approach. Several slightly different implementations of the jigsaw method exist. Nevertheless, all of these jigsaw-type collaboration scripts include at least two phases (Dillenbourg & Jermann, 2007): In an individual learning phase, learners study a specific concept and thus become an “expert” for this concept. Each learner becomes an expert for a different core concept, establishing strong knowledge interdependence. In a subsequent collaboration phase, learners explain the individually studied concepts to one another, and work on joint tasks requiring their complementary expertise.

1.2.1. Benefits of knowledge interdependence

The main benefit of establishing knowledge interdependence with regard to core concepts is motivational (Berger & Hänze, 2009). Knowledge interdependence creates a special form of positive social interdependence, which has well-documented, positive motivational effects (Johnson & Johnson, 2009). When learners know that they can solve a joint task and reach their own learning goals only by pooling and integrating their complementary knowledge on core concepts, this interdependence renders collaboration meaningful and relevant, and thus increases individual motivation to participate (Buchs et al., 2004; Johnson & Johnson, 2009; Slavin et al., 2003). Additionally, some degree of knowledge interdependence is beneficial for fostering interactive knowledge co-construction, as differences in perspectives or opinions often lead to fruitful argumentation, elaboration, or mutual explanations (e.g., Jucks & Paus, 2013; Schwartz, 1995). Particularly positive motivational effects are reached when knowledge interdependence is combined with personal accountability, for example when learners expect to be tested regarding their individual knowledge about the whole range of core concepts (Johnson & Johnson, 2009).

1.2.2. Disadvantages of knowledge interdependence

When instructors establish strong knowledge interdependence within a group in order to motivate collaboration, this implies that each individual learner lacks knowledge on core concepts when entering collaboration. Under some circumstances this may be problematic, as existing knowledge is an important predictor of future learning (e.g., Schneider & Bullock, 2009). Thus, to constructively engage with learning materials, learners need basic knowledge on all to-be-learned core concepts, on which they can build, for example, by constructing principle-based self-explanations (Renkl, 2014), by devising well supported arguments (Noroozi, Weinberger, Biemans, Mulder, & Chizari, 2012), or by working out a comprehensive problem solution (Rummel & Spada, 2005). Such constructive, individual engagement is also the basis for effective interactive knowledge construction (Chi & Wylie,