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The role of task design and argumentation in cognitive development during peer interaction: The case of proportional reasoning

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Abstract

This paper examines task design that affords deep changes in mathematical thinking in the context of peer interaction. We describe a study in which 60 low-level high-school students solved a proportional reasoning task, the ''blocks'' task as individuals and/or in dyadic interaction. We show that we could tailor the design of the task in order to create a cognitive conflict among dyads, notwithstanding the strategies used by the students. We show that students' proportional reasoning strategies did not improve as a result of discussion even when guided by an experimenter dedicated at reaching consensus; however the introduction of a hypothesis testing device *and* the guidance of the experimenter to accommodate divergent views led peers to impressive conceptual change in their discussion and in an individual post-test. Examination of one case of dyadic interaction shows that beyond the value of given characteristics of individuals or of tasks, the process of argumentation that takes place between the peers explains the subsequent gains of the individuals. The conditions under which conceptual change was attained challenge theoretical views on cognitive development and social interactions.

Keywords: Proportional reasoning; Conceptual change and social interactions; Argumentation

1. Cognitive development and peer interaction

The role of a child's interaction with peers in the development of his or her cognition has long been discussed from both Piagetian and socio-historical perspectives (e.g., Rogoff, 2003; Vygotsky, 1986). In keeping with this approach, this paper examines task design that affords deep changes in mathematical thinking in the context of peer interaction, taking into account the mediating role played by argumentative mechanisms.

Many studies of cognitive development of peers have pointed to the benefits of cooperative learning in terms of mastering academic skills. For example, cooperative organization of classrooms has yielded higher academic achievements than traditional classroom instruction in which the teacher addresses the class as a whole (Huber & Eppler, 1990; Shahar & Sharan, 1995). Furthermore, Johnson and Johnson (1987) analysis of 378 studies showed that cooperation

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usually leads to better achievements than individual activities. As for the kind of knowledge whose acquisition is particularly facilitated by peer collaboration, it is more effective than individual or competitive learning for complex tasks (Johnson & Johnson, 1987), for conceptual development (Phelps & Damon, 1989) and discovery tasks (Kruger, 1994) rather than on skill tasks and rote learning. While such general studies are valuable in that they encourage educators and researchers to find inventive ways to improve achievements and learning, it is equally imperative to explore the conditions under which cognitive gains are optimized, as well as the processes that lead to cognitive development.

Beyond motivation and intersubjectivity as general factors that facilitate the cognitive development of interacting peers, researchers have attempted to identify how the process occurs. According to Piagetian tradition, ''cognitive conflict'' leads children to seek equilibrium. Such conflict may be realized by pairing students with different opinions or expertise (Azmitia & Perlmutter, 1989; Ellis, Klahr, & Siegler, 1993) or by confronting them with a perspective that better fits reality than their own (Tudge, 1992; Tudge & Rogoff, 1989), e.g., via a hypothesis-testing device. However, these methods alone generally do not provide a sufficient condition for learning (see Limon, 2001, for a review on difficulties in introducing a cognitive conflict strategy).

Therefore, grouping people with different opinions to solve a problem provides opportunities for learning, but change/learning is not the inevitable result of this grouping. As noted by Brown and Palincsar (1989), ''change is not the automatic outcome of group problem solving… It is the result of certain social settings that force the elaboration and justification of various positions'' (p. 408). Similarly Rogoff (1998) states, ''it may be not the conflict but the processes of co-elaboration which support cognitive progress, as several points of view are examined and modified to produce a new idea that takes into account the different standpoints'' (p. 717). The children's collective process of argumentation with peers has been claimed to be a basic developmental process where the coordination of arguments leads participants toward a set of collectively valid, objective and coherent statements (Miller, 1987).

Several researchers attempted to study experimentally the role of argumentation in reasoning and knowledge construction (Hershkowitz & Schwarz, 1999; Pontecorvo & Girardet, 1993; Resnick, Salmon, Zeitz, Wathen, & Holowchak, 1993). In those studies, argumentation was defined as a ''verbal and social activity of reason aimed at increasing (or decreasing) the acceptability of a controversial standpoint'' (van Eemeren, Grootendorst, & Snoeck Henkemans, 1996) or as ''the social practice of justifying decisions under conditions of uncertainty'' (Zarefsky, 1995).[1] With such (mostly implicit) definitions, the above studies showed how argumentative activity helped inter-subjective processes become intra-subjective.

So far, and in spite of the studies mentioned above, research on the role of argumentation in learning and development is nascent only: in all studies mentioned above, argumentation was recognized as responsible for learning gains in post hoc analyses. It was not treated as an independent variable. After all, this is not very surprising: one cannot rule people to argue or to stop arguing. What teachers or experimenters can do is to invite peers to discuss an issue or to accommodate divergent views. Such an invitation does not necessarily lead them to actually engage in argumentation. In fact, researchers have recognized that true argumentation on scientific issues is difficult to sustain and rarely occurs (Baker, 2003; Nonnon, 1996). We are then in a weird situation in which researchers can illustrate the beneficial role of argumentation (in post-hoc analyses) but cannot prove it (by using methods of inferential statistics), recognize that its emergence is not common in school tasks but have the intuition that its elicitation is possible and beneficial for learning.

Our approach in the present study is to consider the role of argumentation for conceptual change in peer interaction, through conditions that have the potential to lead to argumentation among peers. We measure learning effects of the peer interaction in these conditions and then analyze representative protocols to observe whether argumentation happened and how it led to conceptual change. To a large extent, this approach shifts research from argumentation and learning to what we call *argumentative design* – the set up of conditions that have the potential to lead to argumentation, and its learning outcomes.

The first condition we consider in argumentative design is very general. It concerns the ways peers work together. These ways are multiple and may lead to different effects. Dillenbourg (1999) differentiated between these ways and

[1] There is no general consensus on the definition of argumentation. However, all cited researchers belong to a socio-cultural trend that considers argumentation as a central social activity in which knowledge is shared. According to such a perspective, disagreement does not necessarily lead to argumentation since people may stick to their positions and may not engage in a social activity.