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Challenges in the innovation of mathematics education for young children

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1 The early bird catches the worm

Technological developments over the past 50 years have opened new opportunities for action and prosperity for many citizens all over the world. Consequently this has also significantly raised the need for an ever improving education system that is supposed to equip citizens with high quality cultural tools, skills and attitudes to keep up with the pace and innovations of cultural development.

Governments all over the world try to answer these increasing demands with a number of policies regarding how the educational system should contribute to a higher general educational level among people, how to lay the foundations for new expertise and innovations for the future, and take care that no child is left behind. Governments spend big (though differing) amounts of money in research for improvement of the educational system and require accountability of schools in return. In the ways that governments in the industrialised countries try to influence the research agenda, and maximize the value of research outcomes and school improvements, a number of communalities can be seen. First of all, there is a strong tendency worldwide to concentrate on raising the achievement levels of students in the domains of reading and mathematics. This aim is furthermore often combine with a firm belief that achievement levels are validly represented by test scores. The difficulties in achieving these goals have furthermore led to the tendency to concentrate on research and program development for the younger children. It is widely believed that early starts in domains like reading and mathematics (when properly implemented) will provide children with benefits that can help them flourish in a future society. It is the early bird who catches the worm.

Educational research over the past decades has definitely produced useful understandings that can support the innovation of early childhood education and confirm this “early bird assumption”. However, it also turned out that the complexity of the problem denies easy solutions and requires a multidisciplinary approach. Each of these ambitions produces many different challenges (ethical, cultural, theoretical, practical) that ask for further elaboration and collaboration, and that may finally even contest some of the current assumptions involved.

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The articles in this special issue of *Educational Studies in Mathematics* can be placed against this background of worldwide educational changes, in particular with respect to mathematics education. Each article can be seen as an attempt to contribute to the improvement of mathematics education for young children and addresses one or more of the nagging challenges on the basis of empirical study or conceptual clarification. When reading the articles, it is clear that they have a shared background in the research program of the Centre of Individual Development and Adaptive Education (IDeA) based in the Goethe University in Frankfurt am Main in Germany. They demonstrate a multidisciplinary approach, bringing together mathematics education, psychological theory of learning, cultural theory, sociology and psychoanalytic theory. In my commentary I want to reflect on some of the challenges that are addressed in the articles and give comments drawing from my own academic background in the Cultural-Historical Activity Theory (CHAT).

2 Mathematical tasks and situations

One of the issues that runs through several of the articles of this special issue is the notion of mathematical task or mathematical situation (see for example the articles of Vogel; Brandt; Münz et al.). It is one of the most widespread and old mistakes to consider a task a mathematical task on the basis of the fact that it is construed or recognised by an expert (or adult for that matter) as a mathematical task. All achievement tests are based on this assumption: a test is considered a mathematical test because experts made it that way by constructing an ordered set of mathematical tasks (items). This assumption, however, is only valid when the pupil who takes the test, is socialised in a culture that helps him/her to see these tasks (test items) immediately as mathematical. Especially for young children this is rarely the case. It is an important merit of the work of Vogel and Brandt to put this problem explicitly on the research agenda. Interestingly, Vogel has demonstrated that an increasing openness of the task and freedom for the pupil to identify problems in a situation enhances the chances that a situation will be seen as one with a problem that can be solved with mathematical means. But still this author is not unequivocally clear how a mathematical task should be defined, for instance when she points out that "situations of play can be characterized structurally" by [among others] "the mathematical task or problem". In her analysis of the *Wooden sticks*-task, Vogel states that this task can be allocated in the mathematical field of "patterns". From her analysis, however, it is obvious that the pupils construe the meaning of the task in many different ways, but there are no signs that this task really becomes mathematical for the pupils (for example by analysing, comparing, linking patterns from an explicit rule). The only conclusion can be that this task was not a mathematical task at all for the pupils involved. The fact that the task can be allocated on one or more mathematical domains is actually irrelevant for the characterisation of the pupils' task-oriented actions.

Likewise, Brandt constructs mathematical play situations in order to study early mathematics teaching–learning situations and demonstrates that young children can act differently and sometimes unpredictably in such situations. But even though the situations are allocated in mathematical domains and meant to arouse mathematical activities, no evidence is provided that the children were indeed involved in activities that could be reliably dubbed as "mathematical" from the children's situated point of view. No doubt, the children were arranging geometrical figures, but the descriptions give no evidence that they were using mathematical rules to evaluate the symmetry of the butterfly rather than for example good perceptual fit or aesthetic evaluations. On the basis of the descriptions one could conclude that the children were actually not executing a mathematical task. Brandt claims correctly that mathematical knowledge arises on the basis of negotiations and not by transmission. The same is true for the attribution of a mathematical meaning to a setting. A pedagogue's claim that she/he is implementing "mathematical play situations" in Kindergarten classrooms deserves further scrutiny of the process of children's identification of the nature of the problem in the play context and the tools required and available to solve it.

As Krummheuer also pointed out in his article on diagrammatic and narrative argumentation "the 'final' definition of the problem situation is a matter of negotiation of meaning in the concrete situation of interaction". But even "negotiation" by itself (as a fact) is no firm argument to call a task mathematical from the child's perspective. Eventually it is the problem solver (pupil) him or herself who should transform the meaning of a situation into a mathematical task that makes mathematical sense to him/her, and who self-evidently makes the choice for mathematical actions. Only when the pupil defines the situation as a mathematical task, we can justifiably maintain that he carries out mathematical actions in order to solve the problem embodied in the situation and makes a start with true mathematical learning. Further elaboration of the process of situation-defining by children themselves is badly needed when we want to be sure that children are involved in mathematical tasks, mathematizing and mathematical learning. Solving this problem is a major challenge for the future of early childhood mathematics education and testing.

3 The theory of mathematical learning and development

Most of the authors in the special issue refer to socio-constructivism as their theoretical perspective without further explaining what it means. In addition to that, Krummheuer (in his article on diagrammatic and narrative argumentation) rejects the idea (correctly in my opinion) of general psychological theories of learning and development that can be applied to the domain of mathematics for the design of mathematics education. I would strongly endorse his idea that the subject matter of mathematics be a "constitutive dimension of the developmental theory" for the domain of mathematics education. It is quite remarkable, however, that he adheres to socio-constructivism, which is also a universal theory that has to be applied to specific subject matter domains in order to contribute to educational innovation. And socio-constructivism is even worse than classical (universal) learning theory. At least this learning theory tried to explain and conceptualise its own core concept (i.e. the process of learning), but socio-constructivism does not give any explanation whatsoever of "construction". As a general description of an epistemological stance (saying that knowledge is not something out there, given, and universal, but constructed by human beings through dialogues) this might be useful. As a psychological theory, though, which should be expected to conceptualise and explain (mathematical) learning and construction in detailed ways, socio-constructivism is a void idea (see for further elaboration van Oers, 2006). Krummheuer "solves" this problem by referring to the cultural–historical approach of Vygotsky and Leont'ev, but unfortunately he does not explicitly use the concepts (and language) of this approach to elaborate his ideas of an activity-based theory of mathematical learning. Neither do his colleagues, when referring to socio-constructivism as their basic theoretical perspective.

From an activity theory point of view, it is, by definition, impossible to talk about a universal theory of subject matter learning, as all learning is based on situated tool-mediated actions on specific objects. Mathematical objects (like concepts, theorems, algorithms, proofs etc.) provide the rules that constitute the organisation and course of an activity.

This is not the place to elaborate an activity theory of learning that is rich enough to specify the conditions of mathematical learning (for general descriptions of this approach see van Oers, 1996a and b, 2012). I just want to emphasize here that the elaboration of a theory of mathematical learning that is specific enough to help solving concrete problems of educational design is an important challenge for the future elaboration of early childhood math education. My guess is that socio-constructivism is a dead end.

Whatever theory of mathematics learning in young children is adopted, this theory should be rich and sufficiently conceptually detailed to give explanations of mathematics in play (as play is a dominant form of activity for young children) and explain how mathematical learning can be embedded in play, can include adults as co-players and how this mathematics within play activities can finally evolve into a new self-relying activity able to adopt a playful character itself (i.e. into playful mathematics, see for example van Oers, 2013c). Playful activity is for young children the interactional niche for the development of their mathematical thinking. Obviously, the elaboration of play as a context for meaningful mathematics learning, is a clear challenge for future mathematics education. Vogel has made an interesting start with integrating play and mathematics learning, but further elaboration is needed to include play activities that go beyond adult defined rule-games (with sticks and blocks). One may also doubt here, whether the old assumption of "purposelessness" (as in Vogel's definition) is a productive assumption for a valid definition of play as an educational context, and whether this is a necessarily to be included as a defining characteristic (van Oers, 2013a).

A specific theory of mathematics learning may also be helpful (more than socio-constructivism) to understand some of the core topics in this special issue: gender differences in mathematical achievements and creativity. I will address these briefly below.

4 Some specific challenges

Intriguing findings are reported in the article of Lonnemann, Linke-Hasselhorn, Hasselhorn and Lindberg. They found gender differences in mathematical achievements in young children. Their finding that girls were overrepresented in the low-ability end of the distribution, while boys were more present in the higher levels of performance cries out for an explanation and for further hypotheses regarding the possibilities to change this situation (if possible). Lonnemann et al. propose a number of facts that show that socio-cultural factors might be involved here (such as math-related gender stereotypes). It may be interesting to investigate further if traditional educational presumptions about math in young children may be involved as well, which focus traditionally on memorising formal arithmetical facts, not on language-based narrative competences that help children to talk and reason about the aspects of reality that have to do with number, space, relationships. It might be that the chance to get higher scores on math ability tests are easier to get on the basis of the (memory-based) abilities that boys have been able to acquire, than on the basis of narrative competences. The girls' headstart in narrative competence is manifest in their better reasoning skills, but this evidently doesn't always help them to get into the higher levels of performance on the quantity–number tests. It might be interesting to investigate if the boys in the upper quartiles of the distribution also have a good narrative *understanding* of their quantity–number operations that goes beyond errorless operating with numbers. For both boys and girls we need more insight in the relationships between narrative competence and mathematical thinking in order to find out if the differences are only biologically based, gender-stereotype-based, or a result of the teachers' stereotypes regarding the nature of mathematics teaching in young children, separating operational mastery of arithmetical facts from narrative competence (see van Oers, 2002, 2013b).

Without doubt, the development of mathematical thinking should go beyond the instruction of facts and algorithms, but needs to foster creativity as well. In her interesting article about mathematical creativity Münz construes the concept of creativity as a phenomenon that includes both a general dimension and a domain-specific one and pays due attention to the social conditions that stimulate the origin and development of mathematical creativity. In her argument, Münz also refers to Vygotsky concept of creativity. For Vygotsky creativity was a general characteristic of meaningful life, and an essential part of all cultural activities. Hence, any activity-based theory of mathematical thinking necessarily has to develop a concept of mathematical creativity, including both the personal and socio-cultural dimensions. A real challenge then would be to develop a unitary theory of mathematical activity (including its creativity aspect) that doesn't have to resort to another (maybe even incompatible) theory like psychoanalysis to explain creativity. As creativity seems to be based on blind variation and selective retention (see Simontov, 2012) neural mechanisms may be involved as well (e.g. mechanisms that can mitigate impulse control and inhibition). As Luria has already demonstrated, cultural–historical activity theory is compatible with neuropsychological explanations (see for example Luria, 1973), but there is still a long way to go to explain (mathematical) creativity in more detailed ways from an activity theory point of view. For the development of an activity theory account of mathematical thinking it might also be useful to consult the work of Kurt Lewin as well, especially his ideas of "valences" ("Aufforderungscharactere der Aufgabe", e.g. Lewin, 1935). Münz's challenging attempt to explain mathematical creativity by taking resort to two quite different theories, may be taken as a further challenge to construct an encompassing theory of mathematical thinking and learning that integrates both explanations of problem solving, learning, and creativity. That is to say: a theory that helps in designing educational approaches for young children that foster optimal conditions for the development of a creative attitude for variation and surprising combinations.

5 The role of the teacher

It goes without saying that the future of mathematical thinking in young children strongly depends on the quality of early years teachers to recognise mathematical actions in children, to see the mathematical potential of play activities and play objects, and to guide children into the future where they can still participate autonomously and creatively in mathematical communications (without necessarily becoming expert mathematicians themselves).

Brandt explained in her article how different epistemological points of view on mathematics influence how teachers look at young children and organise their pedagogical practices. On the basis of her research she suggests that the teacher's view on mathematics may finally influence children's conception of mathematics (as a narrow operation based practice, or as a creative field of human expertise). Brandt's argument and her empirical underpinning is interesting and opens a new strand of future research on teacher' abilities to guide young children into mathematics. Indeed, the teacher can be seen as a key figure in the evolution of mathematical thinking on the basis of diagrammatic argumentations into narrative argumentation on the basis of explicit rules of logic (as suggested by Krummheuer). But the teacher is also responsible for practicing creative productions with children when problem solving, encouraging the continuing "*mathematicalisation*" of children's language, and building up a tool kit of relevant algorithms. Finding ways to educate such a teacher for young children, with a deep understanding of the psychological characteristics of young children's playful learning, with valid mathematical understandings, with abilities to demonstrate the relevance of mathematical creativity and the attitude to improvise in her pedagogical practice within a strongly structured field (see for example Sawyer, 2011) may be the biggest challenge that we face in our attempts to improve mathematics education for young children.

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