The Relationship between cultural Expectation and the local Realization of a Mathematics learning Environment

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> Momma used to say that life is like
> a box of chocolates: you never
> know what you're gonna get.
>
> — Forrest Gump

Abstract

Has always something "gone wrong", when preschool children do not correctly solve a carefully designed mathematical problem? This paper deals with the tension between the "culturally expected" behavior of young children and their actual, locally accomplished comprehension of presented mathematical problems and their "unconventional" solutions. Employing the concept of the "developmental niche in the development of mathematical thinking" (NMT), it will be explicated that the usual confrontation between instruction and construction dissolves in an evolutionary spiral in the development of mathematics thinking.

1 Introduction

I would like to talk about the interface between "cultural expectation" and "local realization" in the social context of encounters that "serve" as mathematical learning opportunities for children. In the analyses of several episodes from a German kindergarten or from family observations dealing with different mathematical domains, we were confronted with an interpretation of certain scenes in which somehow something "went wrong". Obviously, local productions of a solution can take another path than anticipated by "normal" expectations about how the given problem is supposed to be coped with. It was a remark of Newcombe & Huttenlocher 2003 about the child's development of spatial representation and reasoning, stressing the factor or necessity of "mishaps resulting from ambiguous communication" for this development that gave me food for thought:

> Presumably, in the course of normal development, feedback from confused listeners and/or from mishaps resulting from ambiguous communication drive the development of organized description strategies and explicit marking of frames of reference (ibid, p. 205).

My first thought was: is this appropriate wording, when obviously crucial conditions of the child's development connote a negative outcome, like the word "mishap". I do not mean to idealize the conditions of learning mathematics in everyday situations — the kinds of normal interaction with parents, adults, nursery teachers, siblings and peers. I would rather support a position, which might be similar to what Garfinkel calls the "ethonomethdological indifference":

> Administering Ethnomethodological indifference is an instructable way … to pay no ontical [sic!] judgemental attention to the established corpus of social science (Garfinkel 2002, p. 171).

From a socio-constructivist perspective I am interested in reconstructing the ways and modalities, how the situationally emerging form of participation of a child in a social encounter can be conceptualized as a moment in the child's development in mathematical thinking.

This way of looking at the process of interaction is based on a long discussion in the science of mathematics education that resulted in "my" conceptualization of learning as a dual process, as the individual's cognitive construction of knowledge and as his increasingly autonomous participation in social situations. Tomasello 2003 speaks of the „dual inheritance" (S. 283; see also Voigt 1995; Krummheuer 2011b; Krummheuer 2011a).

Refering to my initial remarks, the following issues might be helpful in finding an appropriate wording for the theoretical concepts :

1. If one looks into mathematics learning processes of young children of preschool and kindergarten age, one cannot assume that the attending adults have a sufficient mathematical background to serve as experts who can help avoid the occurrence of such mishaps. Neither the nursery teacher nor the parents or elder siblings of a child necessarily possess the desirable mathematical competence. Referring to the epigram, one could say: Forrest Gump cannot be sure, what kind of chocolates are in the box.
2. From an interactionist's stance, all interaction situations principally entail the potential of developing in an *unexpected* way where the participants cannot easily refer to routinized and/or standardized applications of knowledge – they have to interactively negotiate a novel "shared meaning". – Forrest Gump, who is going to get a box of chocolates, might have another understanding of what such a box is going to be.

In order to deepen this issue theoretically, I will introduce the concept of the "interactional niche in the development of mathematical thinking" and thereafter apply this concept to several episodes which had been analyzed in our projects "erStMaL" and "MaKreKi". Finally, I will draw some conclusions about the question how much one could or should instruct small children in the development of their mathematical thinking.

2 The Concept of the „Interactional Niche in the Development of mathematical Thinking"

The theoretical perspective of the generation of mathematical thinking taken here is one of socio-constructivism. This perspective encompasses two research traditions: The one strand is based on the phenomenological sociology of Alfred Schütz (Schütz & Luckmann 1979) and its expansion into ethnomethodology (Garfinkel 1972) and symbolic interactionism (Blumer 1969)[1]; the other tradition refers to the cultural historic approach of Vygotksky and Leont'ev etc. (see Wertsch & Tulviste 1992 and Ernest 2010).

Generally speaking one can characterize the cultural historic approach as one which takes culture as a given that the child adapts to by its development; an important issue hereby is the notion of language that stores and transmits the cultural accomplishments in a symbolic form allowing the child to enter into this culture, step by step, finally becoming a full participant. One can characterize this approach as structuralistic (see Gellert 2008). In contrast, the micro-sociological approach views culture as a continuously and locally emerging course of action that is accomplished by the mutual exchange of meanings in the steady interaction among the members of a group or society. Goffman 1983 calls this a "situational perspective" (p. 8; see also Krummheuer 2007). Hereby the child co-constructs the culture in each social event in which it is participating.

From the stance of the cultural historic approach, one can consider the child's development as a general individual progression starting with statuses of participation that are dominated by observing and imitating actions of other participants and aiming toward statuses that are rather characterized by taking active influence on the course of interaction. Respectively, the interactionistic approach implies the idea of a "leeway of participation"[2] within which a child explores its cultural environment while co-constructing it. With respect to the child's development of mathematical thinking, I will amalgamate the two approaches in a "socio-constructivist paradigm" thus allowing the introduction of the notion of the "evolutionary spiral":

- The child individually utilizes the leeway of participation that is interactively accomplished and to be understood as a result of the culture the participants share.[3] The development of thinking is then comprehensible as an individual

[1] Surprisingly, Ernest 2010 does not mention this research tradition that usually is subsumed under the name „micro-sociology". For its reception in mathematics education see Bauersfeld 1995; Krummheuer 1995; Voigt 1995.

[2] See the notion of „Partizipationsspielraum" in Brandt 2004 that is translated into English as „leeway of participation"; see also and Krummheuer 2011a.

[3] culture taken here either as a macro-sociological global precondition or as a micro-sociological phenomenon of locally stabilized and routinized procedures of meaning negotiation

process of cognitively active adaptation to those aspects of the process of negotiation of meaning that are conceivable to the child.

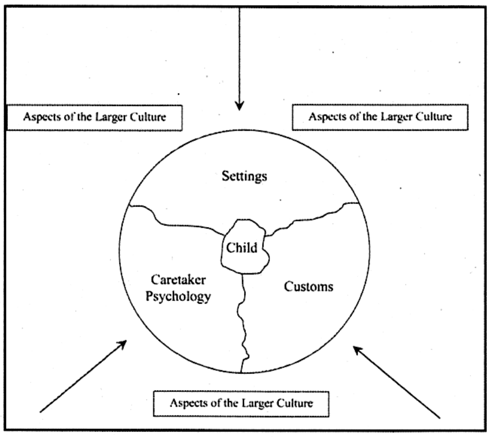
- By these processes of adaptation, the procedure of interaction develops over time allowing the child incrementally to take over activities and responsibility for the outcome of the interaction. This might lead to modifications of the structure of interaction that eventually can become stabilized in this new mode over a longer period of time. Thus, the framing conditions of the culture for such social occasions change, in that in subsequent encounters the participants are likely to accomplish (slightly) differently structured processes of negotiation of meaning.[1]

For the purpose of further developing this notion of the evolutionary spiral, I refer to the concept of „developmental niche“ from Super & Harkness 1986:

„The developmental niche, .., is a theoretical framework of studying cultural regulation of the micro-environment of the child, and it attempts to describe the environment from the point of view of the child in order to understand processes of development and acquisition of culture“ (p. 552)

The authors introduce three subsystems for such a developmental niche:

- „the physical and social settings in which the child lives“,
- „culturally regulated customs of child care and rearing“ und
- „the psychology of the caretakers“ (p. 552; the diagram is published in Harkness et al. 2007, p. 34S).



Super and Harkness conducted anthropological studies without focusing on the situational aspects of social interaction processes. I stress the component of the interactively local production of such processes and speak of an “interactional niche in the development of mathematical thinking” (NMT). It consists of the

- provided “learning offerings” of a group or society, which are specific to their culture and will be categorized as aspects of “allocation”, and of
- situationally emerging performance occurring in the process of meaning negotiation, which will be subsumed under the aspect of the “situation”.[2]

I modify Super and Harkness’s three components of the developmental niche in that, first, I merge the categories “customs” and “caretaker psychology” to the component “pedagogy and education”, second, redefine the category “settings” to the component “cooperation” and third, add the new component of the content.

[1] One might call this a „conceptual change“ on the individual level (Vogel & Huth 2010).
[2] For more details see Krummheuer 2011c.

These modifications allow a combination of each of these novel components with either of the mentioned aspects.

NMT	component: content	component: cooperation	component: pedagogy and education
aspect of allocation	mathematical domains; body of mathematics tasks	institutions of education; settings of cooperation	scientific theories of mathematics education
aspect of situation	interactive negotiation of the theme	leeway of participation	folk theories of mathematics education

In the following I would like to further explicate the details of this table:

1. *Content*: Children are confronted with topics from different domains of mathematics as they appear in their everyday life. The following data was gathered in the research project erStMaL and in everyday mathematic classroom situations. These mathematical topics are usually presented in the form of a sequence or body of tasks, which are adapted with respect to their content and difficulty to the assumed mathematical competencies of these children. On the situational level the presentation of such tasks elicits processes of negotiation, which necessarily do not proceed in concordance to the ascribed mathematical domain nor to the activities that are expected in the tasks.
2. *Cooperation*: Beside this content related component, the children participate in culturally specific social settings which are variously structured as in peer-interaction or small group interaction guided by a nursery teacher or primary mathematics teacher etc. These social settings do not function automatically; in fact they need to be accomplished in the joint interaction. Depending on each event, a different leeway of participation will come forward.
3. *Pedagogy and education*: The science of mathematics education develops theories and delineates - more or less stringently - learning paths and milestones for the children's mathematical growth. In the concrete situation, however, it rather is the folk pedagogy of the participating adults and children that becomes operant. It cannot be assumed that these different theories coincide.

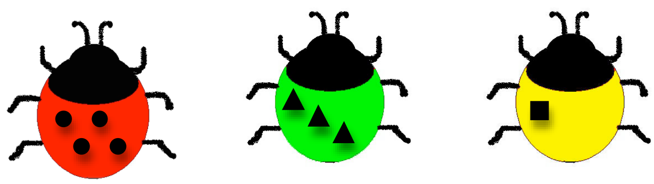
3 Some Insights from our recent Analyses in the Projects erStMaL and MaKreKi

First, some information about two projects on which my empirical analyses are based. They are a part of the "Center for Individual Differences and Adaptive Education" in Frankfurt am Main, Germany: "early Steps in Mathematics Learning" (erStMaL) und "Mathematische Kreativität bei Kindern mit schwieriger Kindheit" (MaKreKi; Mathematical Creativity of Children at Risk).[1] Both projects are longitudinal studies that range over a period of 5 to 6 years. Within this time frame we are in contact with the children from age 3 to 10. In erStMal we initiate learning opportunities for children in small groups in preschool and kindergarten and later in primary mathematics classes. Additionally, with a few children we also observe their families at home as they play with mathematically challenging material that we provide. In MaKreKi we selected children with a seemingly extraordinary degree of mathematical creativity. In this project we integrate our analyses with psychoanalytical insights about the development of the attachment behavior of the child to his/her mother.

I will present the results of our analyses of three episodes in these two projects.

3.1 First Episode: the June Bug Problem

In a preschool, the German Kindergarten, the two children Marie (age 4,8) and René (4,9) and an adult person are sitting together around a table. They have cards on the table that show June bugs, which differ in size (small and large), in color (red, green, yellow), and in the types of spots on the June bugs (circle, triangle, square and also by the sizes small and large).



The two children invent two systems of descriptions for the size of the bodies: the size (small and large) and the family-position (mom, dad, parents and kids;) for example:

[1] For more details of both projects see Acar Bayraktar et al. 2011S

I will refer to the end phase of a collective processing of the task. As mentioned, also a familial system of description has been invented: The small June bugs represent child-bugs and the big one mom-bugs, dad-bugs, or parents-bugs. During the period before this episode, they also compared the number of cards according to their size and color and found out that all these subgroups are of equal number.

After this comparison, the children realigned the cards around the round carpet, which is a kind of defined space for playing and exploring the material.

Finally, there were the following three cards in the center of the table:

Routinely, the adult opens this kind of constellation with the question "which one doesn't belong" (Wheatley 2008). And routinely we expect as an answer: the June bug with the few and big triangles doesn't belong. But René comes up with the solution that both June bugs with the many, small triangles do not belong. His justification has two aspects:

- Comparing the figures of the small and the big cards, he concludes, that the June bugs of the small cards should also only possess small figures on their tops.
- The two cards with the many and small triangles cannot exist in the system of the cards at all.

If one interprets his explanation in terms of the invented familial system of description, one could rephrase it in this way:

- big June bugs have big figures because they are parents
- small June-bugs have small figures because they are children
- so, big June bugs with small figures do not exist.

If one understands the figures on the June bugs to be, for example, people's hands, René's argument is: parents do not have hands the size of kids, this is impossible. They cannot be parents and children "at the same time", as he says.

René creates a non-canonical solution. The observing adult seems to have difficulty comprehending his approach. Possibly she assumes that he wants to say that the two June bugs with the many and small triangles are the ones that remain and therefore the third one with the few and big triangles does not belong. This constellation of misinterpretation evokes the short dialog in which Renè rephrases his solution. With respect to the interactional setting, it is René, who takes over the adult's perspective of being puzzled and explains his position to her. Obviously, the adult person did not anticipate René's solution. It was beyond the canonical expectations of what a child might answer.

From the viewpoint of the design of the problem, one could argue, if the different patterns of triangles would not have been printed on the backs of June bugs but just in an "inexpressive" circle, the children would not have had the "chance" to be "confused" and to thus develop an anthropomorphic view of the problem. This might be correct, and Wheatley, who developed the problem, does it with circles. But by discussing the results of this scene in this inexpressive way means that a kind of deterioration occurred in the process, namely that a mishap occurred. From an interactionistic stance, however, one would rather argue: this is what happened and it was rather René who "saved" the situation by taking over the adult's perspective. (Forrest Gump got a box of something that he did not take to be a box of chocolates. So what!)

3.2 The Second Episode: The Birthday-Party Problem

In a preschool the four children and a student research assistant „B" are seated at a table.[1] The children are Karoline (4;11), Fanny (4;0), Otto (5;4), and Klara (5;10).

[1] This scene is first mentioned in Krummheuer 2011a.

B opens the conversation: „Do you remember the chipmunk[1] that we brought with us the last time? It has its birthday today and wants to have a birthday party“. B then takes off a cover from a set of dishes and eating utensils that was put on the table. It contains four cups (pink, blue, green, yellow), four mugs, four plates all in the same four colors, four forks and knifes, four teaspoons and four tablespoons. The children take some of the items and move them around the table. Each child has a placemat in front of him/her and they group their items on it.

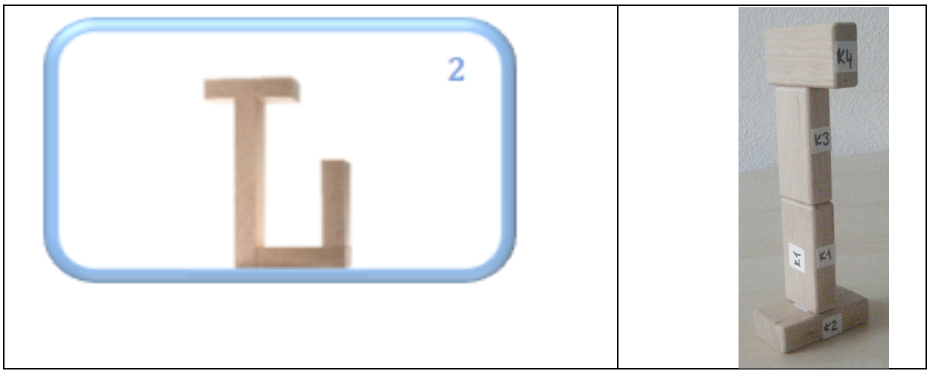
After 8 minutes of sorting out the utensils and the dishes Otto takes his turn and says: „One thing we forgot, where is the chipmunk supposed to sit?“ The group declares a part of the table to be the place where the chipmunk as a toy is supposed to sit (as a toy, it is physically not really present). The peers discover that there are no more dishes available and that only a few teaspoons remain. B comments on this situation: We haven’t got enough. But perhaps you guys can hand over some of yours”.

In the following the children make several attempts to distribute their eating and drinking utensils among five participants of the party. They develop some ideas that can be seen as the very initial steps to the concept of the division in the set of rational numbers. It, however, did not merge into more tangible results.

Here again one could argue from the stance of design science, that one could have anticipated the remark that the chipmunk should sit with them at the table and one could have been appropriately prepared for this. But again: “You never know what you’re gonna get”.

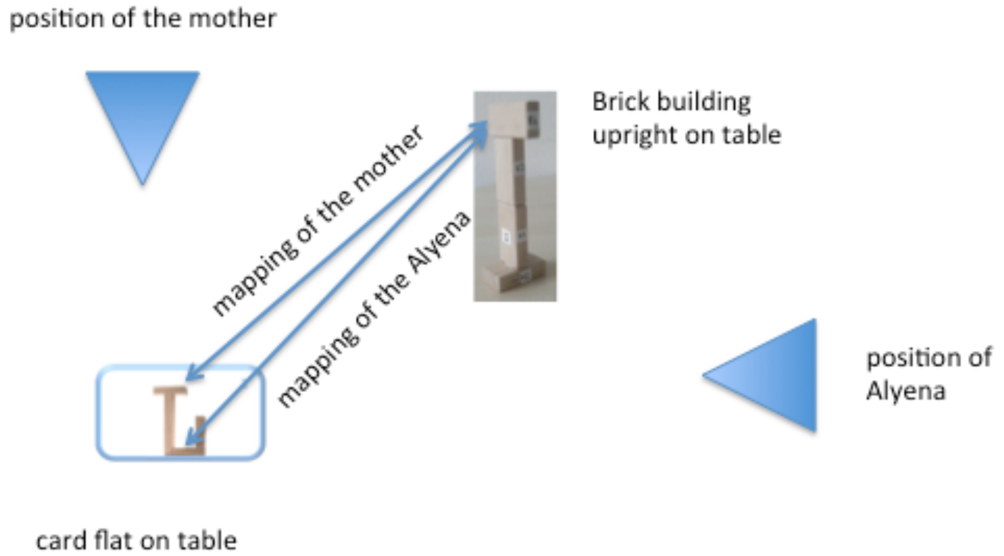
3.3 Third Episode: The Game: “Building Bricks” in the Family AK

In a family setting the mother and the daughter Aleyna of age 4;8 play a game in which they have to rebuild a construction of bricks according to a given picture on a playing card.



[1] The chipmunk is the mascot of the project erStMaL. It is a stuffed animal..

At the end of a relatively intense discussion they came up with the solution shown above in the right cell of the table. Our analysis of the interaction between mother and daughter reveals that the two partners, sitting at different sides of the table, interpret the bricks in their final joint construction as different parts of the picture.



Here again, we are facing a situation that developed in a surprising and unexpected way. At least Aleyna does not feel satisfied with the result, though the mother decided that their construction coincides with the picture on the card. It can be assumed that the designer of this game had not envisioned such a solution.

4 Final conclusion: the Application of the Notion of NMT

For a deeper analysis one can reconstruct these three examples with the help of the concept NMT. In all of these episodes a specific niche emerged, which conjointly can be characterized by the tension between the expected production of the solution and the actually realized outcome.

- With respect to the *component of content* we have to consider that the intended mathematical activities, like pattern identification, partitive division and spacial reconstruction of two dimensional diagrams, were accomplished in the first two cases in a more elaborated way than assumedly intended by the designers of the task. René's application of two different systems of categorization combined with certain restrictions that were based on a common sense understanding of human growth is a somehow unique and not expectable solution, that from a mathematical point of view, might entail a more sophisticated mathematical potential than the expected "canonical" solution. Also the birthday party problem advanced in a direction that, from a mathematical point of view, promises a deeper mathematical understanding of division than the expected partitive division of dishes and eating utensils. It encompasses the options of dealing with the division with a remainder, the overcoming of the positive integers etc. The third example appears to be different from the first two. Here the analysis leads to the insight that the negotiations between mother and daughter end in a deadend. We assume that it is not the different geometrical perspectives of mother and Aleyna that produce this calamity but that it is the effect of interactively wiping away their differences. Finally, this leads to unclarified and unspoken discrepancies that are most unlikely to stimulate any process of cognitive (re)-construction.

- With regard to the *component of cooperation* we have to tackle the phenomenon that, initially designed asymmetrical situations of interaction in which an adult is supposed to order, structure, and/or correct, emerge in a rather symmetrical discourse of co-construction. In the case of René we can even assume that he conducts himself in a more adult manner with the capacity of taking over the perspective of the adult.
- Referring to the component of *education and pedagogy* we recognize that theories of design science overestimate the immediate and direct impact of the cognitive constructions on the learner. It is as if the wedge of the social affair of negotiating meaning in the interaction among the participants is driven between the provided problem and the mind of the child. With reference to Goffman 1983 we can speak of the “interaction order” that is somehow like a more or less thick wedge that is driven between the allocated learning material and the cognizing child. What the child is processing in his mind is not the “inherent” meaning of this material but the interactively negotiated working consensus of the definition of the *situation* in which this material was implemented. This interaction order is to be taken as a social institution that for the most part independently functions with its own regularities and dynamics.

Taking this all into regard, we can reconstruct NMTs in the first two episodes that do not fail but rather proceed in an evolutionary spiral. Mathematically more sophisticated definitions of the situation and rather symmetrical forms of discourse are emerging as well. New mathematical concepts are in the incubator of these processes: the making of meaning and the potential of symmetrical co-construction can be exploited. The longitudinal design of our projects will give us the opportunity to analyze the actions of these children in later phases of their development. We also can gain insights in accomplished niches that go awry. This happens in the interaction when the emerging differences in the individual definitions of the situations are not distinguishable. It is neither the persistence of differences nor the situational impossibility of dissolving them, it is instead the act of sweeping these discrepancies under the carpet that extinguishes the NMT. Bauersfeld 1980 called it once the "hidden dimension(s)" (see also Krummheuer 2009; Krummheuer 2012).

The results of these first studies about the functioning of NMT allow a relatively differentiated standpoint on the question how much one should instruct children in kindergarten age in mathematics and how much one should let them have their own experience in constructing personally new insights that in the long term can be incorporated in the buildup of their mathematical knowledge (see the discussion in Tobias & Duffy 2009). It is not as much a matter if something goes right or wrong, which from an instructional point of view would be an indicator whether the instruction needs to be improved. There is always the possibility of unexpected ways in which the actual situations emerge. The allocative components will always be mediated in the concrete encounter by the interactive process of negotiation of meaning. Both aspects together define the interactional niche, by which the child might perceive the appropriate *stimulus* and the appropriate *guidance* as well for his/her cognitive development.Stimulus and guidance are on the one hand distinguishable as allocative and situational; on the other hand they are two sides of the same coin: they are concepts that in terms of NMT appear as a whole and not as one of its aspects. Empirically, there seem to be various constellations of NMT, which "operate" differently with respect to stimulus and guidance. Depending on these realizations of NMT, the evolutionary spiral then advances along different loops and opens different options to the process of children's mathematical thinking. — You never know what your're gonna get.

Further research is necessary in order to reconstruct these options and describe their effects.

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