Individual ways of dealing with the context of realistic tasks – first steps towards a typology

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Abstract: In this paper interim findings of an empirical study on the effects of context are presented. The study focusses on the question how upper secondary students deal individually with contextual aspects. This research project is based on a qualitative approach. Triangulation of methods is applied in order to get a broader access to the field. It becomes clear that the context is neither an objective nor an invariable feature of the task. Students deal very individually with the context, and it can be an object of change during the solving process. Four types of dealing with the context are gained from the analysis of the empirical data. These types can be embedded in and explained by the concept of sociomathematical norms and the theory of situated learning.

Kurzreferat: In diesem Artikel werden Zwischenergebnisse einer empirischen Studie zur Rolle des Sachkontextes beim Lösen realitätsbezogener Aufgaben vorgestellt. Ziel der Studie ist es, einen Einblick in den individuellen Umgang von Oberstufenschülerinnen und -schülern mit Sachkontexten zu bekommen. Um einen angemesseneren Zugang zum Feld zu erreichen, wurde eine Methodentriangulation durchgeführt. Es wird deutlich, dass der Sachkontext weder ein objektiver noch ein unveränderlicher Aspekt einer Aufgabe ist. Schülerinnen und Schüler gehen sehr individuell mit dem Sachkontext um. Es zeigt sich, dass der Sachkontext im Laufe der Aufgabenbearbeitung Veränderungen und Entwicklungen unterworfen ist. Die Auswertung der empirischen Daten führt zu vier Idealtypen des Umgangs mit dem Sachkontext. Diese Idealtypen können in die Theorieansätze des situierten Lernens und der soziomathematischen Normen eingebettet und durch sie erklärt werden.

ZDM-Classification: M10, C20, C30, C60

1. Introduction

Contextualised tasks in the mathematics classroom deal with a more or less realistic part of the extramathematical world which provides the background for a problem. This part of the extramathematical world is the *context* of the task.

The effects of context have not been investigated comprehensively yet but certain aspects have been highlighted: Clarke & Helme (1996) distinguish between *context* in the above mentioned sense and *context* which refers to the situation. They point out that both kinds of contexts act in combination and are individually constructed. Papastravidis et al. (1999) claim that students perform better in pure mathematics than in contextualised tasks with the same mathematical structure. They conjecture that familiar contexts enhance the performance. Boaler (1993) claims that in an open, discussion-centred mathematics-classroom context has smaller effects than in traditional classrooms, although there is no pattern which contexts have a fostering and which have a hindering effect. According to Kaiser-Messmer (1993) there are differences between boys and girls concerning their preferences for certain contexts: Boys prefer technology and physics, whereas girls prefer biology, medicine and ecology. Stillman (1998) states that the degree of involvement with the context is influenced by the task type. Modelling-tasks provoke most involvement with the context. Generally she claims that medium to high involvement with the context is connected to better performance. Stillman (2000) focusses on the influence of contextual knowledge on the performance. She points out that it can have both, a fostering and a hindering effect, but especially knowledge based on personal experience shows a positive influence on the performance. Carvalho de Figueirdo (1999) emphasises the effects of the cultural background on the way contexts are understood.

The studies carried out so far do not satisfactorily answer the question how an *individual* deals with the context and how the context given in a task-text is *internalised*. These questions are the basis of an explorative qualitative orientated study of which parts are going to be presented in this paper. More details concerning the study can be found in Busse (2001a & 2001b) and in Busse & Kaiser (2003).

2. Method

In the following methodical aspects are presented only to that extent which is necessary to understand the findings. A more detailed discussion with references can be found in Busse & Borromeo Ferri (2003).

Eight test persons (16 to 17 year old students, four boys and four girls) work in pairs on several realistic tasks outside of the mathematics classroom. Compared to a classroom setting this laboratory setting is appropriate in order to reduce the complexity.

One of the tasks given to the test-persons is shown in fig. 1:

In a little wood a home for aged people has been built. In the figure shown below the seven residential buildings are marked by black dots. There are paths in the wood so that the aged people do not need to walk through the undergrowth. The paths are marked by bold lines. On the path between the two crossings (marked by a dotted line) a common house is planned to be placed. This common house is meant to serve for afternoon coffee and evening events. The question is where exactly on this path the common house is to be built.

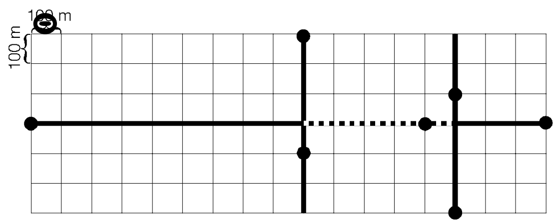

fig. 1: sample task

Since no criterion for an optimal position is explicitly given in this task one has to deal with a certain openness in order to solve it. The criterion has to be found on one's own, possibly considering contextual reflections. There is more than just one answer possible, so the test-persons have to give reasons for their choices.

The students are videotaped while working. After that they watch individually (together with the researcher) the video record. The playback is interrupted at certain moments in order to give the test-person an opportunity to utter something concerning the context that has crossed his or her mind while working on the task (*stimulated recall*). In a third step (*interview*) the test-person is asked more detailed about the statements he or she has made before.

By this *three-step-design* a set of data containing three different kinds of data is created. Caused by the three different conditions, in which the data are recorded, each kind of data has certain characteristics, e.g. relating to the role of the researcher, the time which has elapsed since working on the task, or the way the data are collected.

First the different kinds of data are analysed separately, i.e. the stimulated recall data are analysed separately from the interview data, and the data gained from the work on the task are analysed separately from both of the other two data. After that the three partial analyses are brought together to a comprehensive analysis. In this sense the procedure can be seen as a triangulation. In case of diverging partial analyses the above mentioned characteristics are used to explain and to understand the differences.

The data analyses follow the pardigm of qualitative interpretative research in mathematics education, as it is particulary done in German speaking countries (cf. Jungwirth 2003).

In order to reduce the complexity of the analyses the Weberian notion of *Idealtypen*[1] (*ideal types*) is used. According to this notion ideal types are used to describe and understand complex situations. By unilateral exaggeration of some and fusion of other aspects an essential structure becomes apparent. The purpose of creating ideal types is not exclusively to categorise facts, but to become aware of the characteristics of the real case by contrasting it to an ideal type.

3. Findings

It can be distinguished between general findings which are applicable to all test-persons and specific findings which are related to the position a case has within a typology.

3.1 General findings

Two general findings can be emphasised:

Subjectivity: The context of a task is interpreted very individually. The same task provokes different *contextual ideas* (Busse 2001b) in different individuals. So it does not make sense to speak of *the* context of a task. The contextual aspects that are used for solving the task are not an objective part of the task itself. It is rather the personal interpretation of the contextual situation described in the task text – which might differ a lot from individual to individual – that shows effects when solving the tasks. A sometimes distinct subjectivity of the contextual ideas could be observed throughout all test-persons.

Dynamics: The contextual ideas triggered by the task text are not spontaneously present from the very beginning of the work on the task. On the contrary: Contextual ideas come into being, develop and change in the course of the work on the task. Therefore contextual ideas cannot be seen as static but rather as dynamic. This phenomenon could also be – to a greater or lesser extent – observed throughout all test-persons.

3.2 Typology of dealing with the context

In addition to the general findings described in the preceeding section we will attempt now to distinguish between different kinds of dealing with the context. This distinction considers the above mentioned notion of ideal types (cf. section 2).

There are two aspects immanent in each realistic (or feignedly realistic) task: *reality* on the one hand and *mathematics* on the other hand. In the process of reconstructioning and contrasting the cases it emerges that there are distinctive differences in dealing with these two aspects, especially how they relate the first to the latter and vice versa.

It is not yet clear if the way a person deals with the above mentioned aspects is a constant characteristic of the person or if it depends on the special context. Further evaluation of our data will be necessary to answer this question. Consequently the ideal types presented in the following refer to ways of dealing with the context and do not refer to persons.

The following four ideal types can be distinguished by analysing the empirical data:

Type *reality bound*: Representatives of this type consider a realistic task as fully characterised by the real problem which is described in the task text. During the solving process they use extramathematical concepts and methods. They do not mathematise the real problem and they do not apply mathematical methods.

Type *mathematics bound:* Representatives of this type regard the context of a realistic task as a mere decoration. They translate contextual expressions that are used in the task text immediately into mathematical expressions. They use only that amount of contextual information which is given in the task text. Additional personal contextual knowledge is not applied. The task must be solved exclusively by mathematical methods.

Type *integrating*: Representatives of this type perceive the realistic task in its real context, but they also apply mathematical methods. They use personal knowledge about the context which exceeds the contextual information given in the task text in order to mathematise the problem and to validate the solution. During the solution process they apply mathematical methods.

Type *ambivalent*: Representatives of this type perceive the realistic task with its two aspects mathematics and reality. But they feel ambivalent concerning the legitimacy of the way they are supposed to solve the task: Internally they prefer contextually accentuated reasoning while externally a mathematical reasoning is preferred. These two ways of reasoning just coexist, they are not synthesised to a whole.

In figure 2 these four types are shown graphically. The upper arrows indicate how the type *ambivalent* is torn between the two aspects *mathematics* and *reality*. The lower arrows show how theses two aspects are merged into the type *integrating*.

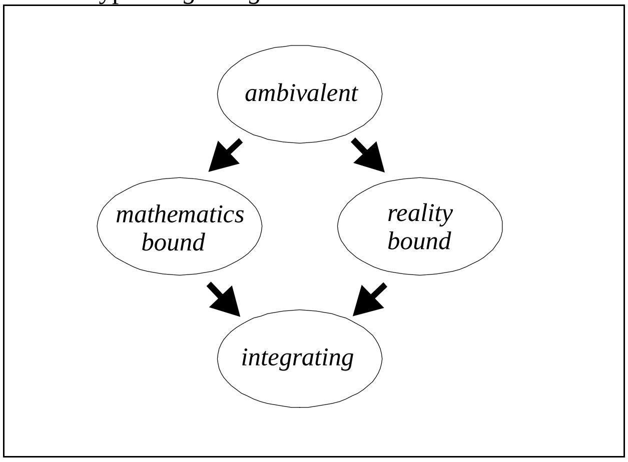

fig. 2: ideal types of dealing with the context

3.3 Descriptions and assignments of four cases within the typology

In the following four of the eight cases are briefly characterised and assigned to ideal types within the typology.

Since in a typology idealisations (and not real cases) are represented, ususally the real cases deviate more or less from the ideal types. So the assignment of the cases to ideal types are not meant to be a categorisation. A typology is rather meant to provide a background which makes the particular features of a special case perceptible and therefore provides the opportunity to understand the single cases in a more comprehensive way.

3.3.1 Karla

In the course of the work on the task Karla develops no contextual ideas at all. The context plays no role in the solving process. Karla considers contextual ideas as no legitimate means in order to solve the task. She prefers a purely mathematical reasoning. Since she does not find a purely mathematical approach she decides – as a second choice – for a special interpretation of the task text: She reads the task text passage "between the two crossings" as "in the middle of the two crossings". Doing this she gets an answer for the problem without using contextual ideas.

Karla is assigned to the type *mathematics bound*, but the evaluation of her data possibly indicates a consideration of contextual aspects in the future. In this case a learning process would have taken place. It remains an open question whether she will tend to the type *ambivalent* or to the type *integrating*. On account of her clear preference for a purely mathematical solution a future assignment to the type *reality bound* cannot be expected.

3.3.2 Luise

Luise develops a rich world of contextual ideas. She uses them directly for solving the task. Although a mathematical approach is Luise's first choice, she regards contextual ideas as a legitimate means in order to solve the task as long as a mathematical approach is impracticable. Nevertheless Luise is slightly doubtful regarding the legitimacy of this purely contextual based reasoning. However, these doubts appear mainly as a response to her partner and are not uttered on her own initiative. Luise's preferred location for the common house is close to the left crossing.

Due to her clearly contextual based reasoning Luise is assigned to the type *reality bound*. However, her doubts and her preference for a mathematical based approach (if practicable) possibly indicate a different assignment in the future. Because of her clear reference to realistic aspects a tendency to the type *mathematics bound* is not assumed.

3.3.3 Heinrich

While working on the task Heinrich uses contextual ideas exclusively to find a criterion for the best location and to validate results. An actual solution is preferably found by applying mathematical methods. By using the criterion that the sum of all pathlenghts is to be minimal he obtains a location close to the residential building on the dotted line. But already while working on the task he develops an intensive and emotional world of contextual ideas. This is probably caused by a recollection of his great-grandmother's experiences in a home for aged people. These contextual ideas suggest a different location for the common house, but during the working process Heinrich keeps preferring his formerly found result. Only after a longer struggle with himself he decides to choose a contextual based solution which minimises the longest path (i.e. a location on the left crossing). This decision takes place not earlier than the stimulated recall phase.

Since Heinrich uses contextual ideas in productive combination with mathematical methods he is assigned to the type *integrating*. His tendency to a pure contextual reasoning during the stimulated recall phase is presumably based on very personal experiences and therefore specific for the context.

3.3.4 Evelyn

During the work on the task Evelyn develops a rich world of contextual ideas which she uses silently in order to solve the task. She is interested in and shows an affection towards to the context. She is committed to social problems. However, many aspects of her silent contextual reasoning remain unsaid during the work on the task. She avoids to mention contextual references while working on the task. Therefore some of her utterances during the work on the task appear to be unexpected, and their context based origin can only be understood by analysing her later remarks in the stimulated recall phase or in the interview. Although she silently reasons based on context, she seems to regard this kind of reasoning as inappropriate in the public phase of working on the task. Her choice is a location close to the left crossing.

Since on the one hand Evelyn's way of reasoning is context based and on the other hand she seems to regard this as inappropriate, she is assigned to the type *ambivalent*. Due to her above mentioned personal proximity to the context, her contextual emphasis is possibly specific for the context of the home-for-aged-people-task.

The assignment of the four described cases within the typology is graphically shown in figure 3:

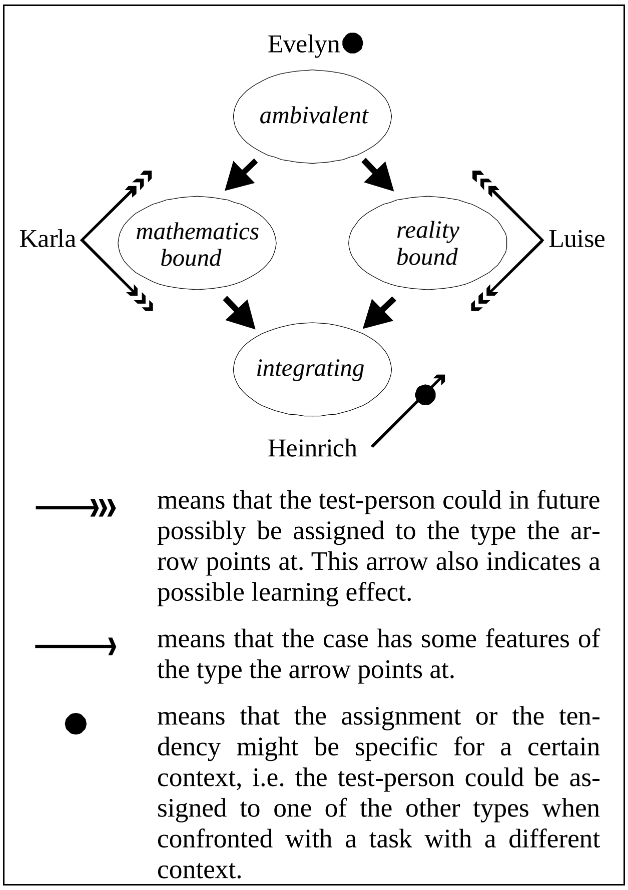

fig. 3: assignment of the four cases within the typology

4. Discussion

4.1 Theoretical framework of the typology

In the following the theory of *situated learning* is briefly described. It provides a background for the notion of *sociomathematical norms*. Using this as a theoretical basis, some of the findings of the study can be understood.

4.1.1 Situated learning

The basis of the theory of *situated learning* (Lave 1993a, Lave 1993b, Butterworth 1993, Mercer 1993, Lave & Wenger 1991, Cobb 2000) is the perception of mathematical activities as embedded in and essentially formed by a social environment. Learning of mathematics can only be understood by considering these circumstances. Within this framework one and the same task given in different situations can trigger very different activities because individuals always assign meaning to their activities, and this meaning depends on the situation in which their activities take place (Mercer 1993). So the concrete form of an activity depends on the meaning a person creates when given a task in order to solve it in a certain situation. Lave elaborates: "That is, the activity of solving word problems and the contents of word problems in school are not the same as 'the same' activity or contents embedded in other systems of activity in other parts of life; they are integrally generative of the practice and the meaning of word-problem solving." (Lave 1993a, p. 89, emphasis in original) In the German version of the paper she adds "Dies ist es, was mit dem 'situiertem' Charakter einer Aktivität gemeint ist."[2] (Lave 1993b, p. 26, emphasis in original).

Consequently the mainspring (Lave (1993a) calls it "dilemma") for a certain activity in a mathematics classroom (e.g. solving a realistic task) is constituted by the student's urge to cope with the requirements at school in order to achieve "blame avoidance" (Lave 1993a). This coping can happen by meeting the official academic requirements, but it can also happen by keeping up appearance (e.g. by cheating). If *blame avoidance* is the mainspring, the latter is an adequate behaviour[3].

Lave (1993a) illustrates this phenomenon by an example of a classroom situation she observed: Children solved multiplication tasks using a method which they regarded as easier than the method the teacher wanted them to apply. Before presenting their results to the teacher the children rewrote their answers so that they appeared to be achieved by the teacher's method. Referring to Laves observation Butterworth (1993, p. 11) aptly describes the children's behaviour as "subterranean".

4.1.2 Sociomathematical norms

In some way or other all test-persons deal with the question how much *reality* on the one hand and *mathematics* on the other hand is to be taken into account in order to solve the task.

In detail: According to Karla's ideas using contextual reasoning is strictly forbidden. At any price she tries to reason in a way which she considers as close to mathematics. Heinrich applies contextual reasoning not before some time has elapsed since work on the task ended. Luise is doubtful if realistic reasoning is permitted. Evelyn at last seems to think that open contextual reasoning is out of place when working on the task, so she does it mutely.

The test-persons seem to have normative ideas to what degree contextual reasoning is legitimate in order to solve the task. According to Yackel & Cobb (1996) this kind of social norms that refer to mathematical activities are called *sociomathematical norms*. Since – as mentioned before – mathematical activities have to be considered as situated it can be assumed, that the contents of sociomathematical norms depend on the situation a person person is acting in.

In the following it is assumed that the conditions of the three-step-design constitute – in the sense of the notion of situatedness – three distinct social environments. An essential aspect of their differences is formed by their proximity to the mathematics classroom: The activities while working on the task are very close to the common mathematics classroom activities, in a way they can therefore be characterised as official. In the stimulated recall phase the activities are only indirectly connected (via the videorecord) to common mathematics classroom activities. The interview does not even provide this connection to common mathematics classroom activities, here more general aspects are on the agenda. The method of analysing the data separately (see above) provides the opportunity to detect differences in the data that are gained from different steps of the three-step-design.

It can be assumed that the sociomathematical norms a test-person has experienced in his or her mathematics classroom come into effect especially during the work on the task. The effects of these norms are presumably less distinct during the stimulated recall phase and even lesser during the interview.

The notion of differences between the three steps of the design concerning the effects of sociomathematical norms provides a background for the explanation of possible diverging partial analyses.

So it can be explained why Heinrich applies contextual reasoning not until the stimulated recall phase: During the work on the task he presumably feels the effects of certain sociomathematical norms which probably emphasise the use of mathematical methods. Only when out reach of these effects he is able to reason in a contextual manner. Due to personal important former experiences this contextual reasoning – in this case – presumably meets his wishes.

In this discussion special emphasis has to be put on the type *ambivalent*. Diverging partial analyses of Evelyn's data suggest that her internal reasoning differs from her external one. Against the above mentioned theoretical background it is suggested that Evelyn tries to meet sociomathematical norms (which presumably have the strongest effect when working on the task). It can be assumed that these norms include that reasoning has to be mathematical, with no reference to contextual aspects. However, internally – beyond the official and public situation of the collective work on the task – the focus of the reasoning moves to contextual aspects. So externally a norm is met while internally this is not the case[4,5].

Generally there might be different reasons for not meeting the norms internally: A refusal in principle or a lack of mathematical skills and abilities. Although in this study no analyses of mathematical skills and abilities have been carried out, the data suggest that probably a lack of them causes the described phenomenon. Therefore students assigned to the type *ambivalent* should attract special attention because they tend to hide their problems in learning mathematics.

4.2 Further aspects of the discussion

4.2.1 Assignment type-person

The assignment of the four cases to the types within the typology suggests that the types are not necessarily invariably linked to persons. This conjecture is supported e.g. by Karla's possible change in dealing with contexts in the future due to a learning effect. Furthermore Heinrich and – to a lesser extent – Evelyn show a distinct emotional involvement in the context *home for aged people*. Therefore it can be assumed that – at least Heinrich – will not tend to the type *reality bound* if a different context is to be dealt with. In other words: It is possible that, due to learning processes and context specifity, persons cannot linked invariably to types[6]. Further analyses of other tasks given in the study will provide better insight to the problem of the assignment type-person.

4.2.2 Gender specifity

Figure 4 shows – in a simplified way – the assignment of all eight cases to the types within the typology. The figure suggests a question: Do have girls a stronger tendency to the type ambivalent than boys? It is interesting to know that all girls of the study were confused by the openness of the task whereas only one boy showed a confusion. Further reflections are necessary to find out in what way boys and girls deal differently with sociomathematical norms. Due to the qualitative approach of the study a generalised statement is impossible. Nevertheless the question of genderspecifics is an interesting one, possibly it could be answered by an quantitative approach.

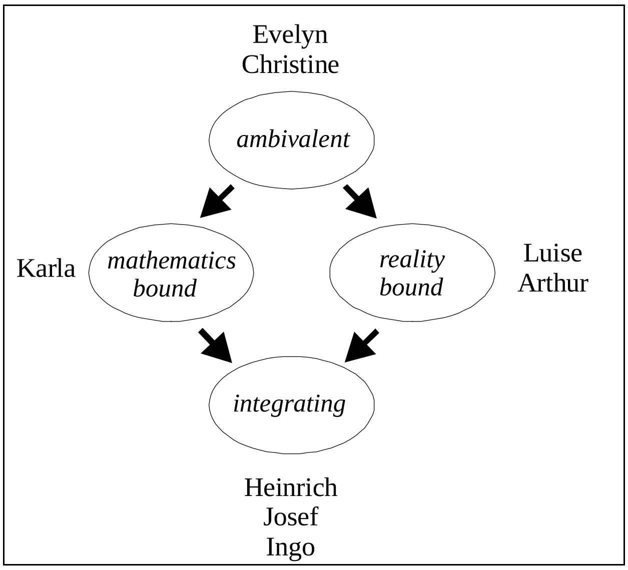

fig. 4: simplified assignment of all eight cases to types

5. Final remarks

In this paper interim findings of a broader study have been presented. The findings already provide a certain insight in the matter. Analyses concerning other tasks which were solved by the test-persons have to be made in order to sharpen the findings.

The three-step-design together with a data analysis that considers the conditions in which the data come into being, has proven to be a powerful tool in order to get an insight in processes of solving contextualised tasks. This methodical approach provides the empirical basis for a typology, which can be understood within the framework of the theory of situated learning.

Although the data analyses have not been fully completed some conclusions can already be drawn:

The often claimed hopes concerning the fostering of motivation by certain contexts have to be qualified. *Dynamics* and *subjectivity* of contextual ideas make it difficult to predict the effects a certain context can have on a student. So the justification for using contextualised tasks should be less psychological but more normative. Therefore the question should be to a lesser extent *Which contexts are generally considered to be helpful for students?* but rather *Which realistic problems should students learn in the mathematics classroom?*

The notion of *subjectivity* seems to contradict the claims for a higher degree of standardisation, as it has been recently discussed in Germany. This is, because a higher degree of standardisation of academic requirements is closely linked to a standardisation of examination questions. Against the background of our findings the problem is obvious: Realistic tasks trigger individual contextual ideas based on personal experiences, with unpredictable effects on the solution process. These individual effects oppose the idea of standardisation. Of course this is not a plea to avoid realistic tasks, because their inclusion in the mathematics classroom is well-founded. But we think that the problem of contextualised tasks in standardised examinations is worth to be pointed out, although no easy answers can be given at the moment. One possible way of thinking about the problem could be the idea of standardising certain *contexts*, so that every student knows in which part of the extramathematical world examination tasks are embedded in.

Since something is perceived easier if it is known to be existing, the typology can help a teacher to become aware of phenomena which he or she might not perceive otherwise. So the typology is a diagnostic tool which serves as a basis for appropriately meeting an individual's problems in dealing with contextualised tasks.

When working on realistic tasks students are confronted by demands on (at least) two levels: On the one hand they are supposed to solve the problem given in the task, on the other hand they have to deal with the conflicting task-aspects *mathematics* and *reality*, and by doing this they have to meet (their perception of) sociomathematical norms.

Since the test-persons deal with the above mentioned conflicting task-aspects in a variety of ways, it can be assumed that sociomathematical norms regarding this are not well established[7]. It can be assumed that these sociomathematical norms are mainly taught implicitly. Probably they also depend on the teacher and on the situation. It is therefore necessary to deal with these norms in an explicit way in order to provide the opportunity of an open discussion and a better understanding. In this case it can be assumed that the uncertainty concerning the use of sociomathematical norms will decrease and that there will be less need for a concealed use of contextual ideas. This proposal is also meant as a contribution to the discussion on standards in mathematics education, especially concerning applications and modelling.

When teaching sociomathematical norms regarding the use of context, meta knowledge about mathematical modelling can be useful (cf. Maaß (2004)). Yackel & Cobb (1996) emphasise the teacher's role as a representative of mathematics and consequently an expert in the field of sociomathematical norms.

However, the idea of teaching sociomathematical norms explicitly in order to achieve a higher degree of transparency is only partly a solution of the problem. From the theory of situated learning it can be concluded that an improved transparency alone does not change the basic dilemmas (Lave 1993a) of learning at school.

It could be argued that our findings depend on our research design alone, so that they would not be applicable in a common mathematics classroom. Certainly it has to be considered that in this study the tasks and their contexts were new and unknown to the test-persons. Regarding this, the research design has more affinity to an examination than to a mathematics lesson. On the other hand it is also true that examinations are integral parts of most mathematics classooms.

But indeed, on the basis of this research nothing can be said about the effects of context in a learning environment where realistic problems and their contexts are discussed in a group over a longer period of time. It is possible that a longer class discussion before the work on the task can lead to a stronger homogeneity of contextual ideas within the group, consequently the above mentioned aspects of *subjectivity* and *dynamics* of contextual ideas would appear to a lesser degree.

When comparing the situation of the research design to a common mathematics classroom it might also be argued that our typology cannot be applied to the latter. Although we have no empirical findings regarding this, it can be assumed that the contributions a student makes during a classroom discussion, or while working in a small group, are based on the same individual contextual experiences and the same individual normative ideas he or she would have in a situation similar to our research design. Consequently, his or her way of dealing with the context is basically the same. However, it must be conceeded that it is presumably more difficult to *identify* a certain type in a complex classroom situation than in a situation similar to the research design.

These last remarks emphasise the need of further empirical research in this field.

6. Notes

[1] These general remarks on ideal types refer to Bikner-Ahsbahs (2003).

[2] "That is what is meant by the 'situated' character of an activity." (Translation by the author)

[3] Here the similarity to the notion of the "hidden curriculum" becomes obvious (Speichert 1975, p. 165), although here the focus is different.

[4] This resembles the strategy of *mathematical jargon* described by d'Amore & Sandri (1996): Although not understood, ideas are uttered that *sound* mathematically in order to meet a norm seemingly.

[5] See Butterworth's above cited expression describing such activities appropriate as subterranean.

[6] Therefore our types do not form a typology of *beliefs*, because the notion of *beliefs* includes a certain temporal and personal stability (Törner 2002).

[7] This statement is emphasised by the fact that even students who are taught in the same class perceive sociomathematical norms differently.

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